RECREATIONAL VEHICLE CHASSIS WORKSHOP MANUAL

Models: MC
MCL
XC
XCF
XCL
XCM
XCP
XCR
XCS
VCL

STI-354, S21 (10/10P)

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Daimler Trucks North America LLC
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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 *Recreational Vehicle 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.

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.

Daimler Trucks North America LLC
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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.

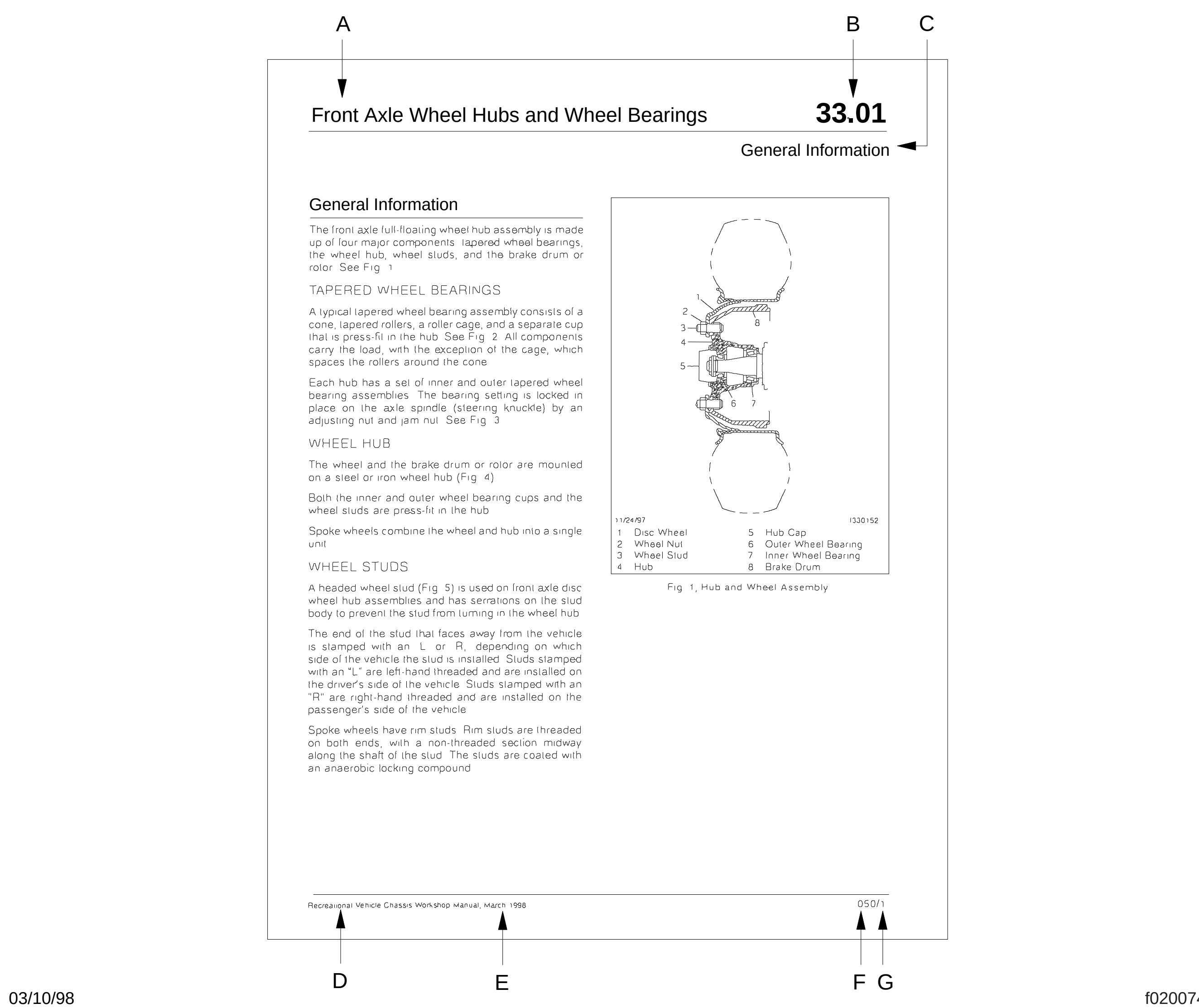
Descriptions of Service Publications

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 *Recreational Vehicle Chassis Workshop Manual* page, see **Fig. 1**.



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

Fig. 1, Example of a Recreational Vehicle Chassis Workshop Manual Page

Workshop Manual Contents

Group No.	Group Title

List of Abbreviations

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

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

List of Abbreviations

ECI .... electronically controlled injection
ECL .... engine coolant level
ECM .... electronic control module
ECT .... engine coolant temperature
ECU .... electronic control unit
EDM .... electronic data monitor
EEPROM .. electrically erasable programmable read-only memory
EFG .... electric fuel gauge
EFPA ...... electronic foot pedal assembly
EGR .... exhaust gas recirculation
ELC .... extended-life coolant
EMC .... electromagnetic compatibility
EMI .... electromagnetic interference
EOA .... electric over air
EP .... extreme pressure (describes an antiwear agent added to some lubricants)
EPA .... Environmental Protection Agency
EPS .... engine position sensor
ESC .... electronic stability control
ESC .... enhanced stability control
ESD .... electrostatic discharge
ESS .... engine syncro shift (transmission)
etc. .... *et cetera* (and so forth)
ETEC ...... electronic truck engine control
EUI .... electronic unit (fuel) injectors
EVA .... electronic vibration analyzer
EXM .... (chassis) expansion module
E85 .... 85% ethanol fuel
FAS .... Freightliner air suspension
FCCC ...... Freightliner Custom Chassis Corporation
FCU .... forward control unit
FET .... field effect transistor
Fig. .... figure
fl oz .... fluid ounces
FLA .... post-1984 advancements Freightliner COE
FLB .... enhanced Freightliner FLA COE
FLC .... steel-cab Freightliner 112 Conventional
FLD .... post-1984 advancements Freightliner 112/120 aluminum-cab Conventional
FLR .... forward-looking radar
FM .... frequency modulation
FMCSA .... Federal Motor Carrier Safety Administration
FMEA ..... failure mode effects analysis
FMI .... failure mode indicator
FMSI ...... Friction Materials Standards Institute
FMVSS .... Federal Motor Vehicle Safety Standard
FRP .... fiberglass reinforced plastic
FSA .... field service authorization
FSM .... fleet service manager
ft .... feet
ft^3 .... cubic feet
ft^3/min ..... cubic feet per minute
FTL .... Freightliner
F.U.E.L. .... fuel usage efficiency level
g .... grams
gal .... gallons
GAWR ..... gross axle weight rating
GHG .... greenhouse gas
GHG14 .... greenhouse gas and fuel efficiency regulations
GL .... gear lubricant
GND .... ground
gpm .... gallons per minute
GPS .... global positioning system
GVWR ..... gross vehicle weight rating
HBED ..... hard-braking event data
HCM .... hybrid control module
HCOE ..... high cab over engine
HCU .... hydraulic control unit
HD .... heavy-duty
HDU .... hybrid drive unit
HEPA ...... high-efficiency particulate air (filter)
HEST ...... high exhaust system temperature
HEV .... hybrid electric vehicle
HFC .... hydrogenated fluorocarbons (refrigerant-134a)
hp .... horsepower
hp .... high pressure
HRC .... Rockwell "C" hardness
hr(s) .... hour(s)
HSA .... hill start aid
HSD .... high-side driver
htr. .... heater
HVAC ...... heating, ventilating, and air conditioning
HVLP ...... high velocity, low pressure
H/W .... hardware
Hz .... hertz
IAD .... interaxle differential
ICS .... integrated child seat
ICU .... instrumentation control unit
i.d. .... inside diameter
ID .... identification
IFI .... Industrial Fasteners Institute
IFS .... independent front suspension
IGN .... ignition
ILB .... intelligent lightbar
ILO .... *in lieu of* (in the place of)
in .... inches
in^3 .... cubic inches
Inc. .... incorporated
inH$_2$O ..... inches of water
inHg .... inches of mercury
I/O .... input/output
IP .... instrument panel
ISO .... International Organization for Standardization
IVS .... idle validation switch
k .... kilo (1000)
kg .... kilograms
km .... kilometers
km/h .... kilometers per hour
kPa .... kilopascals
kW .... kilowatts
L .... liters
lb .... pounds
LBCU ...... lightbar control unit
lbf·ft .... pounds force feet
lbf·in ...... pounds force inches
LCD .... liquid crystal display
LCOE ...... low cab over engine
LED .... light-emitting diode
LFL .... lower flammability limit
LH .... left-hand
LHD .... left-hand drive
LH DR ..... left-hand-drive
LHK .... liters per hundred kilometers
LHS .... low-hydrogen steel
LIN .... Local Interconnect Network
LLC .... limited liability company
L/min ...... liters per minute
LNG .... liquefied natural gas
LPG .... liquefied petroleum gas

List of Abbreviations

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

List of Abbreviations

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

General Information

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)

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)
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
F	6 x 2 Truck
X	Glider

Table 3, VIN Position 4 (Chassis Configuration)

VIN for Vehicles Built from May 1, 2000

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†
AC	MB55 Chassis	None	Class 6‡
AD	MB55 Chassis	None	Class 7§
AE	MC45 Chassis	None	Class 5
AF	MC45 Chassis	None	Class 6
AG	XC Chassis	None	Class 6
AH	XC Chassis	None	Class 7
AJ	XCS Chassis	None	Class 6
AK	VCL Chassis	None	Class 8¶
AM	MT35 Chassis	None	Class H**
AN	MT45 Chassis	None	Class 4
AP	MT45 Chassis	None	Class 5
AR	MT55 Chassis	None	Class 6
AS	MT55 Chassis	None	Class 7
AT	XB Chassis	None	Class 6
AU	XB Chassis	None	Class 7
AV	FS65 Chassis	None	Class 5
AW	FS65 Chassis	None	Class 6
AX	FS65 Chassis	None	Class 7
AY	FS65 Chassis	None	Class 8
AZ	FB65 Chassis	None	Class 6
A1	MBO Chassis	None	Class 7
A2	MBO Chassis	None	Class 8
A3	OMC Chassis	None	Class 7
A4	OMC Chassis	None	Class 8
A5	MT55 Chassis	None	Class 4
A6	XCA Chassis	None	Class 7
A7	XCA Chassis	None	Class 8
A8	FB65 Chassis	None	Class 7
A0	EF Front-Engine Bus Chassis	None	Class 6
BA	EF Front-Engine Bus Chassis	None	Class 7
BB	EF Front-Engine Bus Chassis	None	Class 8

VIN for Vehicles Built from May 1, 2000

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

VIN for Vehicles Built from May 1, 2000

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

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

* Class 4 GVWR is 14,001–16,000 lb.
† Class 5 GVWR is 16,001–19,500 lb.
‡ Class 6 GVWR is 19,501–26,000 lb.
§ Class 7 GVWR is 26,001–33,000 lb.
¶ Class 8 GVWR is 33,001 lb. and over.
** Class H GVWR is 9001–10,000 lb.
†† Class 3 GVWR is 10,001–14,000 lb.

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

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

VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
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
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

VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
B5	Cummins B8.3	Natural Gas	8.3	I–6	Air
B6	Cummins B8.3	Natural Gas	8.3	I–6	Hydraulic
B7	Cummins B8.3	Natural Gas	8.3	I–6	Air/Hydraulic
B8	Detroit Series 50	Diesel	8.5	I–4	Air
B9	Detroit Series 50	Diesel	8.5	I–4	Hydraulic
B0	Detroit Series 50	Diesel	8.5	I–4	Air/Hydraulic
CN	Mercedes-Benz MBE900	Diesel	4.3	I–4	Air
CP	Mercedes-Benz MBE900	Diesel	4.3	I–4	Hydraulic
CR	Mercedes-Benz MBE900	Diesel	4.3	I–4	Air/Hydraulic
CS	Mercedes-Benz MBE900	Diesel	6.4	I–6	Air
CT	Mercedes-Benz MBE900	Diesel	6.4	I–6	Hydraulic
CU	Mercedes-Benz MBE900	Diesel	6.4	I–6	Air/Hydraulic
CV	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Air
CW	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Hydraulic
CX	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Air/Hydraulic
CY	Cummins ISL	Diesel	8.9	I–6	Air
CZ	Cummins ISL	Diesel	8.9	I–6	Hydraulic
C1	Cummins ISL	Diesel	8.9	I–6	Air/Hydraulic
C2	Cummins B3.9	Diesel	3.9	I–4	Air
C3	Cummins B3.9	Diesel	3.9	I–4	Hydraulic
C4	Cummins B3.9	Diesel	3.9	I–4	Air/Hydraulic
C5	Cummins ISB 3.9	Diesel	3.9	I–4	Air
C6	Cummins ISB 3.9	Diesel	3.9	I–4	Hydraulic
C7	Cummins ISB 3.9	Diesel	3.9	I–4	Air/Hydraulic
C8	John Deere 6081H	CNG	8.1	I–6	Air
C9	John Deere 6081H	CNG	8.1	I–6	Hydraulic
DC	CAT C7	Diesel	7.2	I–6	Air
DD	CAT C7	Diesel	7.2	I–6	Hydraulic
DG	Mercedes-Benz MBE900	Diesel	4.8	I–4	Air
DH	Mercedes-Benz MBE900	Diesel	4.8	I–4	Hydraulic
DJ	Mercedes-Benz MBE900	Diesel	7.2	I–6	Air
DK	Mercedes-Benz MBE900	Diesel	7.2	I–6	Hydraulic
DL	CAT C11	Diesel	11.1	I–6	Air
DM	CAT C11	Diesel	11.1	I–6	Hydraulic

VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
DT	Cummins ISB	Diesel	6.7	I–6	Air
DU	Cummins ISB	Diesel	6.7	I–6	Hydraulic
DV	GM 307 HP	Gasoline	6.0	V–8	Hydraulic
DX	Enova 120 KW	Electric	—	—	Hydraulic
E1	Fiat 4P10	Diesel	3.0	I–4	Hydraulic
E2	Powertrain Integration LPG	Propane	8.0	V–8	Hydraulic
E3	Powertrain Integration LPG	Propane	8.0	V–8	Air
00	No Engine	—	—	—	—

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

VIN Position 10 (Model Year)	
Code	**Model Year**
Y	2000
1	2001
2	2002
3	2003
4	2004
5	2005
6	2006
7	2007
8	2008
9	2009
A	2010
B	2011
C	2012
D	2013
E	2014

Table 6, VIN Position 10 (Model Year)

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

Table 7, VIN Position 11 (Build Location)

Threaded Fastener Types

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

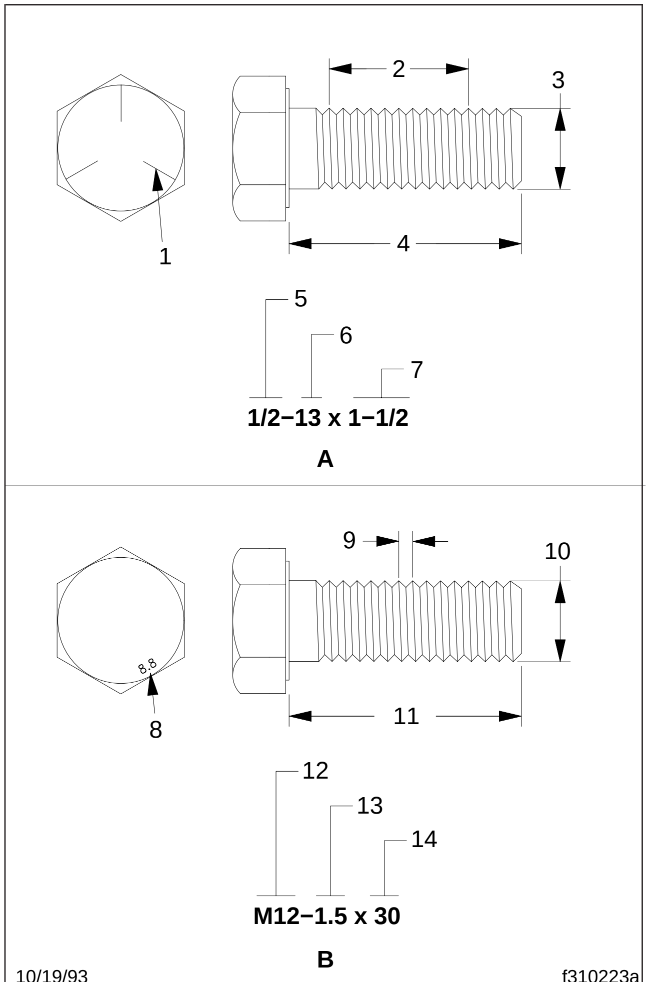
Most threaded fasteners used on the chassis that are 1/2-inch diameter or larger are plain hex-type fasteners (non-flanged); *all* metric fasteners are non-flanged. Special hardened flatwashers are used under the bolt head, and between the part being attached and the hexnut, to distribute the load, and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

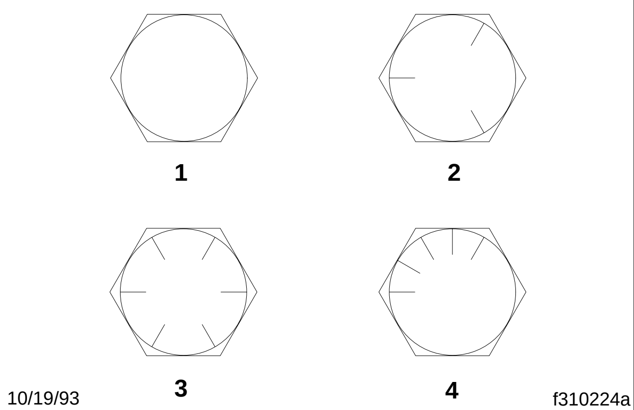


A. Bolt with U.S. Customary Threads
B. Bolt with Metric Threads

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

Fig. 1, Fastener Size and Thread Identification

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

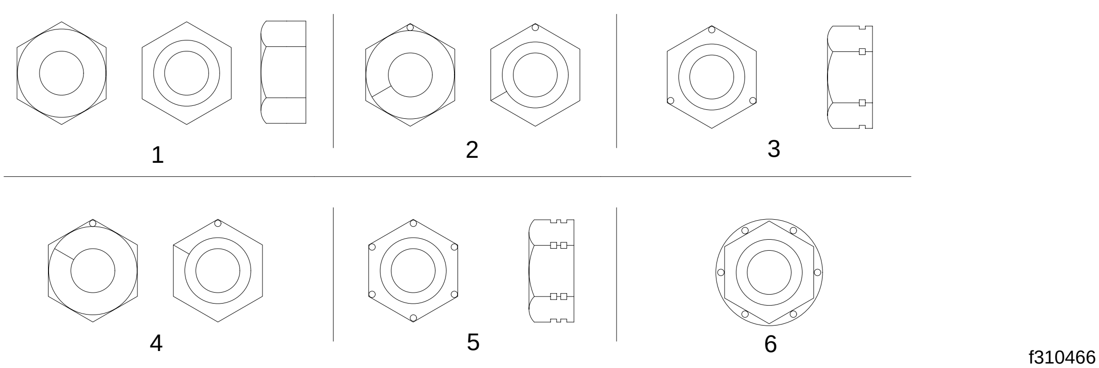
Fig. 2, Bolt Grades

Frame Fasteners

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

Tightening Fasteners

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

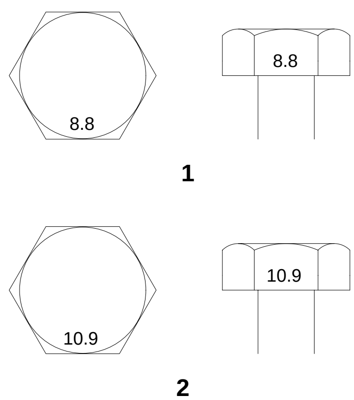


NOTE: Grade 2 (S.A.E.) and grade A (I.F.I.) nuts have no identification marks or notches; they are rarely used by Freightliner. Grade B (I.F.I.) nuts have three identification marks at 120 degrees, or 6 notches. Grade C (I.F.I.) nuts have three identification marks at 60 degrees, or 12 notches. Grade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

General Information



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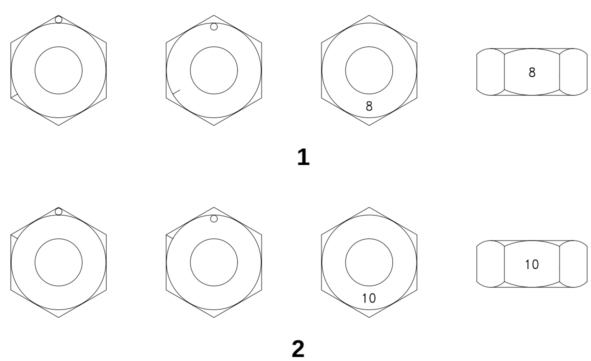
NOTE: In addition to the class markings, the bolt head must also carry the manufacturer’s trademark or identification.

1. Class 8.8
2. Class 10.9

Fig. 4, Bolt Classes



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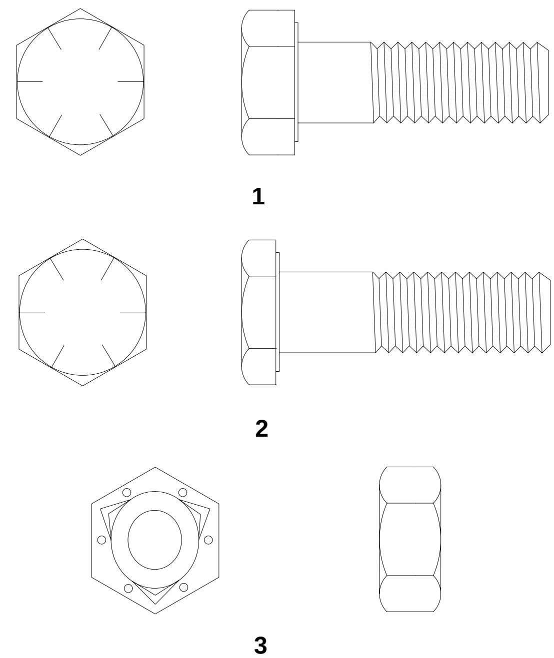
1. Class 8 Nut
2. Class 10 Nut

Fig. 5, Nut Classes

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



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

Fig. 6, Frame Fastener Identification

threaded hole, or the friction between the threads of the nut and bolt.

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

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

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.

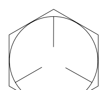
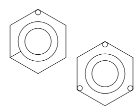
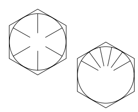
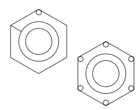
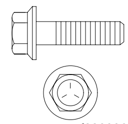
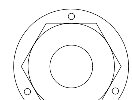
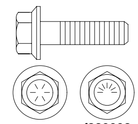
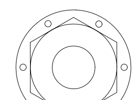
General Instructions

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.

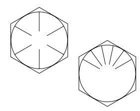
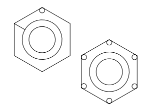
Torque Values for U.S. Customary Thread Fasteners with Lubricated * or Plated Threads †								
Thread Diameter–Pitch	Regular Hex				Flanged			
	 f230002	 f230003	 f230004	 f230005	 f230006	 f230007	 f230008	 f230009
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 5 Bolt	Grade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

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

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

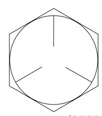
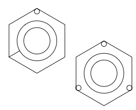
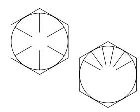
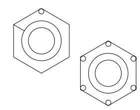
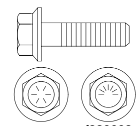
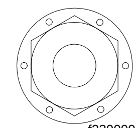
Table 1, Torque Values for U.S. Customary Thread Fasteners with Lubricated or Plated Threads

Specifications

Torque Values for Grade 8 Regular Hex Zinc-Yellow Plated Capscrews and Cadmium- and Wax-Coated Prevailing Torque Locknuts *		
Thread Diameter-Pitch	Regular Hex	
	 f230004 Grade 8 or 8.2 Bolt	 f230005 Grade 8 or C Nut
	Torque: lbf·ft (N·m)	
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

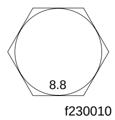
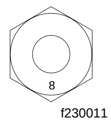
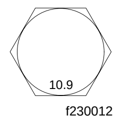
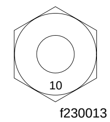
Torque Values for U.S. Customary Thread Fasteners with Dry (unlubricated) * Plain (unplated) Threads †						
Thread Diameter–Pitch	**Regular Hex**				**Flanged**	
	 f230002	 f230003	 f230004	 f230005	 f230008	 f230009
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 8 or 8.2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

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

† Male and female threads (bolt and nut) must both be unlubricated and unplated; if either is plated or lubricated, use **Table 1** or **Table 2**. 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)**	
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	231 (313)		320 (434)	
M22	283 (384)		392 (531)	
M22 x 1.5	315 (427)		431 (584)	
M24	360 (488)		498 (675)	
M24 x 2	392 (531)		542 (735)	
M27	527 (715)		729 (988)	
M27 x 2	569 (771)		788 (1068)	
M30	715 (969)		990 (1342)	
M30 x 2	792 (1074)		1096 (1486)	

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

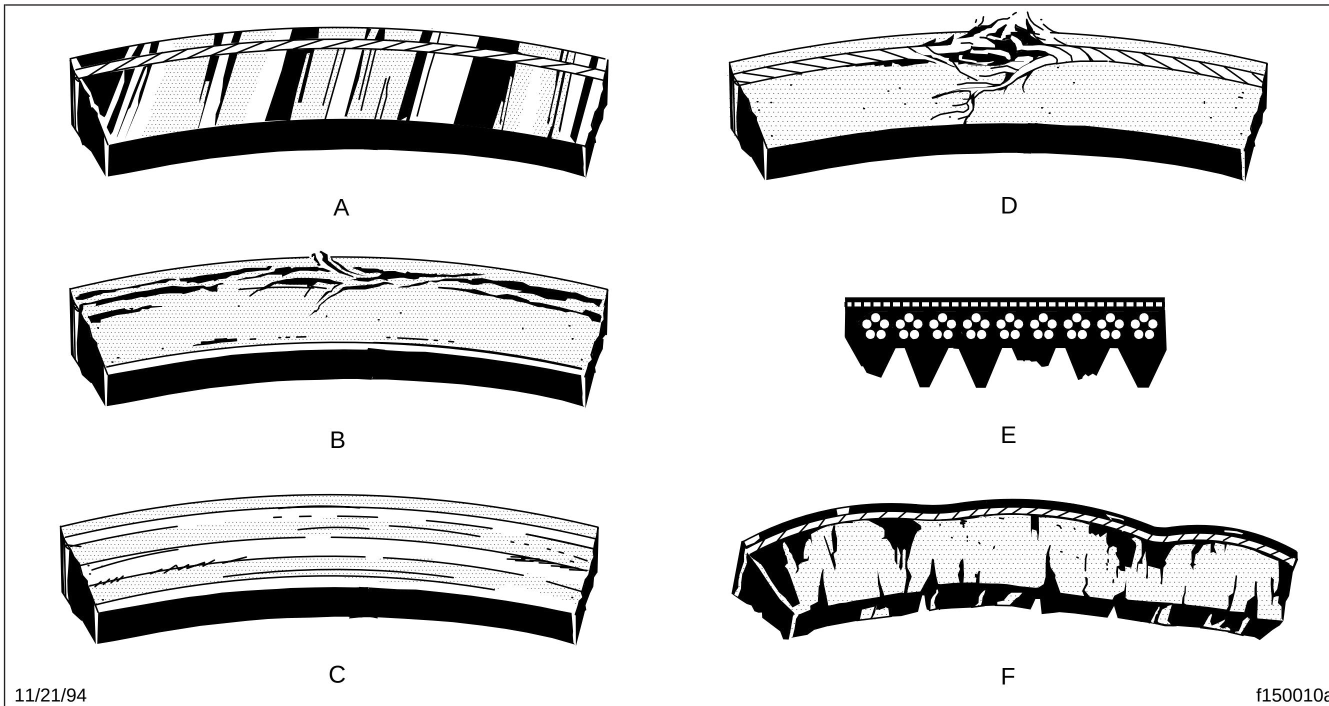
† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, or waxed, Geomet 321XL coated, or waxed).

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

Inspection

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

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.



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.

1.5 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.

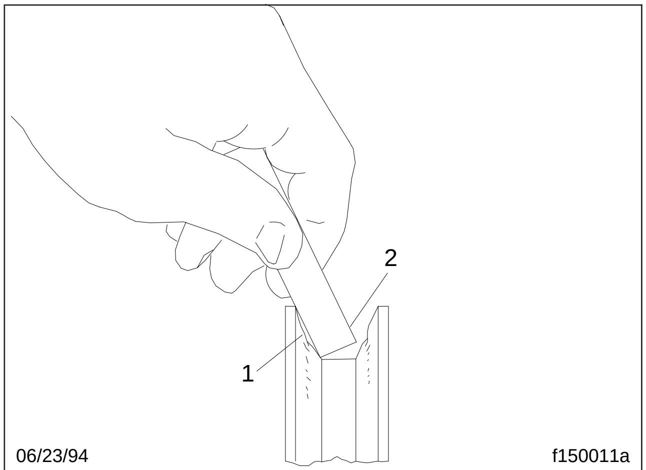
Replace the belt if any of the above conditions are found. Replace both belts of a set, at the same time. Matched belts must be from the same manufacturer.

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

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

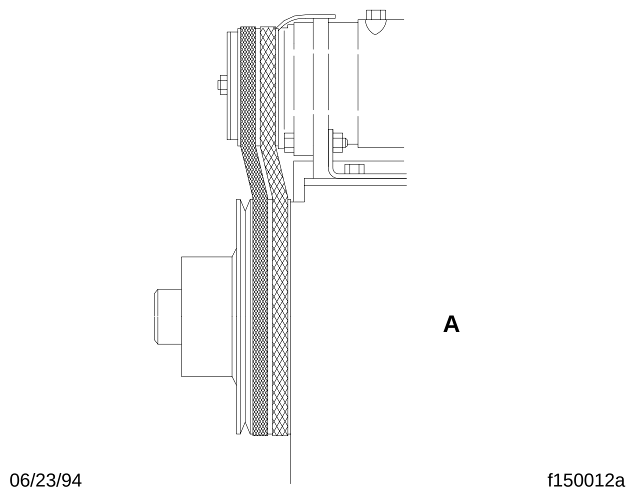
Fig. 2, Check for Pulley Wear

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

Refrigerant Compressor Belt Replacement

1. Loosen the bolt holding the belt tensioner, then swing it down to release the belt tension.
2. Remove the drive belt from the compressor pulley and the engine pulley.
3. Work the belt on over the fan blades and remove it.
4. Work the new drive belt over the fan blades, the slip it over the engine and compressor pulleys. Make sure the belt is correctly seated in the pulley grooves.
5. Move the belt tensioner up firmly against the belt, the tighten the bolt.
6. Tighten the belt tension to 100 lbs (45 kg) by using a belt tension gauge at the center of the belt free-span.

Fan and Alternator Belt Replacement

1. If not already done, 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**.
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**.

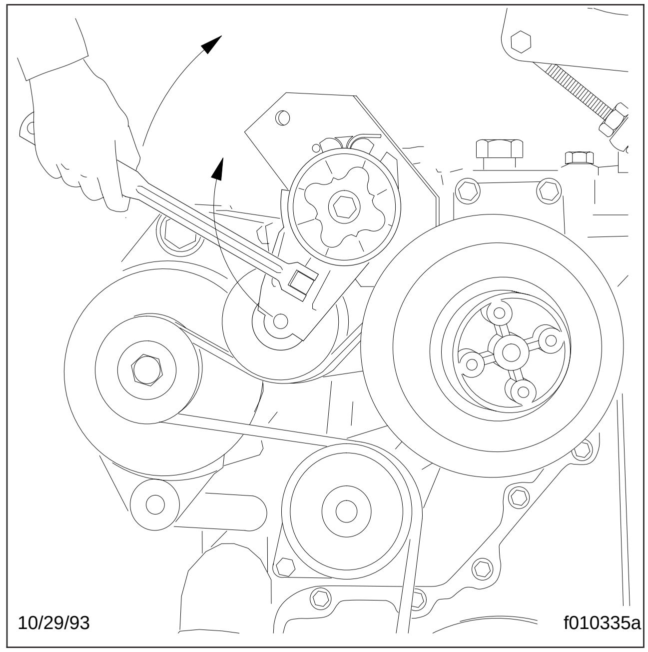


Fig. 1, Belt Tensioner Rotation

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

1. Park the vehicle, set the parking brakes, then chock the tires.
2. From inside the vehicle, raise and support the bed, then the engine hatch cover.
3. Disconnect the driveline from the transmission. For instructions, see **Group 41**.
4. Disconnect the batteries.
5. Drain the engine oil.
6. Drain the automatic transmission fluid.
7. Drain the radiator.
8. Drain the air tanks.

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. Raise the rear of the vehicle high enough to allow for the engine to clear it for removal. Support the vehicle chassis with safety stands.
10. Remove the exhaust brake, following the instructions in this group. Remove the muffler and exhaust piping. For instructions, see **Group 49**.
11. Remove the turbocharger outlet piping.
12. Disconnect the wiring from the transmission.
13. Disconnect the transmission oil cooler lines from the transmission.
14. Remove the transmission. For instructions, see **Group 26**.
15. Remove the oil fill tube from the engine.
16. Disconnect the heater hoses from the engine.
17. Remove the upper radiator hose.
18. Remove the refrigerant compressor from the engine, but do not disconnect the refrigerant lines.
19. Remove the idler pulley.
20. Disconnect the fuel supply and return lines.
21. Disconnect the throttle cable from the injection pump lever. See **Fig. 1**.

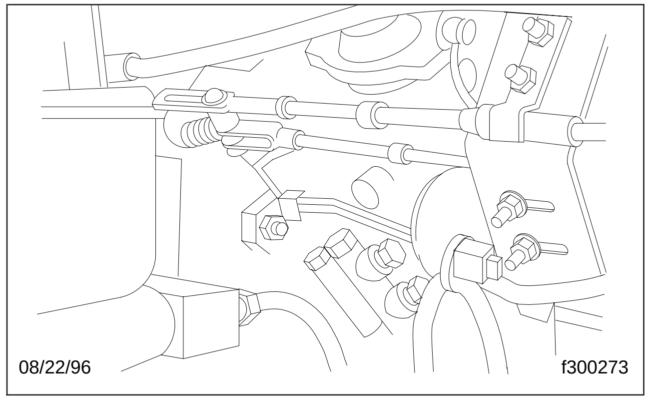
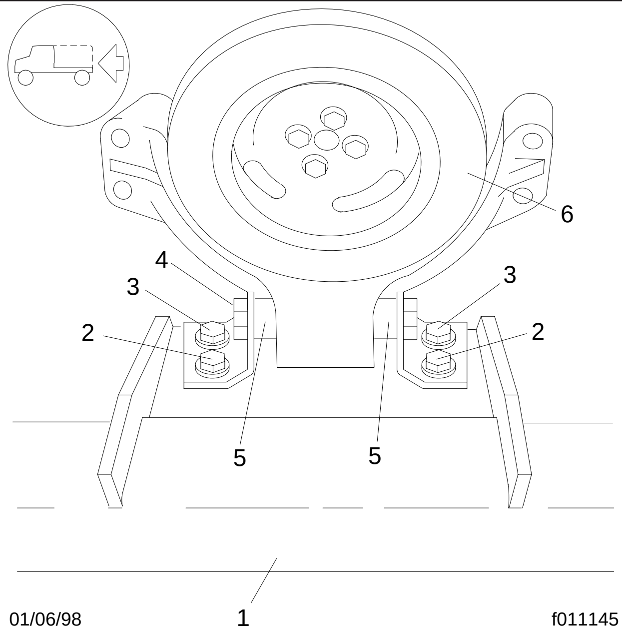


Fig. 1, Injection Pump Lever and Yokes

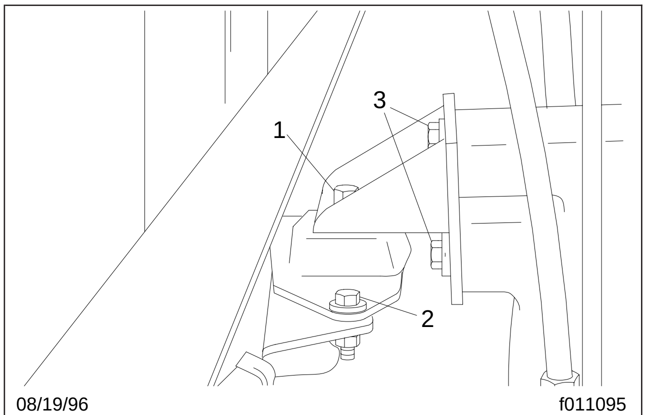
22. Disconnect the transmission cable.
23. Disconnect the cruise control cable.
24. Disconnect the oil dipstick tube.
25. Remove the upper charge air cooling piping.
26. Mark, then disconnect the wiring from the alternator.
27. Disconnect the power steering lines.
28. Remove the power steering pump.
29. Mark, then disconnect the wiring from the starter.
30. Disconnect the ground strap.
31. Disconnect the air lines from the air compressor.
32. Remove the two bolts holding the lower radiator pipe to the front engine mount bracket, then remove the lower radiator pipe. See **Fig. 2**.
33. Remove the block heater, if so equipped, from the engine.
34. Put an engine jack with suitable support under the engine.
35. Remove the two remaining bolts from the front engine mount.
36. Raise the engine enough to remove the two rear engine mounts from each side of the frame rail, near the bell housing. See **Fig. 3**.

Rear Engine Removal and Installation



1. Crossmember
2. Front Engine-Mount-Bracket Bolt
3. Bracket Bolt Holding Lower Radiator Pipe
4. Front Engine-Mount Bolt, 3/4–10
5. Isolator
6. Engine Pulley

Fig. 2, Front Engine Mount



1. Engine-Mount Bolt
2. Insulator-to-Frame Mount Bracket Bolts
3. Engine Mount Bracket-to-Engine Capscrews

Fig. 3, Rear Engine Mount

37. Move the engine toward the front of the vehicle, away from the radiator and fan shroud.
38. Remove the fan from the engine.
39. Remove the engine mount brackets from each side of the bell housing.
40. Lower the engine, then remove it from underneath the vehicle.
41. Place the engine on a suitable engine stand.

Installation

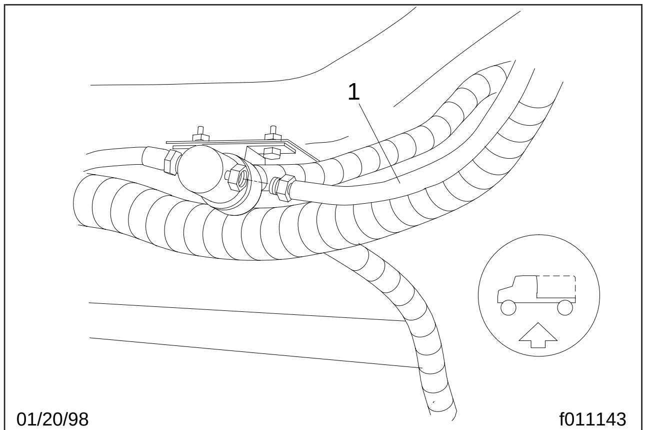
1. If you are installing a new engine, remove the following parts and assemblies (unless they are damaged) from the old engine, and install them onto the new engine:
   - alternator
   - oil sender unit
   - heater hoses and fittings
   - coolant temperature sender
   - block heater
   - air compressor, lines and fittings
   - fuel line fitting
   - throttle linkage and bracket
   - engine oil dipstick tube
   - coolant bypass hose
   - speed sensor (from the bell housing)
   - transmission flex plate and adapter
   - front engine mounting brackets
2. Put the engine on a jack, then position it under the vehicle.
3. Raise the engine up, then install the fan blade.
4. 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 55 to 65 lbf·ft (75 to 78 N·m).
5. Install the rear engine mounts and isolators onto the frame rail brackets. Tighten the fasteners 91 lbf·ft (123 N·m).
6. Install the rear engine mounts onto each side of the bell housing. Tighten the fasteners 62 lbf·ft (84 N·m).
7. Install the rear engine-mount bolts and isolators. Do not tighten them all the way.

8. Attach the front engine mount to the crossmember.
    - 8.1 Install the two bolts that do not hold the lower radiator hose to the mount. See **Fig. 2**.
    - 8.2 Install the lower radiator piping and the two remaining front engine-mount bolts.
    - 8.3 Tighten all four front engine-mount bolts 60 lbf·ft (81 N·m).
9. Tighten the two rear engine-mount bolts 157 lbf·ft (213 N·m).
10. Disconnect the engine from the jack, then remove the jack from under the vehicle
11. Install the power steering pump and hoses.
12. Install the air compressor supply and return lines.
13. Install the starter, then connect the starter wiring.
14. Install the turbo outlet piping.
15. Install the cables for the throttle, cruise control, and transmission sensor.
16. Adjust the cruise control cable.
17. Install the fuel supply and return lines.
18. Connect the wiring for the fuel solenoid, refrigerant compressor, oil pressure sensor, coolant temperature sensor, and block heater.
19. Connect the wiring for the alternator.
20. Connect the heater hoses to the engine.
21. Install the upper radiator hose.
22. Install the engine oil fill tube.
23. Install the engine oil dipstick tube.
24. Install the transmission. For instructions, see **Group 26**.
25. Install the turbo outlet piping.
26. Install the exhaust brake. For instructions, see **Group 49**.
27. Lower the vehicle.
28. Install the driveline. For instructions, see **Group 41**.
29. Fill the engine with oil. See the chassis maintenance manual for specifications.
30. Fill the radiator with coolant. See the chassis maintenance manual for specifications.
31. Fill the transmission with fluid. See the chassis maintenance manual for specifications.
32. Fill and bleed the power steering system. For instructions, see **Group 46**.
33. Connect the batteries.
34. From inside the vehicle, close the engine access hatch, then lower the bed.
35. Start the engine; run it and check for leaks and fluid levels. Correct as needed.
36. Remove the chocks from the tires.

Exhaust Brake Removal and Installation

Removal

1. Park the vehicle, set the parking brakes, then chock the rear tires.
2. Drain the air tanks. For Instructions, see **Group 42**.
3. From underneath the vehicle, locate and disconnect the air line supplying the exhaust brake cylinder from the solenoid valve on the crossmember. See **Fig. 1**.



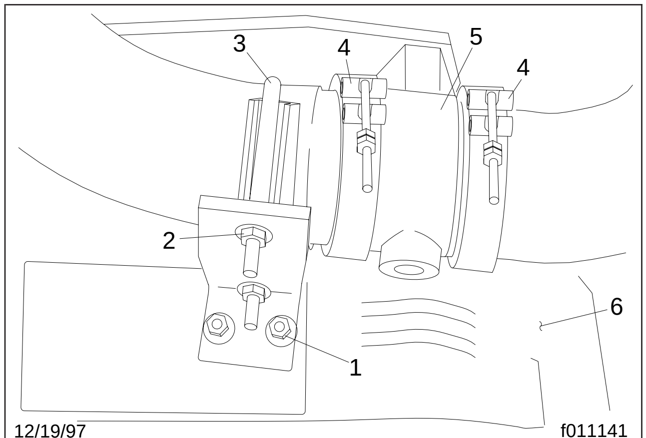
1. Air Line to the Exhaust Brake Cylinder

Fig. 1, Disconnecting the Exhaust Brake Air Line

WARNING

Do not work on the exhaust components while they are hot. To do so could result in serious personal injury from burns. Let the exhaust piping cool before you work on it.

4. Disconnect the exhaust brake from the exhaust piping. See **Fig. 2** and **Fig. 3**.
   - 4.1 Loosen the nuts on the transmission bracket.
   - 4.2 Loosen the nuts on the U-clamp next to the exhaust brake.
   - 4.3 Loosen and remove the two V-clamps holding the exhaust brake to the exhaust piping.
   - 4.4 Pull the exhaust piping apart to remove the exhaust brake.



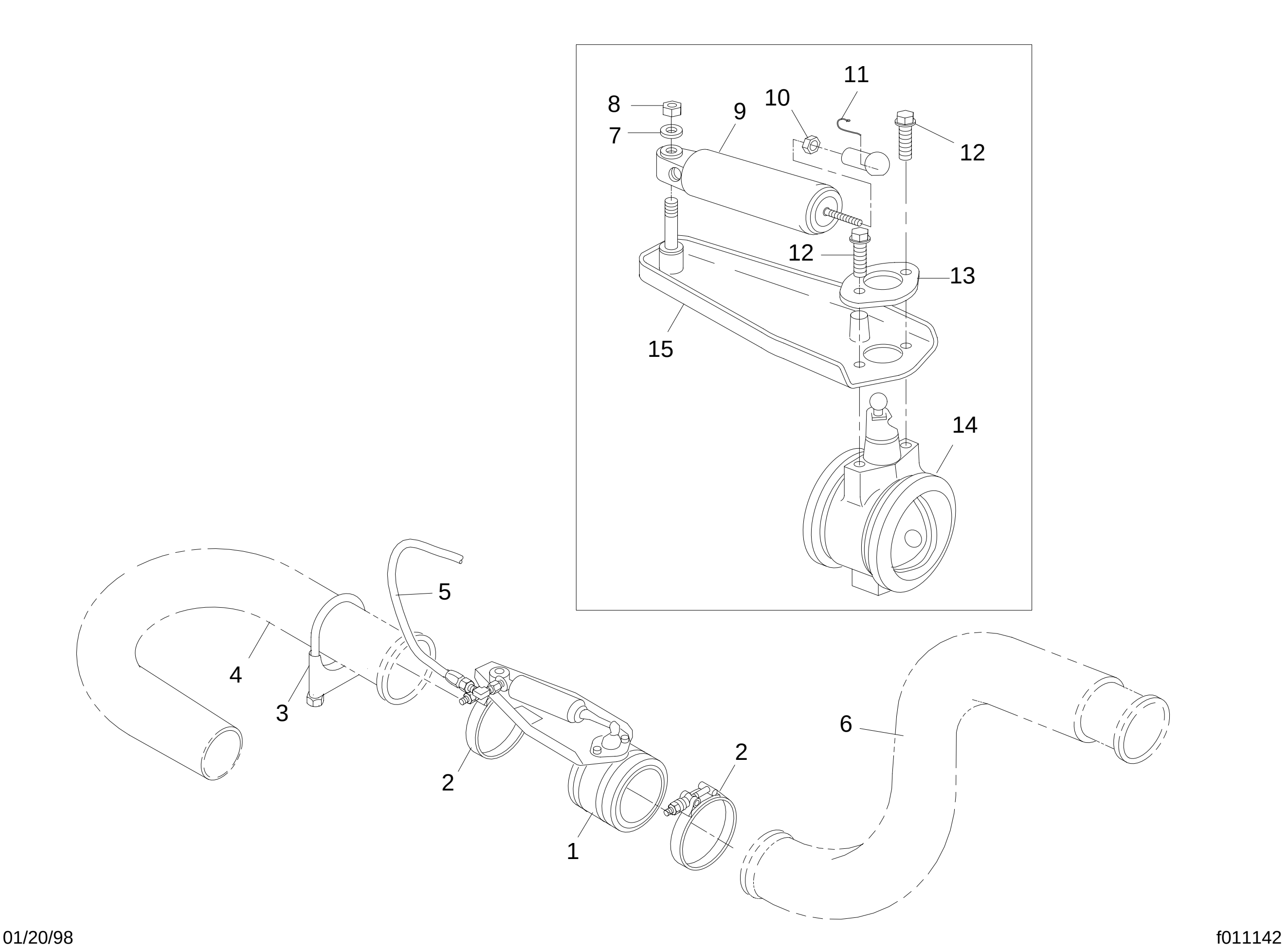
1. Transmission Bracket Nut (2 qty.)
2. U-Clamp Nut (2 qty.)
3. U-Clamp
4. V-Clamp
5. Exhaust Brake
6. Transmission

Fig. 2, Jacobs Exhaust Brake Installed

Installation

1. Connect the exhaust brake to the exhaust piping.
   - 1.1 Put the exhaust brake in place between the pipe coming from the turbocharger and the pipe going to the muffler. See **Fig. 3**.
   - 1.2 Install the two V-clamps. Tighten them 40 lbf·ft (54 N·m).
   - 1.3 Tighten the U-clamp nuts 24 lbf·ft (33 N·m).
   - 1.4 Tighten the transmission bracket nuts firmly.
2. Connect the air line to the solenoid valve on the crossmember. See **Fig. 1**. Tighten the connection firmly.
3. Remove the chocks from the tires.

Exhaust Brake Removal and Installation



1. Exhaust Brake
2. V-Clamp
3. U-Clamp
4. Exhaust Pipe to Muffler
5. Air Line
6. Exhaust Pipe from Turbocharger
7. Washer
8. Nut
9. Air Cylinder
10. Nut
11. Safety Clip
12. Capscrew
13. Gasket
14. Exhaust Brake Housing
15. Air Cylinder Bracket

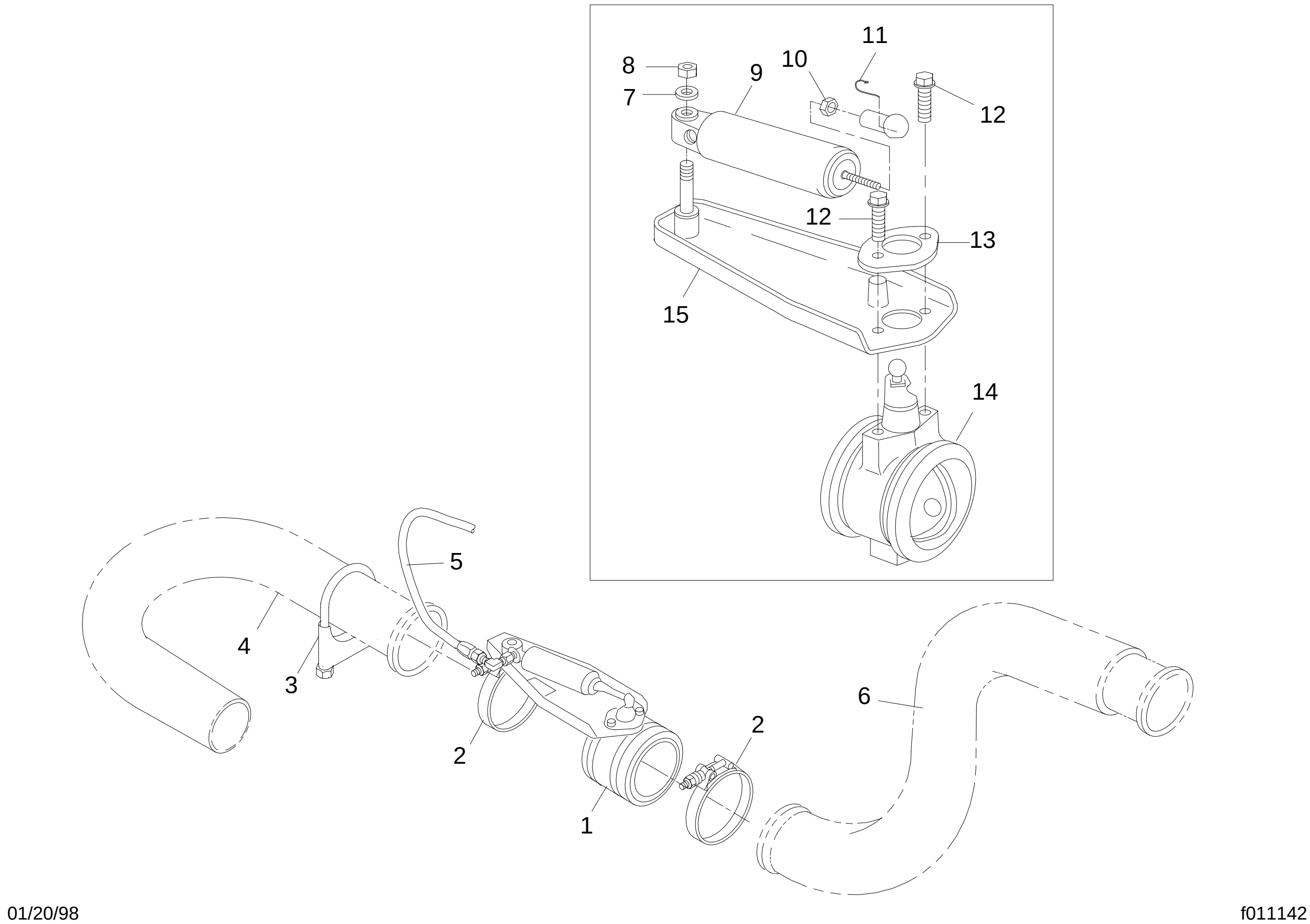
Fig. 3, Jacobs Exhaust Brake Installation

Replacement

NOTE: The air cylinder is the only replaceable part of the exhaust brake. If there is a problem with any other part, replace the entire exhaust brake assembly.

1. Remove the exhaust brake. See **Subject 100** for instructions.
2. Remove the air cylinder from the exhaust brake. See **Fig. 1**.
   - 2.1 Remove the nut and washer holding the air cylinder to its bracket.
   - 2.2 Unscrew the nut connecting the air cylinder to the socket joint.
   - 2.3 Disconnect the socket joint from the ball joint on the exhaust brake housing by removing the safety clip, then prying the socket joint up.
   - 2.4 Remove and discard the air cylinder.
3. Install the new air cylinder onto the exhaust brake.
   - 3.1 Attach the closed end of the air cylinder to the stud on the air cylinder bracket. Tighten the nut firmly.
   - 3.2 Attach the socket joint to the other end of the air cylinder. Install the nut and tighten it until the socket joint lines up with the ball joint on the air brake housing.
   - 3.3 Using the safety clip, secure the socket joint to the air brake ball joint.
4. Test the air cylinder operation by connecting shop air to it. Make any necessary adjustments.
5. Install the exhaust brake. See **Subject 100** for instructions.

Air Cylinder Replacement



1. Exhaust Brake
2. V-Clamp
3. U-Clamp
4. Exhaust Pipe to Muffler
5. Air Line
6. Exhaust Pipe From Turbocharger
7. Washer
8. Nut
9. Air Cylinder
10. Nut
11. Safety Clip
12. Capscrew
13. Gasket
14. Exhaust Brake Housing
15. Air Cylinder Bracket

Fig. 1, Jacobs Exhaust Brake

Removal

NOTE: For engine wiring diagrams, refer to the applicable section in **Group 54**. For troubleshooting 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.
2. From inside the vehicle, raise and support the bed, then the engine hatch cover.
3. Disconnect the batteries.
   3.1 Disconnect the battery ground cable at the vehicle frame.
   3.2 Disconnect the positive battery cable from the batteries.

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.

4. Drain the radiator. For instructions, refer to the vehicle maintenance manual.
5. Remove the air cleaner housing. For instructions, refer to **Group 09**.
6. Label and disconnect the wiring. See **Fig. 1**.
   6.1 Disconnect the wiring from the starter.
   6.2 Disconnect the ground strap from the alternator.
   6.3 Disconnect the wiring from the alternator.
   6.4 Disconnect the wiring from the coolant temperature sensors.
   6.5 Unplug the lower wiring harness connector from the electronic control module.
7. If equipped, disconnect the ether start tube and sensor wire.
8. Disconnect the power steering components. For instructions, refer to **Group 46**.
9. If applicable, disconnect the air lines from the air governor on top of the air compressor.
10. At the fuel/water separator, disconnect the fuel delivery line that runs to the engine.
11. Disconnect the transmission shift cable. For instructions, refer to **Group 26**.
12. Drain the air tanks.
13. Remove the exhaust ducting.
    13.1 Loosen the V-band clamp that holds the forward end of the exhaust ducting to the rear of the turbocharger.
    13.2 Under the cab, disconnect the exhaust pipe from the saddle clamp mounted on the flywheel housing.
14. Disconnect the driveline from the transmission. For instructions, refer to **Group 26**.
15. While under the vehicle, disconnect all other engine and transmission components.
    15.1 Disconnect the wiring from the speedometer sensor at the transmission output.
    15.2 Disconnect the wiring harness connectors from the back-up alarm switch and the neutral start switch on the transmission top cover.
    15.3 Disconnect the fuel return line from the back of the engine block.
    15.4 If applicable, disconnect the wire-braid air compressor outlet line from the chassis air supply line.

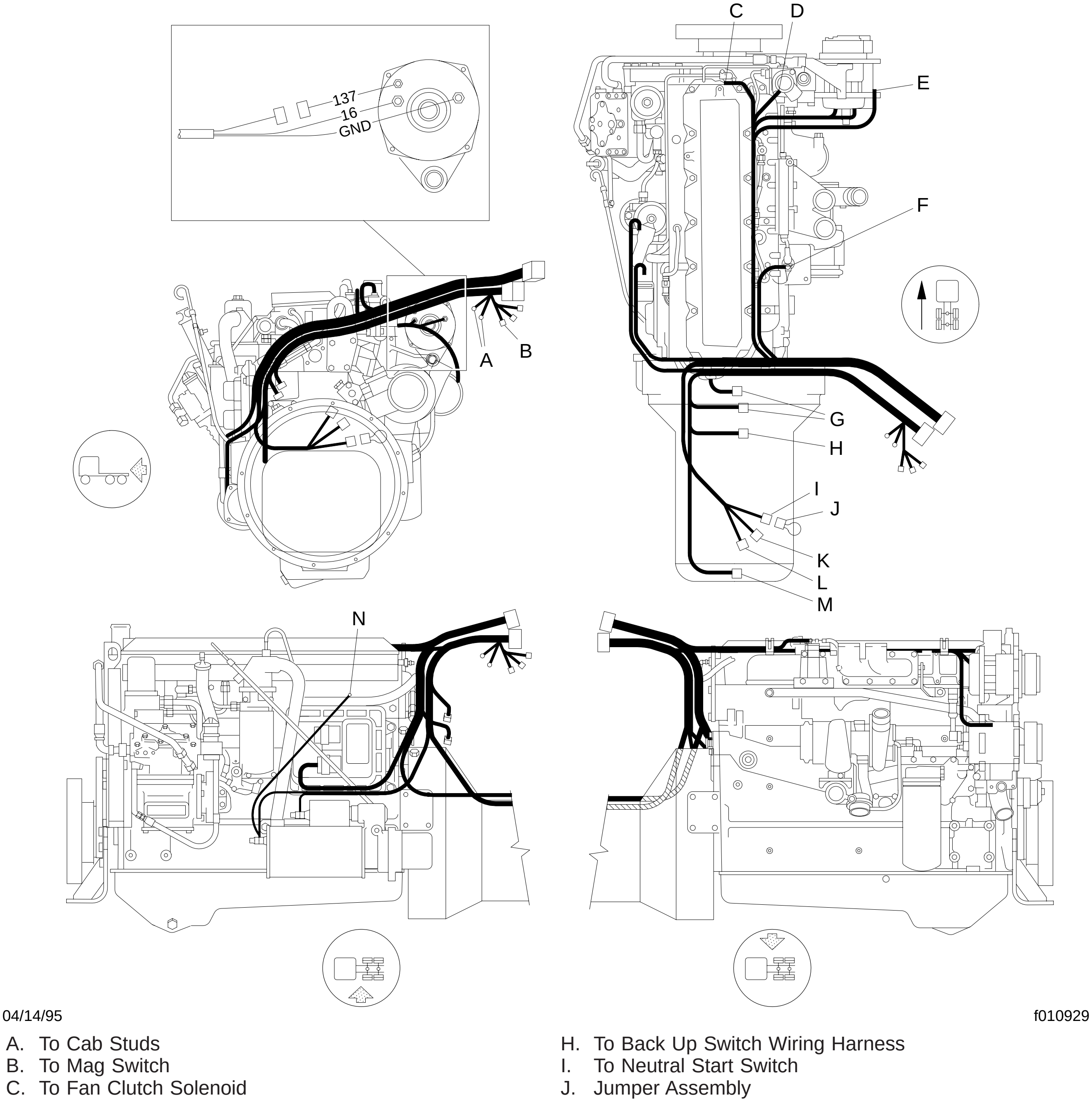
WARNING

The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting 2 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.

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.

16. Remove the engine from the vehicle.

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

16.1 With the engine securely supported by the jack, 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.

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

16.3 Lower the engine, then remove it from underneath the vehicle.

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

Installation

WARNING

The crane and lifting chains used to install 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 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 With the engine on the jack, position it under the vehicle.

   1.2 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).

   1.3 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).

   1.4 Once the engine is securely installed in the vehicle, remove the jack stand.

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.

7. If so equipped, connect the ether start tube and sensor wire.

8. Connect the power steering components. For instructions, refer to **Group 46**.

9. Connect the engine wiring.

   9.1 Connect the wiring to the starter.

   9.2 Connect the ground strap to the alternator.

   9.3 Connect the wiring to the alternator.

   9.4 Connect the wiring to the coolant temperature sensors.

   9.5 Plug the lower wiring harness connector into the electronic control module.

10. Connect the heater hoses.

11. Raise the engine up. Then install the fan blade.

12. Install the air cleaner housing. For instructions, refer to **Group 09**.

Engine Removal and Installation, Caterpillar CFE

13. Connect the parking brake and shift cables.
14. Fill the radiator.
15. Connect the batteries.
16. From inside the vehicle, close the engine access hatch, then lower the bed.
17. Start the engine and check for leaks and correct fluid levels. Correct as needed.
18. Remove the chocks from the tires.
19. Test drive the vehicle.

General Information

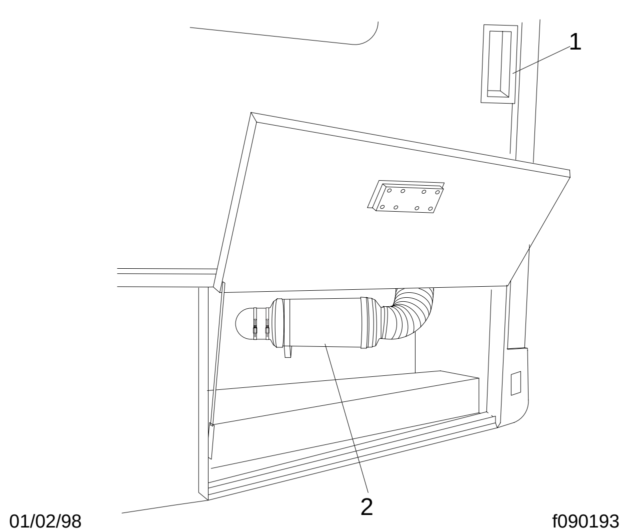
The air cleaner is horizontally mounted on the outside of the left frame rail, at the rear of the vehicle. Air enters through the air intake screen and is diverted into the air cleaner where it passes from the outside to the inside of a replaceable, moisture-resistant, fine-mesh paper air cleaner. See **Fig. 1**. Filtered air exits the air cleaner through an outlet port.

NOTE: On PowerLiner chassis vehicles, the air cleaner assembly is held by two mounting brackets with clips, and is mounted in the engine compartment at the rear of the vehicle.

NOTICE

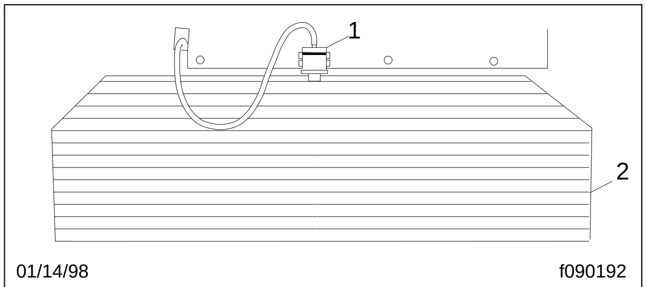
Use the air intake restriction gauge rather than visual inspection to determine if servicing the air filter element is necessary. Removal of the air filter element can cause damage to the primary seal, which may allow contaminants into the engine, potentially causing engine damage.

The air restriction indicator is mounted on the radiator at the rear of the vehicle. See **Fig. 2**. The indicator shows when the air cleaner needs to be replaced.



1. Air Intake Screen
2. Air Cleaner

Fig. 1, Air Cleaner and Air Intake Screen



1. Air Restriction Indicator
2. Radiator

Fig. 2, Air Restriction Indicator Location

Replacement

NOTE: Replace the air cleaner only when it reaches the maximum restriction level allowed by the engine manufacturer. See **Fig. 1**. See **Subject 110**.

NOTICE

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

XC Chassis Air Cleaner Replacement

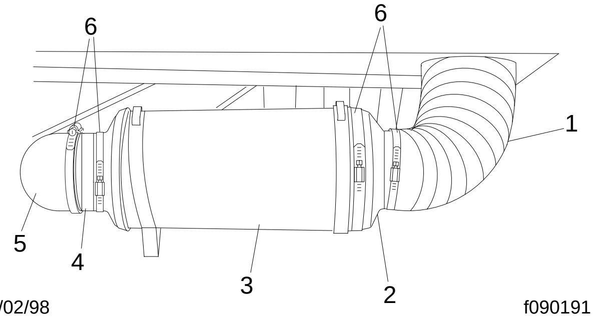
1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Open the rearmost access panel on the left side of the vehicle.
3. Loosen the hose clamp that attaches the air intake ducting to the inlet cap.
4. Loosen the hose clamp that attaches the inlet cap to the air cleaner.
5. Loosen the hose clamp that attaches the air cleaner to the air intake tube.

NOTE: A metal band on the air intake tube controls the distance between the air cleaner and the 90-degree reducing elbow.

6. Open the clamps on the bands around air cleaner.
7. Remove the air cleaner.
8. Attach a new air cleaner to the air intake tube.
9. Attach the inlet cap to the air cleaner.

IMPORTANT: The rivets on the end of the air cleaner must be aligned with the U-shaped cutouts on the inlet cap.

10. Close the clamps on the bands around the air cleaner.
11. Tighten all of the hose clamps securely.
12. Close the left-side, rear access panel and remove the chocks from the tires.



1. Air Intake Ducting
2. Inlet Cap
3. Air Cleaner
4. Metal Band
5. Air Intake Tube
6. Hose Clamp

Fig. 1, Air Cleaner Mounting

VCL (Powerliner) Chassis Air Cleaner Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Open the engine compartment door and gain access to the air cleaner in the engine compartment at the rear of the vehicle.
3. Loosen the hose clamp that attaches the air intake ducting to the inlet end of the air cleaner.
4. Loosen the hose clamp that attaches the outlet elbow at the side of the air cleaner.
5. Release the two clips on the mounting brackets securing the air cleaner.
6. Detach the air cleaner from the inlet ducting and the outlet elbow and remove it from the mounting brackets.
7. Place the new air cleaner in position in the mounting brackets.
8. Attach the inlet ducting and the outlet elbow to the air cleaner and fasten the mounting bracket clips.
9. Tighten the hose clamps at the inlet ducting and the outlet elbow securely.
10. Close the engine compartment door and remove the chocks from the tires.

Air Cleaner Restriction Checking

The restriction of air flowing through the air cleaner is measured at the fitting in the air intake tube between the 90-degree reducing elbow and the 90-degree elbow at the engine turbocharger.

The air restriction indicator is mounted on the radiator. A hose connects the indicator to the fitting in the air intake tube.

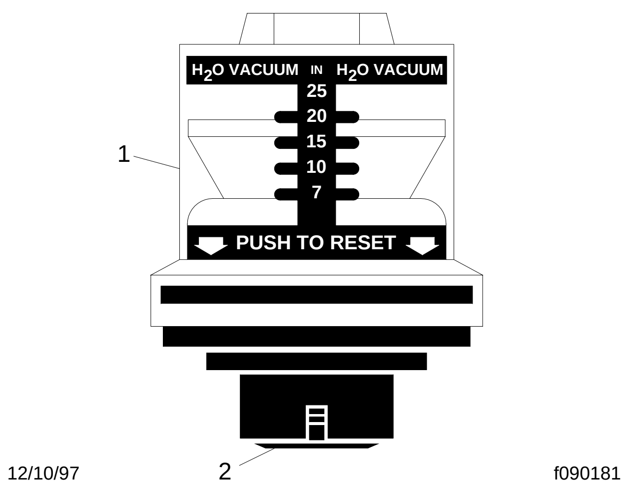
NOTICE

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 the 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 restriction is at or above the maximum, push the reset button on the air restriction 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. See **Fig. 1**.

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

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



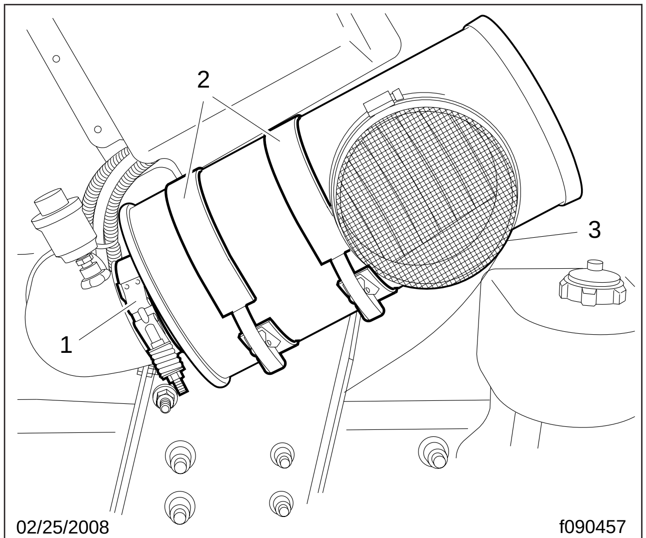
1. Air Restriction Indicator
2. Reset Button

Fig. 1, Manual-Reset Air Restriction Indicator

Farr ECO SE Replacement (front-mounted)

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

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Open the front access panel.
3. Loosen the intake ducting by loosening the T-bolt clamp at the air cleaner outlet. See **Fig. 1**.



1. T-Bolt Clamp
2. Mounting Clamps
3. Screened Air Inlet Cap

Fig. 1, Farr ECO SE Air Cleaner (front-mounted)

4. Loosen the mounting clamps.
5. Loosen the T-bolt clamp at the screened air inlet cap. Remove the screened air inlet cap.
6. Slip the old air cleaner out and discard.
7. Position the two quick-release mounting clamps, by inserting bolts into the mounting brackets. Tighten the bolts finger-tight only.
8. Insert the ECO SE air cleaner on the mounting clamps.
9. Slide the metal elbow into the molded urethane outlet until the bead is positioned into the groove. Do not tighten the T-bolt clamp yet.

IMPORTANT: If the beaded tube or elbow is not positioned correctly into the molded urethane outlet, a positive seal may not occur, allowing dirt to bypass the filter and go into the engine, causing catastrophic damage to the engine.

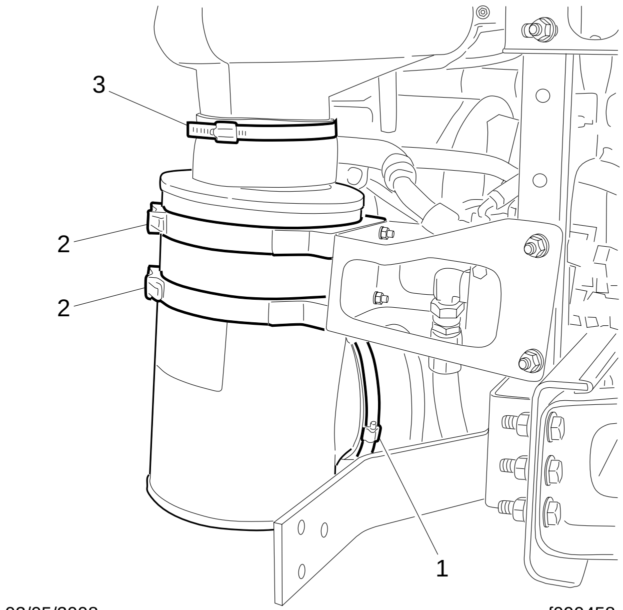
10. Close the mounting clamps to secure the air cleaner in place.
11. Tighten the T-bolt clamp on the outlet tube/elbow.
12. Securely tighten the four bolts on the mounting clamps.
13. Install the screened inlet cap over the filter element.
14. Check all clamps for tightness.
15. Close the front access panel.

Farr ECO BC Replacement (rear-mounted)

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

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 rear access panel.
3. Loosen the clamp at the air inlet tube. See **Fig. 2**.
4. Remove the mounting clamps at the mounting brackets.
5. Using a twisting pulling motion, remove the air filter from the air outlet rubber fitting.
6. Remove the filter from the air inlet rubber fitting.
7. Spray inside of the rubber inlet and outlet connectors with silicon spray for easy installation.
8. Insert the ECO BC filter in the air inlet rubber connector.

Farr ECO Air Cleaner Replacement



1. Air Outlet Clamp
2. Mounting Bracket Clamps
3. Air Inlet Clamp

Fig. 2, Farr ECO BC Air Cleaner (rear-mounted)

9. Insert the side outlet tube of the ECO BC in the air outlet rubber connector, being sure the tube is inserted 1-1/4 inch.
10. Securely install the mounting bracket clamps.
11. Tighten the hose clamps on the inlet and outlet rubber connectors.
12. Recheck all clamps for tightness, including the air outlet side to the engine.

Adjusting Clamp Tension

To Increase Tension

The length of the latch must be slightly shortened by increasing the curve (arc) of the spring latch by gently squeezing with water pump pliers.

To Decrease Tension

The length of the latch must be slightly increased. Reduce the curve (arc) of the spring latch a little at a time by placing it on a flat surface and applying slight pressure until the reduced arc provides minimum tension when installed.

General Information

An average diesel engine needs over 10,000 gallons (38 000 liters) of clean air for each gallon (3.8 liters) of fuel burned. So that 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 an air cleaner followed by air intake tubes and elbows. Stainless steel hose clamps fasten all the components together.

An air restriction indicator is attached to the radiator. A hose connects the air restriction indicator to the air intake tube between the air cleaner and the engine turbocharger. The air restriction indicator indicates when the air cleaner needs to be replaced. The maximum amount of air restriction is 25 inH_2O at full-load and governed rpm or 12 inH_2O at no-load and governed rpm.

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

General Information

WARNING

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

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

IMPORTANT: Replace damaged components with new, identical parts. Hoses, tubes, and 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. Open the rearmost access panel on the left side of the vehicle.
3. Disassemble the air intake ducting. See **Fig. 1**.
   - 3.1 Loosen the hose clamp that attaches the air intake ducting to the inlet cap.
   - 3.2 Loosen the hose clamp that holds the inlet cap to the air cleaner, and remove the inlet cap.
   - 3.3 Loosen the hose clamp that holds the air cleaner to the air intake tube.

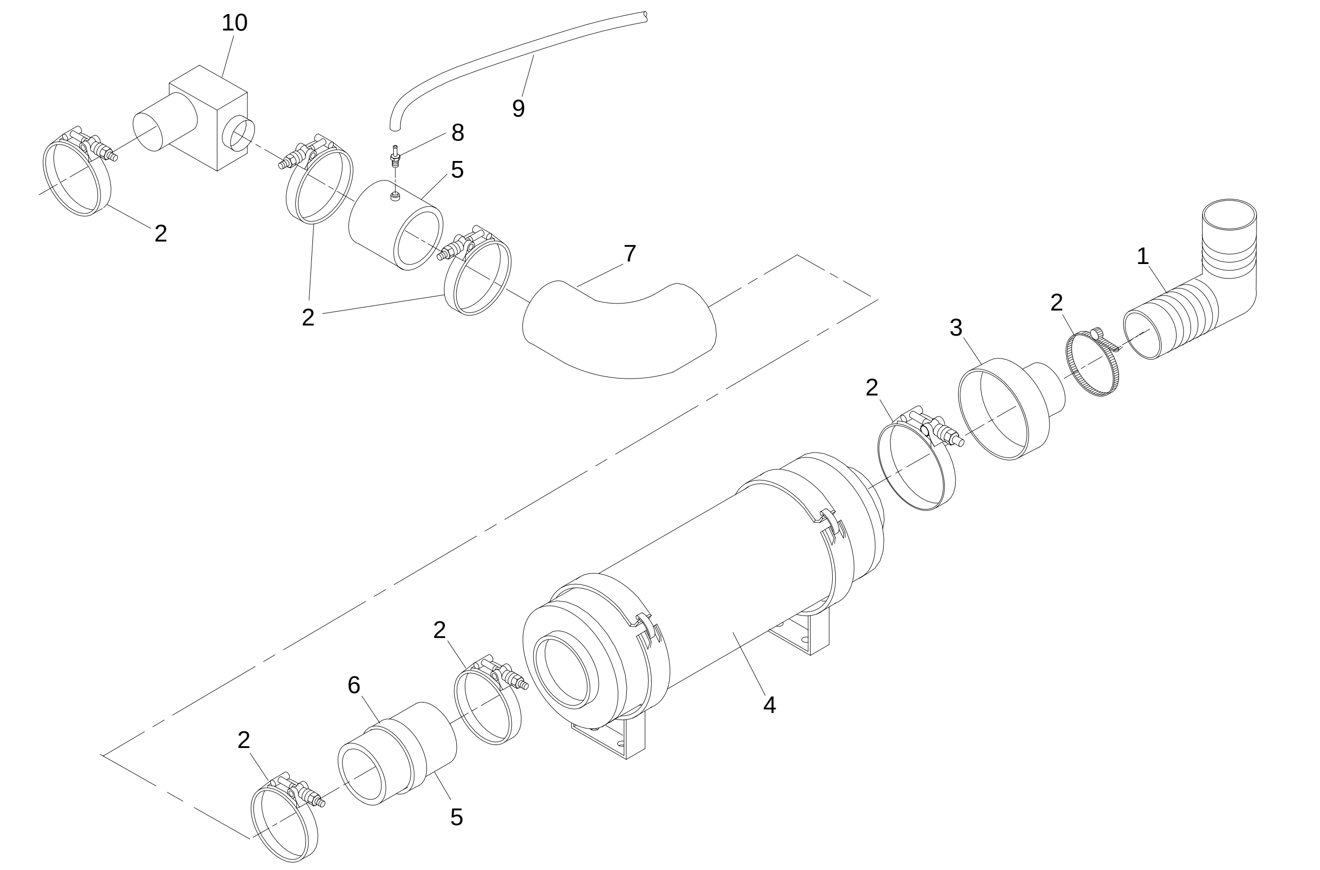
   NOTE: A metal band on the air intake tube controls the distance between the air cleaner and the 90-degree reducing elbow.

   - 3.4 Remove the metal band from the air intake tube.
   - 3.5 Loosen the hose clamp that attaches the air intake tube to the 90-degree reducing elbow, and remove the air intake tube.
   - 3.6 Remove the fitting and hose from the air intake tube.
   - 3.7 Loosen the hose clamp that attaches the 90-degree reducing elbow to the air intake tube, and remove the 90-degree reducing elbow.
   - 3.8 Loosen the hose clamp that attaches the air intake tube to the 90-degree elbow, and remove the air intake tube.
   - 3.9 Loosen the hose clamp that attaches the 90-degree elbow to the engine turbocharger, and remove the 90-degree elbow.

Installation

1. Replace any damaged parts with new identical parts.
2. Assemble the air intake ducting. See **Fig. 1**.
   - 2.1 Attach the new or undamaged 90-degree elbow to the engine turbocharger, and attach, but don't tighten, the hose clamp.
   - 2.2 Attach the new or undamaged air intake tube to the 90-degree elbow, and attach, but don't tighten, the hose clamp.
   - 2.3 Attach the new or undamaged 90-degree reducing elbow to the air intake tube, and attach, but don't tighten, the hose clamp.
   - 2.4 Attach the fitting and hose from the air restriction indicator to the air intake tube.
   - 2.5 Place the metal band on the air intake tube.
   - 2.6 Attach the air intake tube to the air cleaner, and attach, but don't tighten, the hose clamp.
   - 2.7 Attach the inlet cap to the air cleaner, and attach, but don't tighten, the hose clamp.
   - 2.8 Attach the inlet cap to the air intake ducting, and attach, but don't tighten, the hose clamp.
   - 2.9 Tighten all hose clamps.
3. Close the access panel.

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



1. Air Intake Ducting
2. Hose Clamp
3. Inlet Cap
4. Air Cleaner
5. Air Intake Tube
6. Metal Band
7. 90-Degree Reducing Elbow
8. Fitting
9. Hose
10. 90-Degree Elbow

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

4. Remove the chocks from the tires.

Air Intake Ducting, Removal and Installation, Cummins M11 Series Engine

WARNING

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

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

IMPORTANT: Replace damaged components with new, identical parts. Hoses, tubes, and 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 on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Open the engine access door at the rear of the vehicle.
3. Disassemble the air intake ducting. See **Fig. 1** and **Fig. 2**.

   3.1 Loosen the hose clamps that secure the air intake hose to the inlet end of the air cleaner and to the air inlet on the vehicle. Detach the hose from the air cleaner and from the air inlet and remove it.

   3.2 Loosen the hose clamp that secures the outlet elbow to the side of the air cleaner. Detach the elbow from the air cleaner.

   3.3 Loosen the hose clamp that secures the outlet elbow to the air intake tube. Detach the elbow from the tube and remove it.

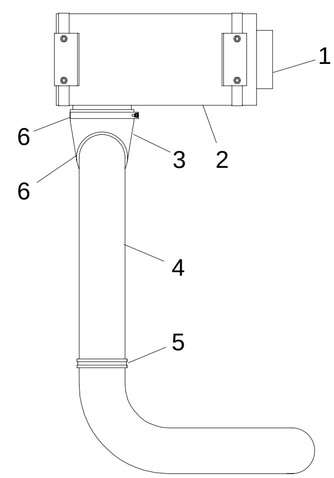
   3.4 Remove the capscrew and nut attaching the intake tube cushion clamp to the twist bracket.

   3.5 Loosen the hose clamp that secures the air intake tube to the turbo elbow and remove the air intake tube.

   3.6 Loosen the hose clamp that secures the turbo elbow to the turbocharger and remove the elbow.

Installation

1. Replace any damaged parts with new identical parts.
2. Assemble the air intake ducting. See **Fig. 1** and **Fig. 2**.



1. Intake Hose Attaches Here
2. Air Cleaner
3. Air Cleaner Outlet Elbow
4. Air Intake Tube
5. Twist Bracket/Cushion Clamp
6. Hose Clamp

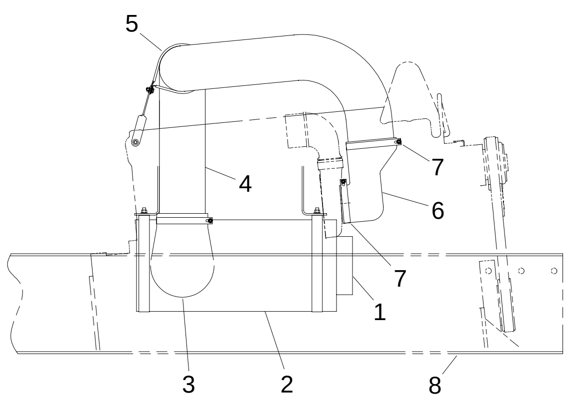
Fig. 1, Air Intake Ducting (overhead view)

   2.1 Attach the new or undamaged turbo elbow to the engine turbocharger. Install, but don’t tighten, the hose clamp.

   2.2 Attach the new or undamaged air intake tube to the turbo elbow. Install, but don’t tighten, the hose clamp.

   2.3 Slide the cushion clamp into position over the air intake tube. Attach the clamp to the twist bracket with the capscrew and nut, but don’t tighten them yet.

Air Intake Ducting, Removal and Installation, Cummins M11 Series Engine



1. Intake Hose Attaches Here
2. Air Cleaner
3. Air Cleaner Outlet Elbow
4. Air Intake Tube
5. Twist Bracket/Cushion Clamp
6. Turbo Elbow
7. Hose Clamp
8. Frame Rail

Fig. 2, Air Intake Ducting (side view)

2.4 Attach the air intake tube to the new or undamaged air cleaner outlet elbow. Install, but don't tighten, the hose clamp.

2.5 Attach the air cleaner outlet elbow to the side of the air cleaner. Install, but don't tighten, the hose clamp.

2.6 Tighten all of the hose clamps securely.

2.7 Tighten the cushion clamp capscrew and nut securely.

2.8 Attach the new or undamaged air intake hose to the end of the air cleaner and to the vehicle air inlet. Install hose clamps at each end of the hose and tighten them securely.

3. Ensure that all of the air intake components are properly installed.
4. Close the engine access door.
5. Remove the chocks from the tires.

General Information

The charge air cooler (CAC) is attached to the radiator, and is similar to the 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 (Rear-Mounted CAC)

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Remove the radiator. For instructions, see **Group 20**.
3. Remove the six bolts that fasten the charge air cooler (CAC) to the radiator, and remove the charge air cooler.

Installation (Rear-Mounted CAC)

1. Attach the charge air cooler to the radiator.
2. Install the six bolts that fasten the CAC to the radiator. Tighten the bolts 55 lbf·ft (75 N·m).
3. Install the radiator. For instructions, see **Group 20**.
4. Remove the chocks from the tires.

Removal (Side-Mounted CAC)

1. Park the vehicle, apply the parking brakes, and chock the front tires.
2. Open the left-side engine access panel and secure it open.

WARNING

Before jacking up the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle should fall, severe injury, death, and substantial property damage could result.

3. Jack up the rear of the vehicle and place jackstands under the frame rails, just behind the rear wheels.
4. Remove the four nuts and washers securing the oil cooler to the two mounting brackets attached to the radiator.

NOTE: Rubber isolators attach to the oil cooler mounting bracket bolts. The isolators are positioned between the oil cooler tubes and expand to secure the cooler in position when the mounting nuts are tightened.

5. Disconnect the upper and lower oil line clamps and set the oil cooler aside, out of the way.
6. Disconnect each oil cooler bracket from the radiator at the bottom. Do not disconnect the brackets at the top.
7. Tie-strap each bracket out of the way at the bottom to the access panel framework.
8. Remove the two constant-torque hose clamps securing the rear (outlet) air piping hose to the CAC.
9. Partially disconnect the left-side mudflap enough to gain access to the forward (inlet) air piping hose.
10. Remove the two constant-torque hose clamps securing the forward (inlet) air piping hose to the CAC.

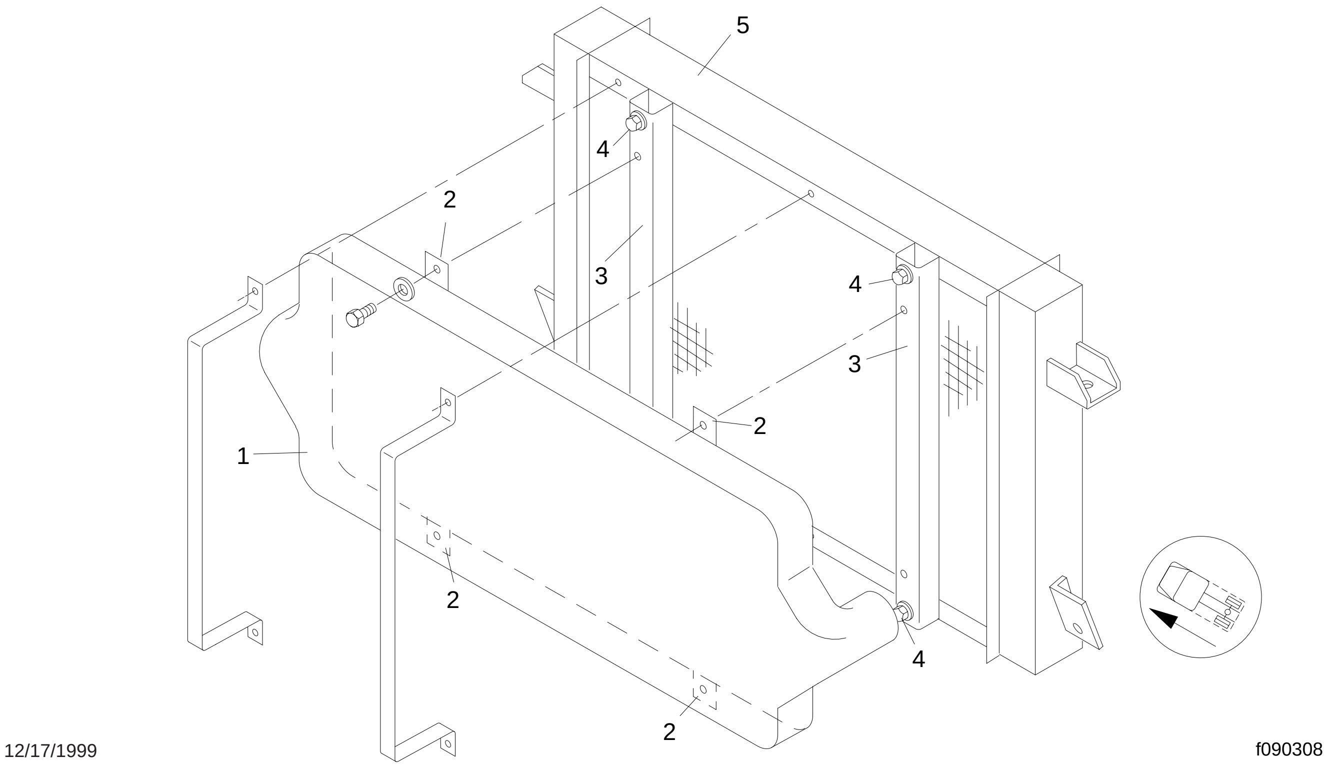
NOTE: It is not necessary to remove the CAC mounting brackets (attached by bolts at the CAC mounting tabs) from the CAC. See **Fig. 1**.

11. Remove the four bolts securing the CAC mounting brackets to the radiator. See **Fig. 1**.
12. With the help of an assistant, pull the CAC away from the radiator and disconnect it from the inlet and outlet hoses. Carefully lower the CAC to the floor and set it aside.

Installation (Side-Mounted CAC)

1. With the help of an assistant, lift the CAC and place it in position against the radiator. Loosely install the two upper CAC mounting bracket bolts into the top of the radiator. See **Fig. 1**.
2. Attach the inlet and outlet hoses to the CAC. Install the two constant-torque hose clamps on each hose and tighten the screws 45 lbf·in (500 N·cm).
3. Install the two lower CAC mounting bracket bolts into the bottom of the radiator. See **Fig. 1**.
4. Tighten all four CAC mounting bracket bolts 55 lbf·ft (75 N·m).

Charge Air Cooler, Removal and Installation



1. Charge Air Cooler (CAC)
2. CAC Mounting Tab
3. CAC Mounting Bracket
4. CAC Mounting Bracket Bolt
5. Radiator

Fig. 1, Charge Air Cooler (CAC) Mounting

5. Remove the tie straps temporarily holding the lower ends of the oil cooler brackets to the access panel framework.
6. Attach the lower ends of the oil cooler brackets to the radiator by installing the two bolts and washers and tightening them securely.
7. If removed previously, ensure that the oil cooler mounting bolts are in place in the oil cooler brackets.

NOTE: Position the rubber isolators between the oil cooler tubes. The isolators will expand and secure the cooler in position when the mounting nuts are tightened.

8. Place the oil cooler in position with the mounting bolts through the rubber isolators.
9. Install the two washers and the two mounting nuts and tighten them securely, so that the isolators expand to hold the oil cooler in position.
10. Install the upper and lower oil line clamps.
11. Attach the left-side mudflap, partially disconnected for access when the CAC was removed.
12. Close the left-side engine access door.

WARNING

Before jacking up the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking. If the vehicle should fall, severe injury, death, and substantial property damage could result.

13. Jack up the rear of the vehicle. Remove the jackstands and lower the vehicle.

Charge Air Cooler, Removal and Installation

14. Remove the chocks from the front tires.

Charge Air Cooler Inspection and Leakage Test

Inspection

1. Park the vehicle, apply the parking brakes, and chock the tires.
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 in **Table 1** represents a loss of less than 0.1 percent of charge airflow. Based on this rate, there should be no measurable loss of performance.

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

Table 1, Leakage Rate Specifications

The CAC core leakage test should be performed using a charge air cooler test kit, part number 5039, which can be purchased from Kent-Moore/SPX at 1.800.328.6657.

CAC Core Leakage Test

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Open the access panel at the rear or left-rear side of the vehicle.
3. Connect the test equipment to the CAC core. See **Fig. 1**.
   - 3.1 Remove the inlet and outlet air piping from the convoluted hoses that attach them to the CAC air inlet and air outlet.
   - 3.2 Slip a safety ring with thumbscrew over each convoluted hose, and onto the CAC air inlet and air outlet, then turn the rings so that the thumbscrews are facing outboard and the safety chains are inboard. Tighten the thumbscrews securely.
   - 3.3 Install an additional constant-torque hose clamp on each convoluted hose.
   - 3.4 Install the test plug without an adaptor in the CAC air inlet, and turn the plug so that the safety chain is inboard. Tighten both of the rearmost constant-torque hose clamps 72 lbf·in (813 N·cm).
   - 3.5 Install the test plug with adaptor in the CAC air outlet, and turn the plug so that the safety chain is inboard. Tighten both of the rearmost constant-torque hose clamps 72 lbf·in (813 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.

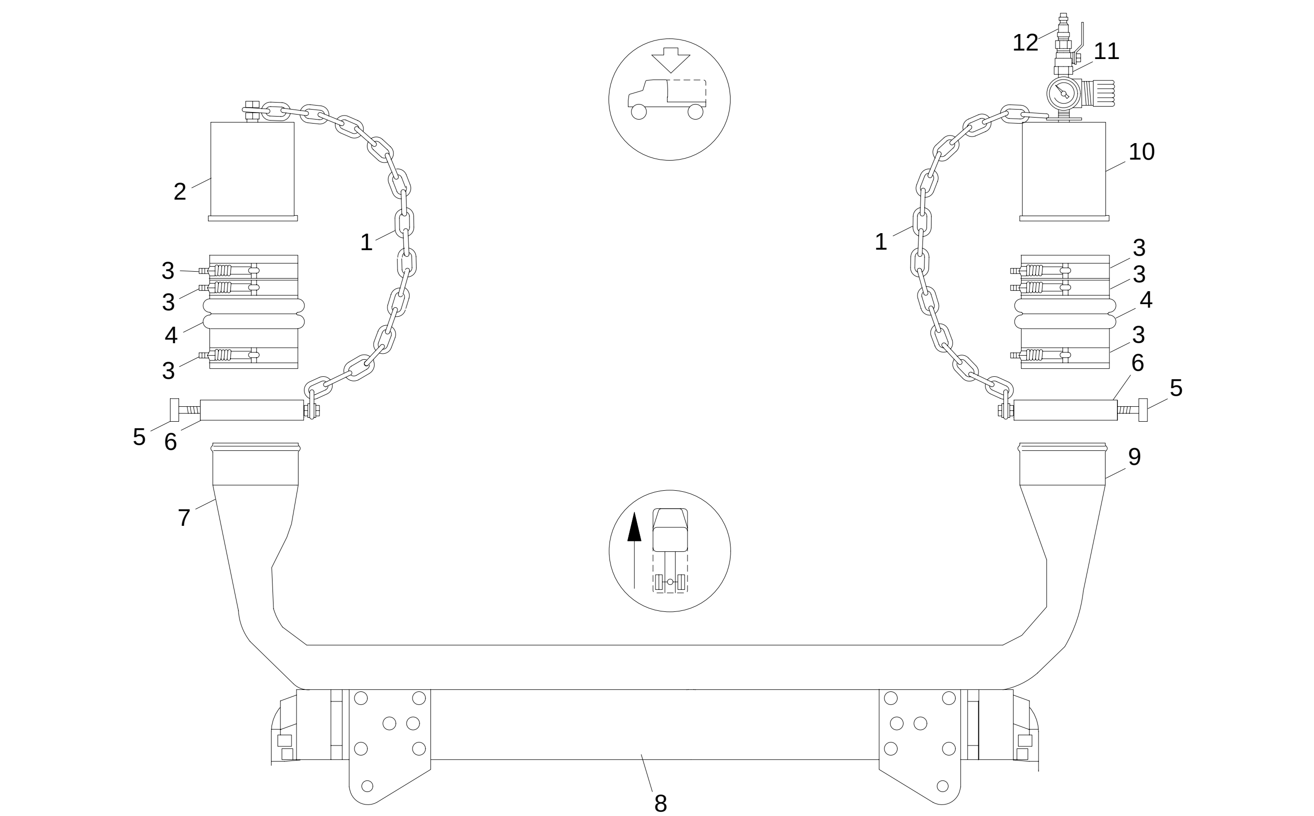
   - 3.6 If not already installed, install a test valve/gauge assembly and air chuck in the test plug with adaptor.
   - 3.7 Attach a pressurized air line to the air chuck on the pressure regulator valve.
4. Test the CAC core.

WARNING

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

   - 4.1 Open the shutoff valve, then slowly open the pressure regulator valve and allow the

Charge Air Cooler Inspection and Leakage Test



1. Safety Chain
2. Test Plug
3. Constant-Torque Hose Clamp
4. Convoluted Hose
5. Thumbscrew
6. Safety Ring
7. CAC Air Inlet
8. Radiator
9. CAC Air Outlet
10. Test Plug With Adaptor
11. Test Valve/Gauge Assembly
12. Air Chuck

Fig. 1, CAC Core Leakage Test (rear-mounted CAC shown)

air intake system to gradually fill with air to the start pressure specified in **Table 1**.

4.2 Close the shutoff valve. Watch the gauge for 15 seconds. If there is more than the specified drop in air pressure in 15 seconds, check the hoses, clamps, and fittings, and retest. If there is still more than the specified drop in pressure, replace the charge air cooler. See **Table 1**.

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

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

5. Remove the test equipment (and the additional constant-torque hose clamps) from the convoluted hoses.
6. 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.

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

Charge Air Cooler Inspection and Leakage Test

8. Close the access panel, 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. Leave the caps off and allow the residual solvent to evaporate.
9. Install the charge air cooler. For instructions, see **Subject 100**.
10. 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

Torque Values		
Description	**Torque lbf·in (N·cm)**	**Torque lbf·ft (N·m)**
Charge Air Cooler to Radiator Mounting Bolt		55 (75)
Charge Air Cooler Constant-Torque Hose Clamp	72 (813)	
Hose Clamp	45 (500)	

Table 1, Torque Values

General Description

Cummins B Series engines use the Midland 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 120 psi (825 kPa), the governor sends an air signal to the unloader 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 90 psi (620 kPa), the air governor stops 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.

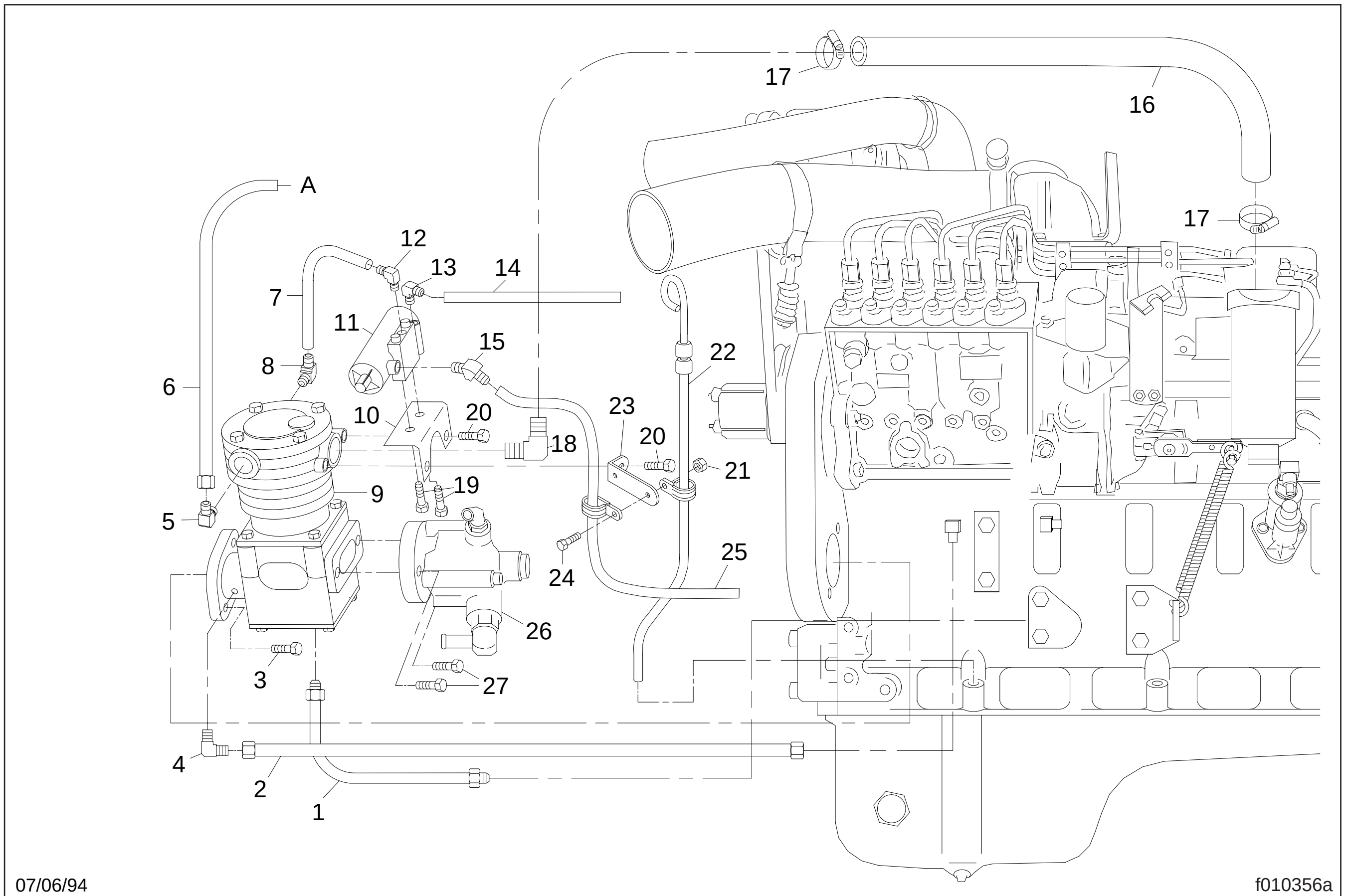
On vehicles with air dryers, when the system reaches the cut-out pressure of 120 psi (825 kPa), the air governor also sends an air signal to open the sludge ejector in the air dryer.

For detailed repair procedures and other engine service not covered in this section, refer to the *Cummins SS191B Air Compressor Shop Manual* or *Cummins Single Cylinder Air Compressor Shop Manual.*

Air Compressor Removal and Installation

Removal

1. Park the vehicle, apply the parking brakes, and chock the tires. See **Fig. 1**.



NOTE: On some vehicles, the air governor is remote mounted to the frame rail.

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. Stand-Off Bracket
24. Bolt
25. Air Governor Signal Line
26. Power Steering Pump
27. Power Steering Pump Mounting Bolt

Fig. 1, Air Compressor Installation, Typical Installation Shown

2. Drain the air reservoirs.
3. Carefully disconnect the air lines.

3.1 Disconnect the air inlet line at the rear of the compressor head.

3.2 Disconnect the air outlet line from the side of the compressor head.

Air Compressor Removal and Installation

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

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

4. Remove the power steering pump.

   4.1 Remove the power steering pump mounting bolts.

   4.2 Remove the pump from the compressor.

5. Disconnect the oil lines.

   5.1 Disconnect the compressor oil return pipe from the engine.

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

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

Installation

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). See **Fig. 1**.

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. Position the pump on the air compressor, and secure it with the power steering pump mounting bolts. Tighten the bolts 28 lbf·ft (38 N·m).

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. Start the engine, and check for leaks in the compressor mounting. Repair any leaks as necessary.

6. Remove the chocks from the tires.

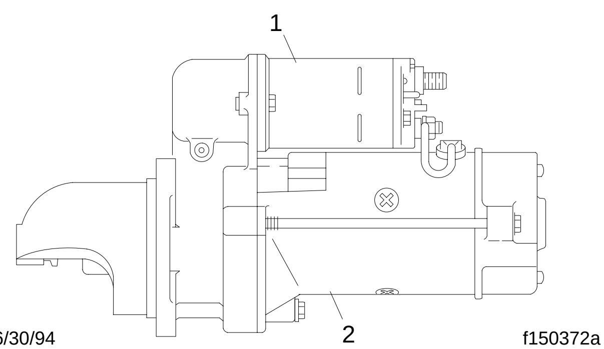
Specifications

Fastener Torques			
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 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**.



1. Solenoid
2. Cranking Motor

Fig. 1, Delco Remy 28-MT Starter

The starter assembly consists of two basic parts: the solenoid and the cranking motor. See **Fig. 2**. 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.

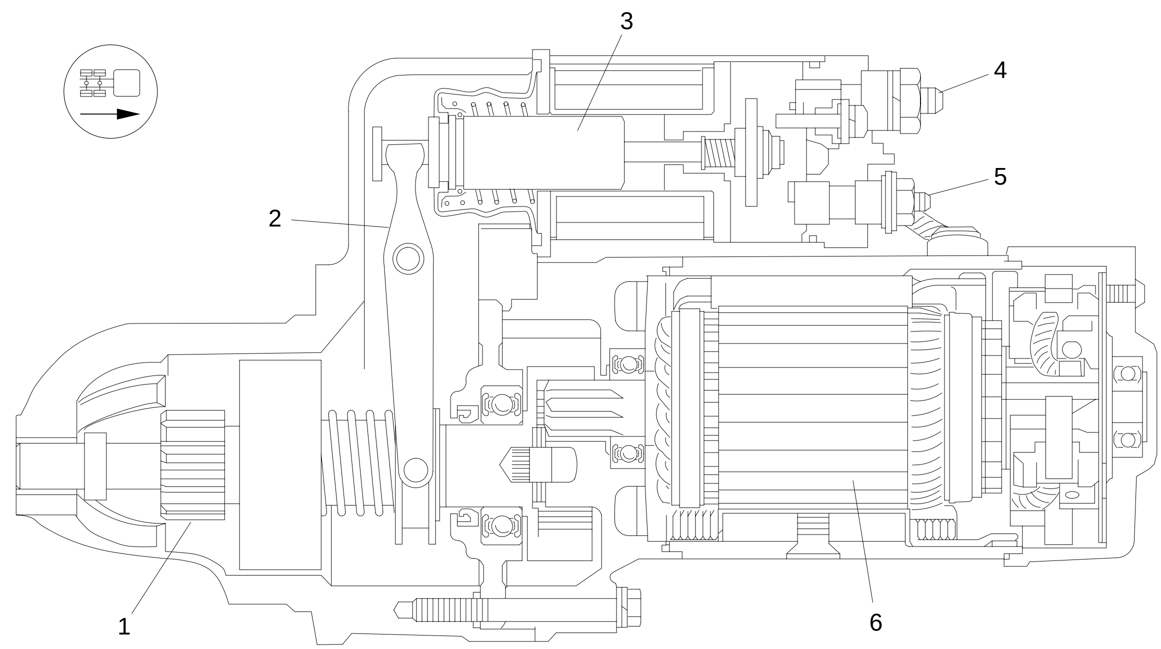
Under normal operating conditions, no maintenance will be required between engine overhaul periods. At the time of engine overhaul, replace the starter with a remanufactured starter.

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



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

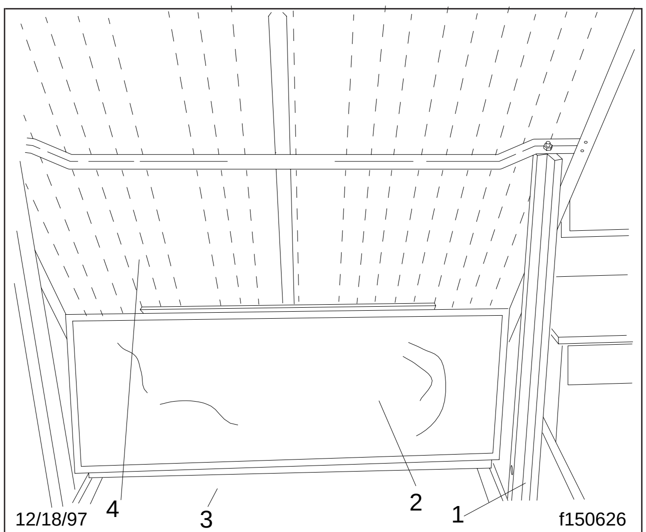
Fig. 2, Starter Components

Delco Remy Starter Removal and Installation

IMPORTANT: Since the engine is located in the rear of the vehicle with the fan pointing backwards, references to the front of the engine or starter refer to aft on the vehicle. Likewise, references to the rear of the engine, or back of the starter, refer to forward on the vehicle.

Removal

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Lift up the bed. Disconnect the support links and prop up the bed using a piece of sturdy metal stock about 3-1/2 feet long (1.1 meter). See **Fig. 1**.

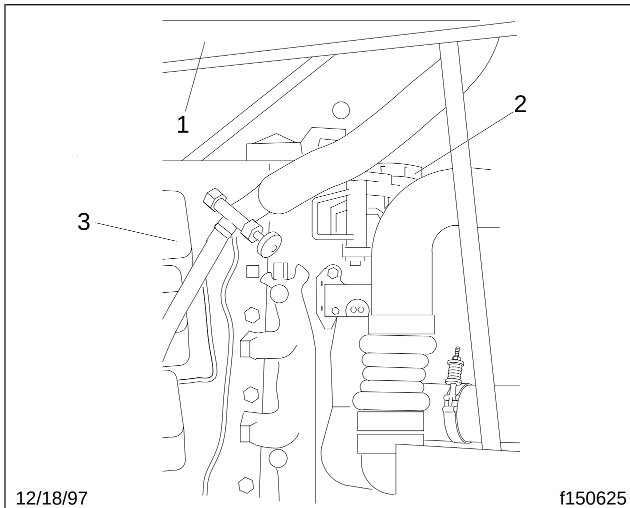


1. Metal Stock, 3-1/2 ft (1.1 meter)
2. Engine Compartment Cover
3. Engine Compartment
4. Bed

Fig. 1, Prop Up the Bed

NOTE: The bed must be propped up to gain access to the starter.

3. Fold up the engine compartment cover to expose the engine and starter. See **Fig. 2**.
4. Disconnect the batteries.
   4.1 Disconnect the battery ground cable at the vehicle frame.



1. Engine Compartment Cover
2. Alternator
3. Engine

Fig. 2, Starter Access

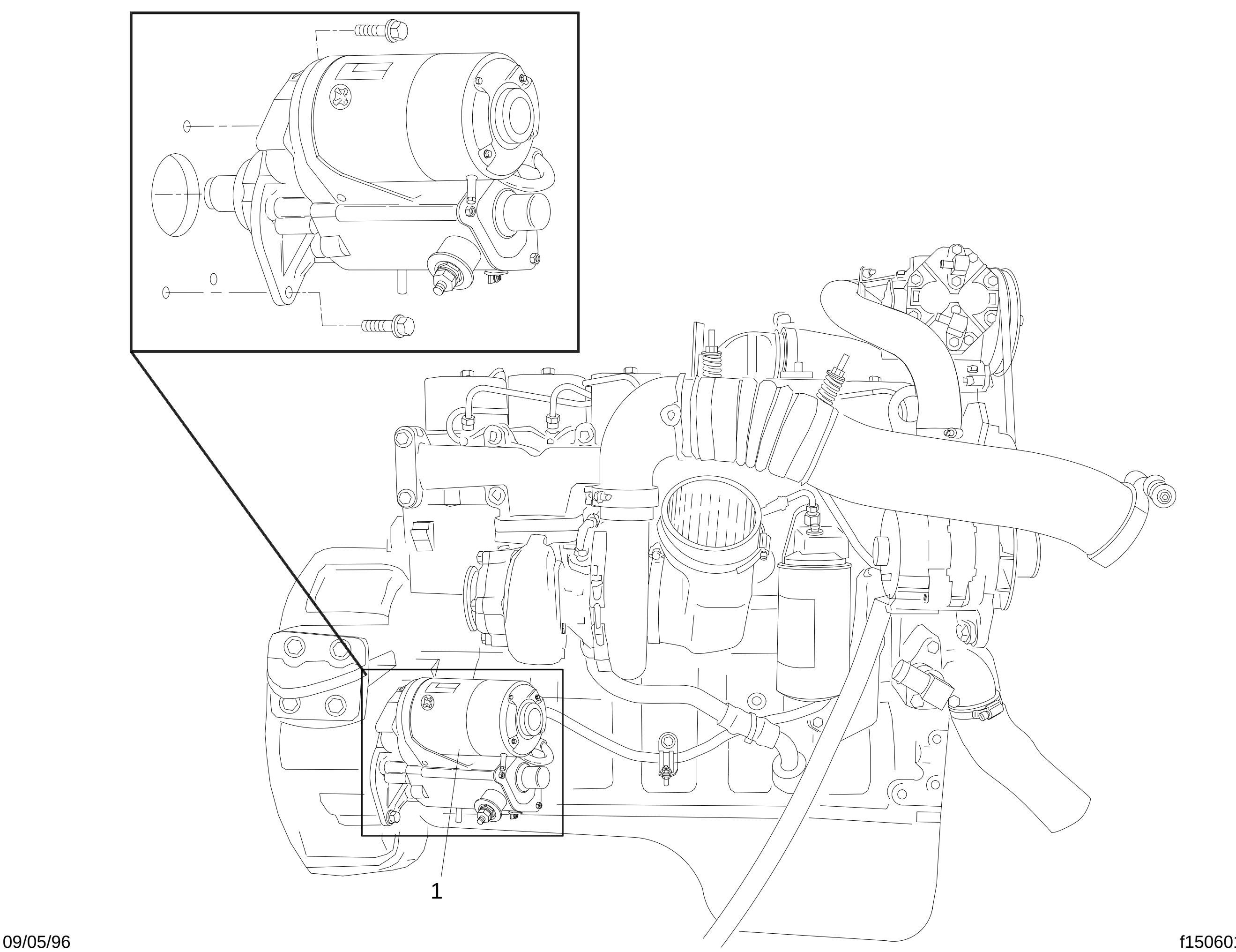
   4.2 Disconnect the positive battery cable from the batteries.

5. Disconnect the wires from the starter solenoid terminals, and label them for reassembly.
6. Remove the starter from the engine by removing the two 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 two capscrews.
   1.2 Tighten the capscrews 38 lbf·ft (52 N·m).
2. Connect the wires to the starter terminals. 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**.

Delco Remy Starter Removal and Installation



1. See insert for detail of mounting bolt installation.

Fig. 3, Starter Installation

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. Close the engine compartment cover and reattach the support links to the bed. Lower the bed.
6. Remove the chocks from the tires.
7. Start the engine to test the starter.

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** 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.
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 starter relay is broken.	Replace the starter relay.
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**.

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**.

Troubleshooting

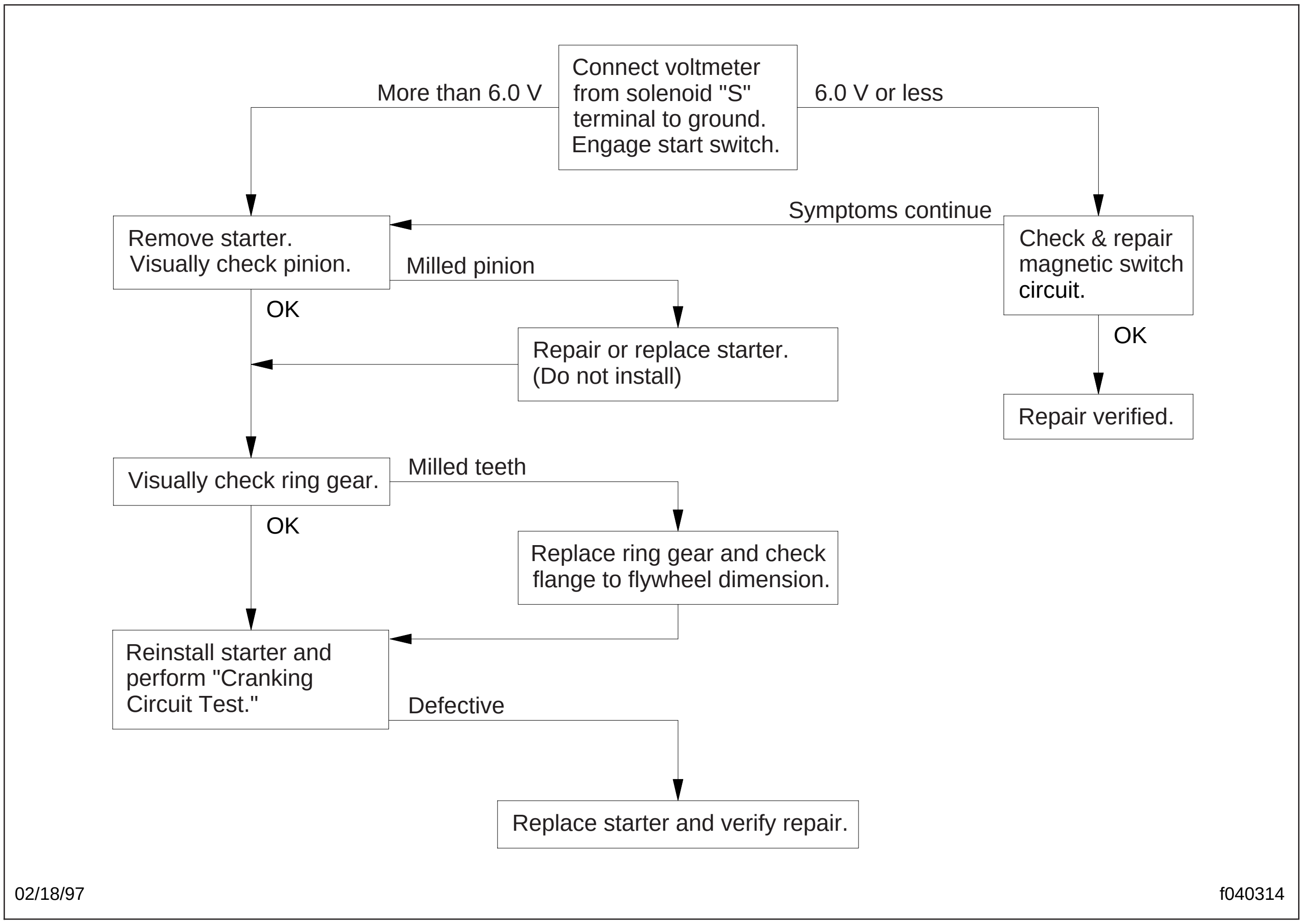


Fig. 1, Milled Pinion Symptoms

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 (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.

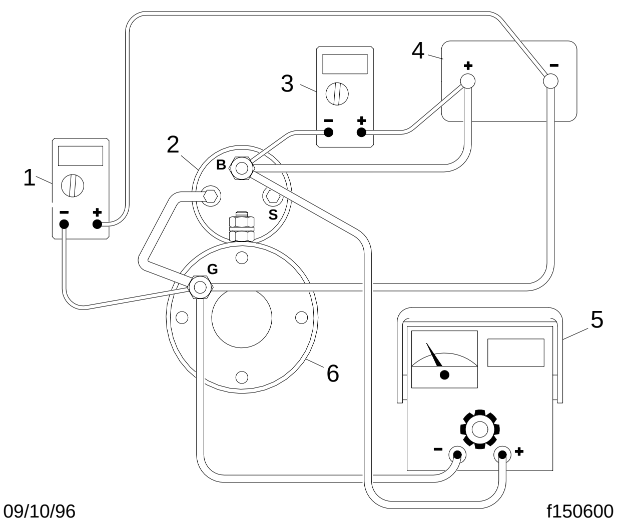
IMPORTANT: Connect the voltmeter to the starter "G" terminal, not to the carbon pile clamp.

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

NOTE: Ignore the minus (–) sign.

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

   Add the positive (V1) and the negative (V2) voltage loss readings together. If the total voltage



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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

loss is more than 0.500 volts, repair or replace as necessary.

7. Disconnect the carbon pile and the voltmeter. Reconnect the starter relay to the starter "S" terminal.

INTERCONNECTING CABLE TEST

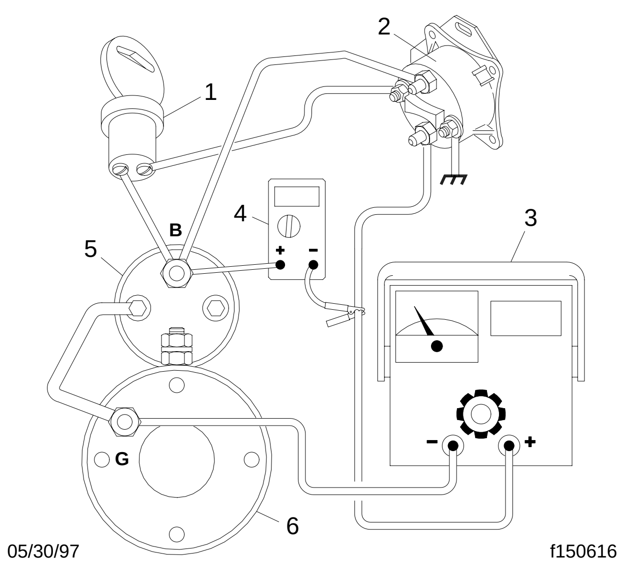
1. This test requires two persons. While the first person cranks the engine, the second person uses a voltmeter to measure the voltage across the starter solenoid "B" (battery) and starter "G" (ground) terminals.
2. If the voltage is 9.0 volts or less while cranking, check the battery interconnecting cables.
   - 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, starter relay, and ignition keyswitch. 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 starter relay to the "S" terminal on the starter solenoid.
2. Use a small clamp or 8-gauge jumper wire to connect this lead to the positive lead of a carbon pile tester. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal. See Fig. 3.



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

Fig. 3, Starter Solenoid Circuit Test

Troubleshooting

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 starter relay lead to which the carbon pile is already connected.
4. Read and record (as V3) the battery voltage shown on the meter, about 12.6V.

NOTE: This step requires two persons.

5. Have one person turn the ignition keyswitch to the START position while the other person listens for the clicking sound of the starter relay closing. Read the voltage on the voltmeter. It should read very low voltage, less than 0.1V.
6. Check the starter solenoid circuit voltage loss.
   - 6.1 Turn the ignition key to the START position; then turn on the carbon pile and adjust it to a 100-amp load.
   - 6.2 Now read and record (as V4) the voltage on the voltmeter. Turn off the carbon pile.
   - 6.3 If the voltage drop (V4–V3) is 1.0V or less, the starter solenoid circuit is OK.

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

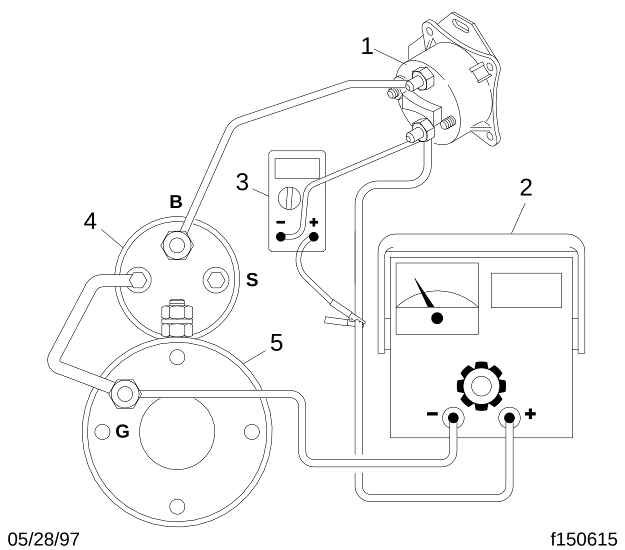
Starter Wiring Test

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

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

2. Connect this lead to the positive lead of a carbon pile tester. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal (leave as in "Starter Solenoid Circuit Test").
3. Set a digital voltmeter on the low scale and connect the positive lead of the voltmeter to the starter solenoid "B" (battery) terminal. Connect the negative lead of the voltmeter to the large terminal of the starter relay that is connected to the starter "B" terminal (circuit 1046). See **Fig. 4**.

   If any voltage shows, reconnect to the other large terminal.

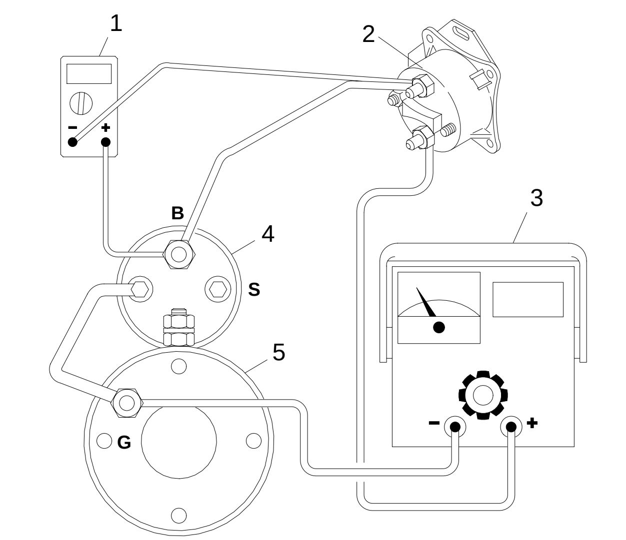


1. Digital Voltmeter
2. Starter Relay
3. Carbon Pile
4. Starter Solenoid
5. Cranking Motor

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

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

4. Have a second person start the engine momentarily.
5. Check the first wire voltage loss (V5).
   - 5.1 Turn the ignition key to the START position, then turn on the carbon pile and adjust it to a 100-amp load.
   - 5.2 Now read and record the voltage (V5) on the voltmeter. Turn off the carbon pile.
6. Now connect the positive lead of the digital voltmeter (still set on the low scale) to the starter relay 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 starter relay (circuit 1045). See **Fig. 5**.
7. Have a second person start the engine momentarily.



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

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

8. Check the second wire voltage loss (V6).

   NOTE: Ignore the minus (–) sign.

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

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

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

   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 starter relay to the starter "S" terminal.

10. Check all wiring and connections and repair or replace as needed. For instructions on wire repair, see **Section 54.00**.

Ring and Pinion Gear Test

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

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

3. If the engine still does not crank properly after replacing the starter, look for a mechanical problem in the engine. For instructions, see 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 starter relay. Remove the jumper immediately to stop the engine from cranking.
2. If the engine starts with the jumper in place, do the "Starter Wiring Test." Repair/replace the wiring connections, terminals, and/or starter relay as necessary.
3. If the engine now starts properly, check the starter mounting bolts for tightness and do the "Alternator Wiring Test." See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
4. If the engine still does not start properly, go to "Available Cranking Voltage Test."

Specifications

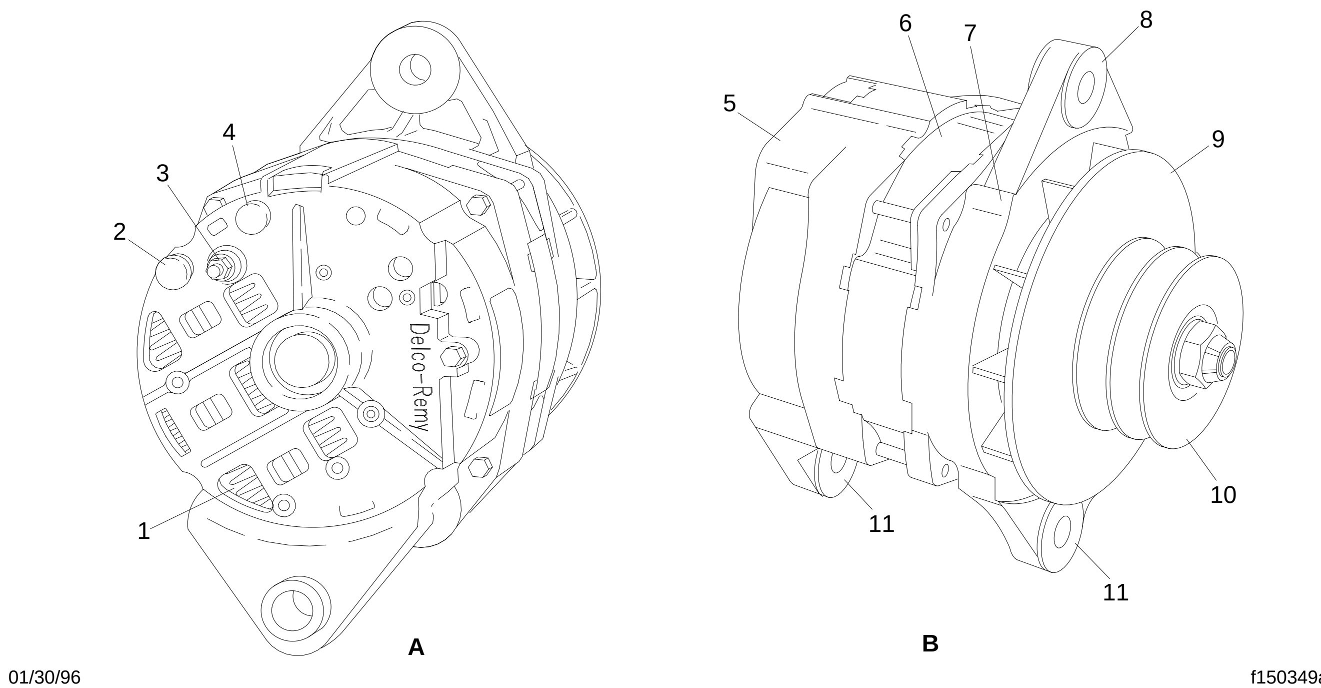
Fastener Torque Values				
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
Starter Mounting Capscrews	10.9	M10 x 1.5	38 (52)	—
Battery (B) Terminal Nut	Brass	M10	13 (18)	—
Solenoid (S) Terminal Nut	Brass	M5	—	13 (18)

Table 1, Fastener Torque Values

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 positive terminal.



A. Rectifier End
B. Drive End

1. Rectifier Bridge
2. Relay ("R") Terminal
3. Output ("BAT") Terminal
4. Indicator Light ("I") Terminal
5. Frame, Rectifier End
6. Stator
7. Frame, Drive End
8. Adjustment Lug
9. Fan
10. Pulley
11. Mounting Lug

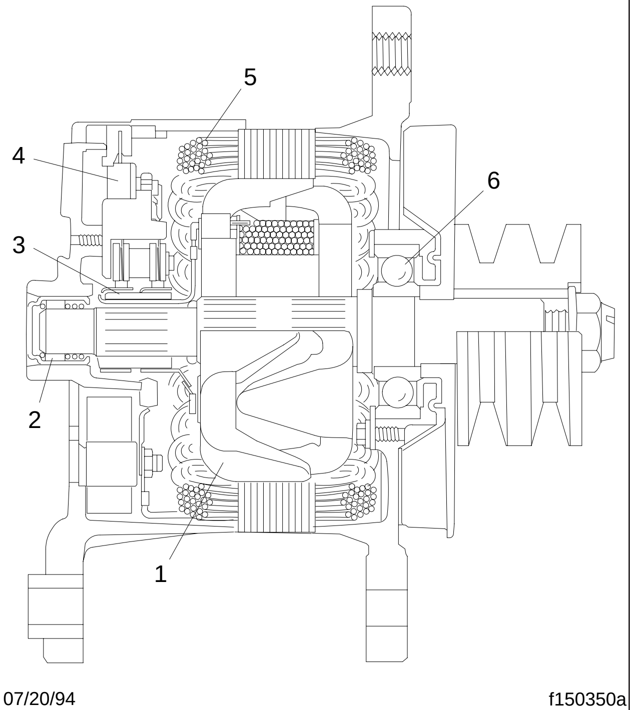
Fig. 1, 21-SI Alternator (exterior view)

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. Field Windings
6. Ball Bearings

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

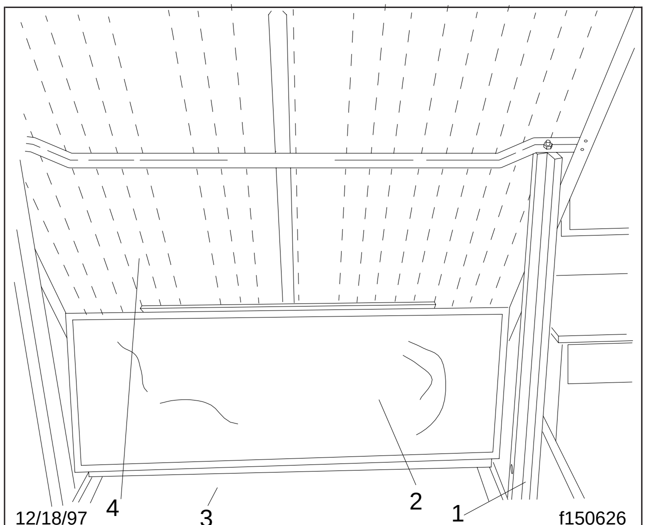
Delco Remy Alternator Removal and Installation, Cummins B

IMPORTANT: Since the engine is located in the rear of the vehicle with the fan pointing backwards, references to the front of the engine or alternator refer to aft on the vehicle. Likewise, references to the rear of the engine, or back of the alternator, refer to forward on the vehicle.

Removal

NOTE: Because the engine is located in the rear of the vehicle, it is easier to remove the alternator using two people, one located on top of the engine, the other underneath.

1. Disconnect the batteries.
2. Lift up the bed. Disconnect the support links and prop up the bed using a piece of sturdy metal stock about 3-1/2 feet long (1.1 meter). See **Fig. 1**.

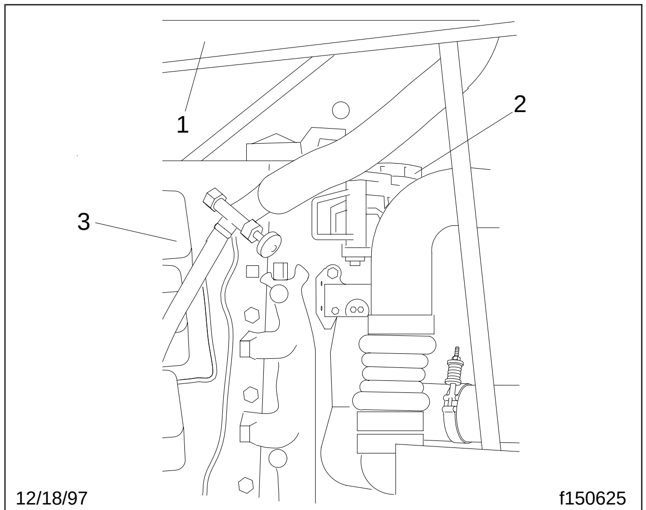


1. Metal Stock, 3-1/2 ft (1.1 meter)
2. Engine Compartment Cover
3. Engine Compartment
4. Bed

Fig. 1, Prop Up the Bed

NOTE: The bed must be propped up to gain access to the alternator.

3. Fold up the engine compartment cover to expose the engine and alternator. See **Fig. 2**.

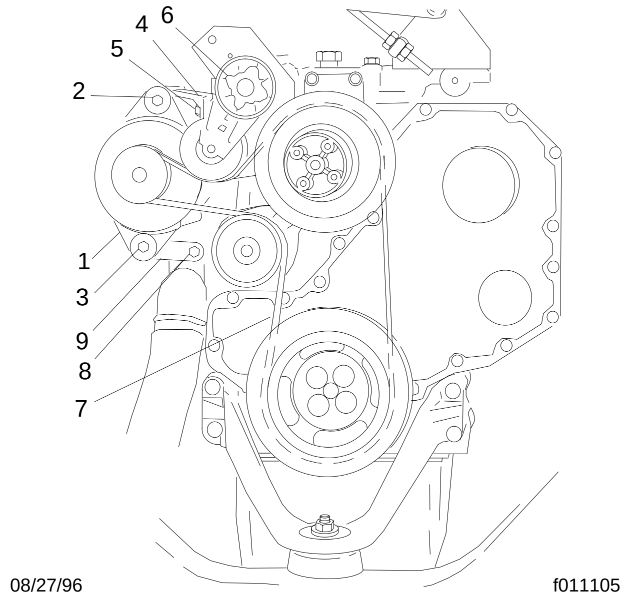


1. Engine Compartment Cover
2. Alternator
3. Engine

Fig. 2, Alternator Access

4. From underneath the vehicle, remove the alternator (lower) mounting capscrew. See **Fig. 3**.
5. Mark all electrical leads and disconnect them from the alternator. See **Fig. 4**.
6. From above, remove the pivot (upper) capscrew and nut.
7. Remove the alternator belt from the alternator pulley. See **Fig. 3**.
   - 7.1 Insert a breaker bar in the belt tensioner and rotate the tensioner up and off the belt.
   - 7.2 Holding the tensioner up, take the belt off the alternator pulley.
   - 7.3 Slowly release the belt tensioner, and remove the breaker bar. It is not necessary to remove the belt from the vehicle.
8. Remove the alternator. See **Fig. 5**.
   - 8.1 Remove the alternator mounting capscrew from the link.
   - 8.2 Remove the nut and washer from the pivot capscrew.
   - 8.3 Securely hold the alternator to prevent it from falling, and remove the pivot capscrew.

Delco Remy Alternator Removal and Installation, Cummins B



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. 3, Alternator Installation, Cummins B Series Engine

8.4 Remove the alternator from the vehicle.

IMPORTANT: The alternator must be removed from above. It can be angled out past the fresh air inlet of the turbo and then up and out.

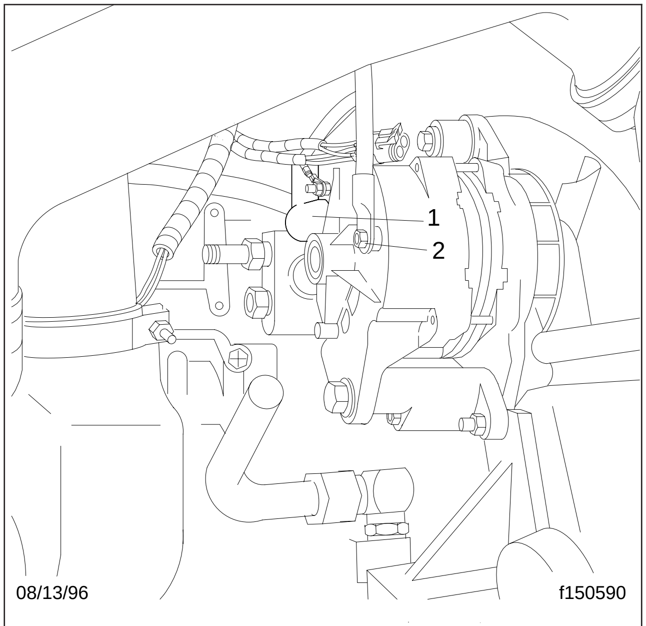
9. Inspect the drive belt. For instructions, see the engine manufacturer's manuals.

Installation

1. From above the engine, install the alternator on the pivot bracket. See **Fig. 5**.

   1.1 Position the alternator on the bracket.

   1.2 Insert the pivot capscrew through the alternator and the bracket.



1. Output Terminal 2. Ground Terminal

Fig. 4, Electrical Connectors

   1.3 Install the washer and nut on the end of the pivot capscrew, but do not tighten the nut yet.

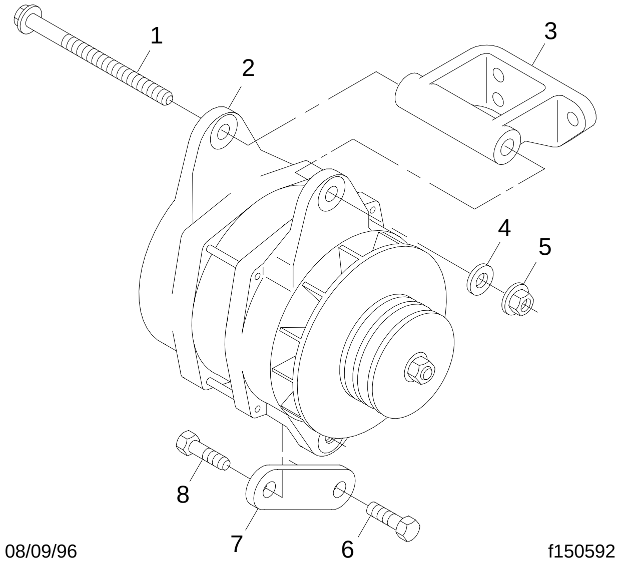
2. Connect the ground lead to the ground terminal on the back of the alternator, as removed. Tighten the ground terminal nut 65 lbf·in (740 N·cm).
3. From underneath, install the alternator mounting capscrew, but do not tighten it yet.
4. Install the drive belt on the pulley as removed. If installing 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.

5. Connect the power lead to the output terminal on the back of the alternator, as removed. Tighten the output terminal nut 100 lbf·in (1140 N·cm).
6. Tighten the alternator mounting fasteners, top and bottom.

   6.1 Tighten the pivot nut 40 lbf·ft (54 N·m).

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. 5, Mounting Hardware

6.2 Tighten the alternator mounting capscrew 16 lbf·ft (21 N·m).

7. 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

8. Close the engine compartment cover and reattach the support links to the bed. Lower the bed.
9. Connect the batteries.
10. 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.

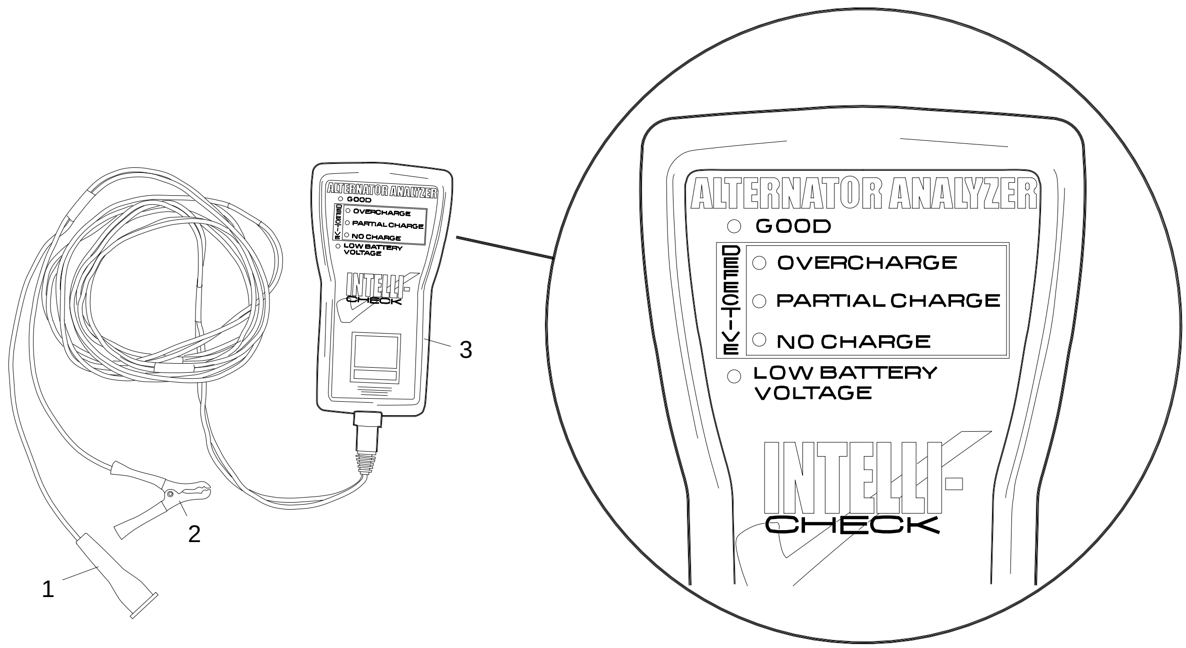
Pre-Test Procedure (Engine Off)

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 sys-

Troubleshooting



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

Fig. 1, Delco Remy Intelli-Check Alternator Analyzer

tem 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

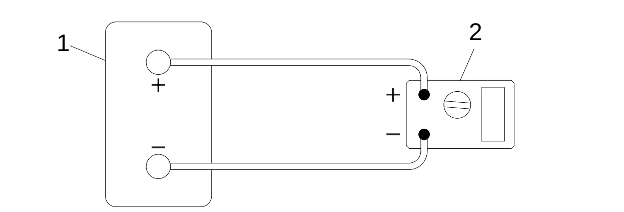
1. Use a digital volt-ohmmeter (VOM) set on the 2-20VDC (or similar) scale to test the battery open circuit voltage (OCV). With the engine shut down and the voltmeter set up as shown in Fig. 2, check for voltage of 12.4 volts or more.

   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**.

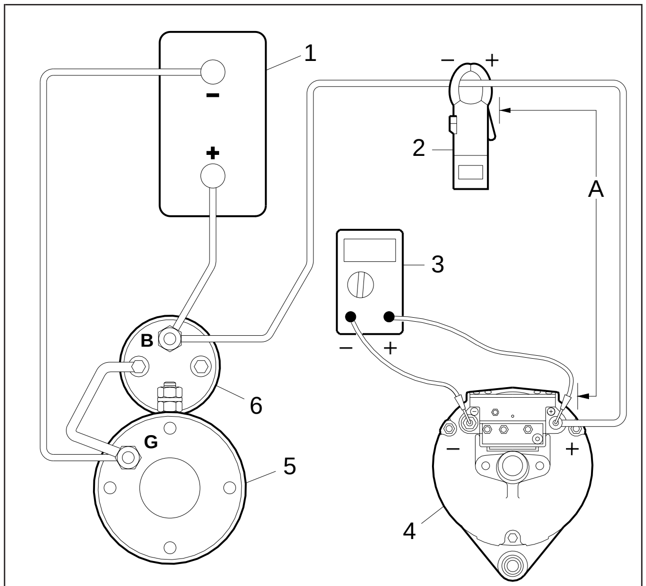
IMPORTANT: Be sure to disconnect the batteries or remove them from the vehicle before charging.

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



1. Battery
2. Digital Voltmeter

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



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

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

Fig. 3, Setup 2: Alternator Output Test

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

2.2 Connect the positive (+) lead of the digital voltmeter (still set on the 2-20VDC 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.

Troubleshooting

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.

Specifications

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 1, Mounting Fastener Torques, Cummins Engines

Terminal Fastener Torques, All 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 2, Terminal Fastener Torques, All Engines

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

Table 3, Pulley Nut Torque, All Engines

General Information

Leece-Neville alternators are equipped with a built-in cooling fan. The purpose of the cooling fan is to circulate air from the rear of the alternator. Air flows through the alternator, and cools the internal components. For an example of a Leece-Neville alternator, see **Fig. 1**.

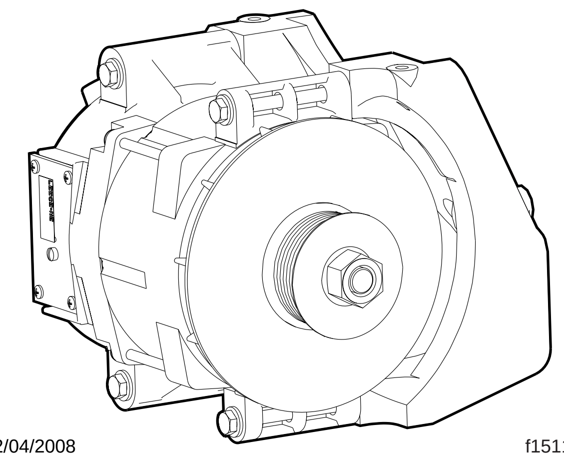


Fig. 1, 4940 Pad-Mount Alternator

The alternator's cooling air source is important. Exhaust leaks near the alternator should be fixed immediately. Excessive heat can melt the alternator back plate, harm bearing lubrication, and destroy the alternator.

Fluid leaks or blow-by fumes circulating in the engine compartment can coat the alternator with oily material, which holds dirt, causing the alternator to retain heat.

Electrical resistance builds as the alternator heats up, which starts a chain of events that can lead to failure of the alternator or other vehicle components. The alternator should be kept clean, but should not be washed with high pressure jets. Avoid using corrosive solutions to clean the alternator; they leave chemical deposits that cannot be completely removed, and can cause corrosion of electronic components.

There are many exposed electrical connections on most Leece-Neville alternators. It is important that these connections are always clean and tight to ensure that a proper charge remains constant. Use 20 psi (138 kPa) low-pressure compressed air, to blow away loose debris.

WARNING

Compressed air can dislodge harmful materials or debris and cause eye injury. Use eye protection, and be careful where the stream of debris may go.

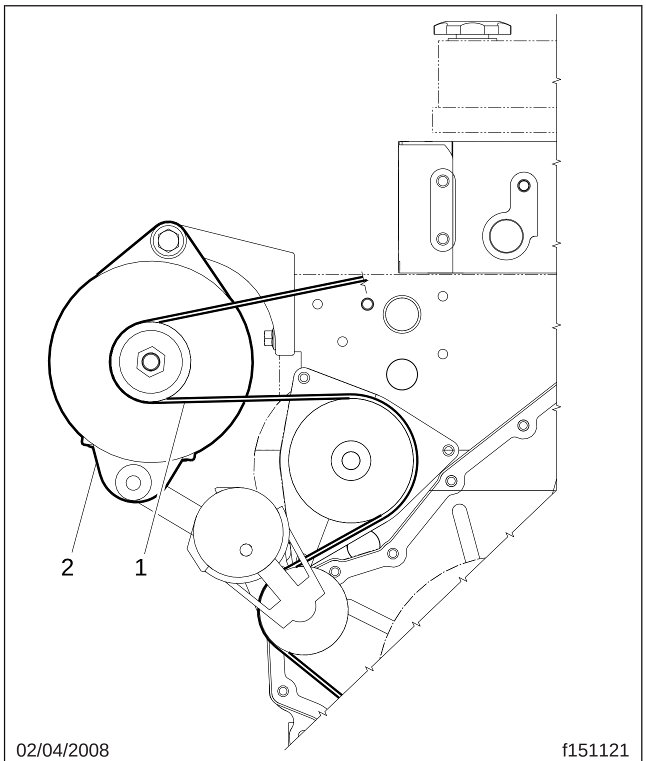
Removal

1. Park the vehicle on a level surface, apply the parking brake, shut down the engine, and chock the tires.
2. Gain access to the engine compartment.
3. Disconnect the batteries at the negative terminals.

NOTE: Be sure the belt is working correctly, before removing the alternator for repair, and note the belt routing as shown in **Fig. 1**.

Many charging system problems originate in the drive belt. Look for signs of glazing, wear (frayed edges), damage (breaks or cracks), or oil contamination. If a belt is glazed, worn, damaged, or oil soaked, replace it.

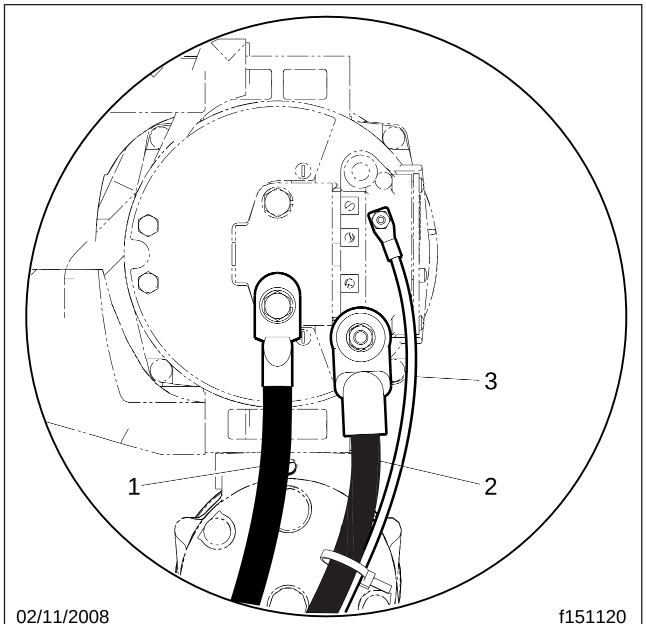
4. Release the tension on the belt, and remove the belt from the alternator pulley; see **Fig. 1**.



1. Alternator Drive Belt
2. Alternator

Fig. 1, Cummins ISB Alternator Mounting

5. Disconnect the cables at the alternator. Note the wire positions on the terminals, for correct installation; see **Fig. 2**.



1. Negative Terminal
2. Positive Terminal
3. Ignition Terminal

Fig. 2, 4940 Pad-Mount Alternator Terminals

6. Remove the alternator-mounting capscrews. Remove the alternator.
7. If the alternator is being replaced, remove the pulley for use on the new alternator.

Installation

1. If the alternator is being replaced, install the pulley on the new alternator.
2. Position the alternator on the engine and start the mounting capscrews. Tighten 35 lbf·ft (48 N·m).
3. Relax the belt tensioner and place the alternator drive belt in position. The correct belt tension is set automatically.
4. Connect the cables to the alternator, as it was before. Tighten the output-terminal hexnut 100 lbf·in (1130 N·cm). Tighten the ground-terminal hexnut 120 lbf·in (1356 N·cm). Tighten the other terminal hexnuts 20 lbf·in (220 N·cm).

Removal and Installation

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. Close the engine compartment.
8. Remove the chocks from the tires.

General Information

The Nippondenso starter mounts on the left-hand side of the engine directly into the transmission, through a hole in the torque converter access cover.

The starter motor incorporates a planetary gear system between the electric motor and pinion gear. This feature allows the armature to rotate at a higher speed and delivers increased torque to the drive plate ring gear or flywheel. At the same time, it reduces the size and weight of the starter.

The starter motor is activated by a solenoid mounted to the overrunning clutch housing.

IMPORTANT: The starter motor and solenoid are serviced as a complete unit only. If either component fails, replace the entire assembly.

Nippondenso Starter Removal and Installation

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.

WARNING

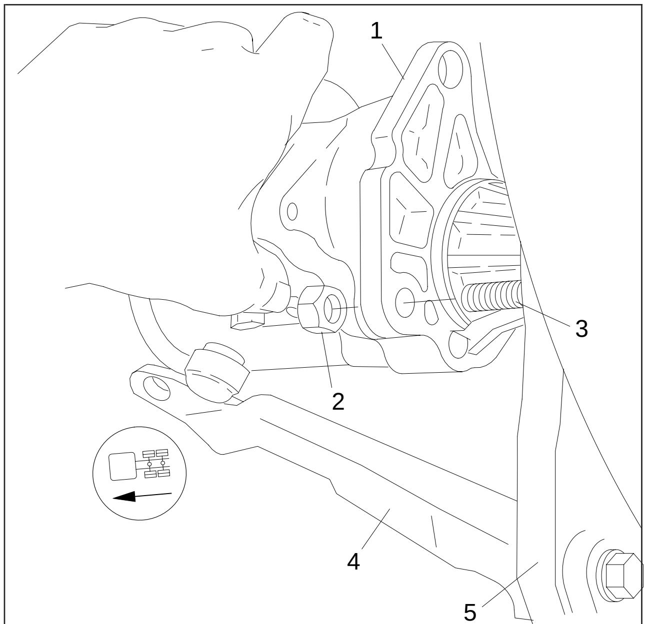
Never work under or around a vehicle that is supported only by jacks. Jacks can slip, causing the vehicle to fall, resulting in possible death, serious injury or component damage. Always support the vehicle with adequate safety stands.

3. Raise and safely support the vehicle with jackstands.
4. From under the vehicle, remove the starter from the bell housing.

   4.1 Remove the battery cable standoff bracket. Remove the battery cable bolt and bracket. Do not remove the clamp from the battery cable.

   4.2 Mark and disconnect the battery and solenoid cable leads. Remove the two starter mounting bolts and the mounting stud nut.

   4.3 Move the starter forward until the nose of the starter gear housing clears the hole in the torque converter access cover and the mounting flange clears the mounting stud. See **Fig. 1.**



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1. Starter
2. Mounting Stud Nut
3. Mounting Stud
4. Engine-to-Transmission Strut
5. Bell Housing

Fig. 1, Starter Removal and Installation

Installation

1. Install the starter. See **Fig. 1**.

   1.1 Attach the battery cable leads to the starter, as previously marked. Tighten the connector on the battery lead 70 to 110 lbf·in (800 to 1240 N·cm). Tighten the connector on the solenoid lead 45 to 65 lbf·in (500 to 740 N·cm).

   1.2 Insert the starter gear housing into the hole in the torque converter access cover. Slip the starter into place over the starter mounting stud.

   1.3 Install the two starter mounting bolts and tighten them 50 lbf·ft (68 N·m). Install the starter mounting nut on the stud and tighten it 20 lbf·ft (27 N·m).

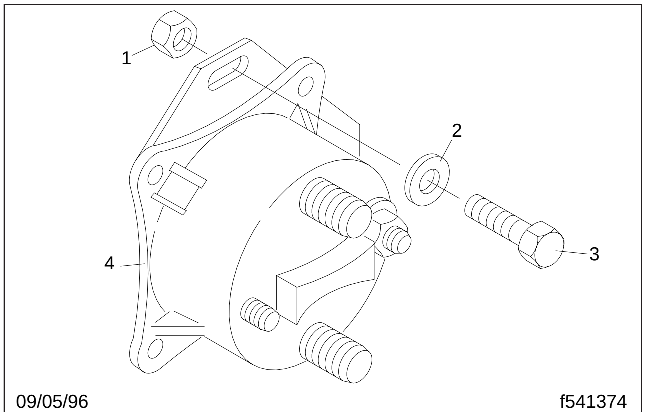
   1.4 Install the battery cable standoff bracket.

2. Connect the batteries.
3. Raise the vehicle, remove the supports, then lower the vehicle.
4. Remove the chocks from the rear tires.
5. Start the engine to test the starter.

Starter Relay Removal and Installation

Removal

1. Disconnect the batteries.
2. Remove the electrical connectors from the four terminals on the starter relay. Mark the connectors and the terminals for ease of assembly.
3. Remove the starter relay from the bulkhead. See **Fig. 1**.



1. Mounting Nut
2. Washer
3. 1/4-20 Capscrew
4. Starter Relay

Fig. 1, Starter Relay

   3.1 Remove the four 1/4–20 capscrews, nuts and washers holding the starter relay to the bulkhead.

   3.2 Remove the starter relay from the bulkhead.

Installation

1. Install the starter relay on the bulkhead. Tighten the four 1/4–20 capscrews 84 lbf·in (940 N·cm).
2. Install the electrical connectors, as removed. Make sure all electrical connections are clean and tight, with no exposed or dangling wires.
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.
5. Start the engine to test the starter relay.

Troubleshooting Table

Problem—Starter Does Not Crank or Cranks Slowly

Problem—Starter Does Not Crank or Cranks Slowly	
Possible Cause	**Remedy**
The batteries are undercharged.	Do a load test on the batteries. See **Section 54.02** 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.
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 ignition keyswitch and/or ignition wiring is broken.	Do the "Starter Operation Test." Make repairs as needed. Start the engine to verify the repair.
The control circuit is broken.	Do the "Starter Operation Test." Make repairs as needed. Start the engine to verify the repair.
The cranking circuit wires and cables are loose or covered with chemical build-up.	Check the wires and cables. Clean and tighten all connections and make repairs as needed. Start the engine to verify the repair.
The starter pinion gear or flywheel ring gear is damaged.	Visually check both 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 **Group 01** or the engine manufacturer's manuals.

Problem—Engine Starts, But The Pinion Does Not Disengage

Problem—The Engine Starts, But The Pinion Does Not Disengage	
Possible Cause	**Remedy**
The starter is damaged.	Replace the starter.

Available Cranking Voltage Test

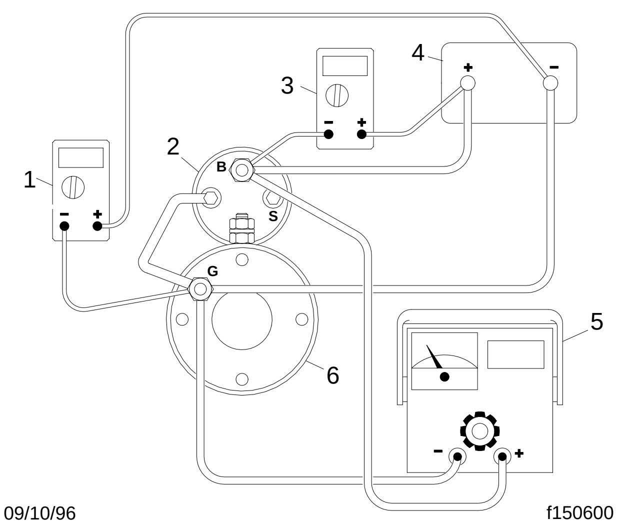
Battery Cable Test

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

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 (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.

Troubleshooting



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

Fig. 1, Battery Cable Test

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

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

NOTE: Ignore the minus (–) sign.

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

   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 starter relay to the starter "S" terminal.

Interconnecting Cable Test

1. This test requires two people. While the first person cranks the engine, the second person uses a voltmeter to measure the voltage across the starter "B" (battery) and "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 Operation Test

IMPORTANT: Before starting this test, make sure that all belts are correctly tightened, and that the wiring and terminals are in good condition and properly protected. Check that the batteries are 95 to 100 per cent charged, and are functioning according to the manufacturer's specifications.

1. Turn the ignition keyswitch to the START position. If the starter relay does not make a clicking sound, go to the next step.

   If the starter relay clicks, do the "Hold-In Winding Continuity Test."

CAUTION

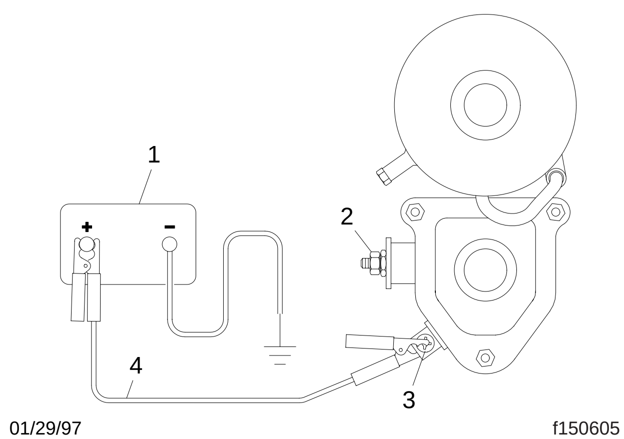
Do not crank the engine for more than 30 seconds at a time; wait 2 minutes after each try to allow the starter to cool. Failure to do so could cause starter damage.

2. Disconnect the battery cable from the starter "B" (battery) terminal.
3. Connect one end of a small clamp or jumper wire to the positive (+) terminal of the battery.

Briefly touch the other end to the "S" terminal of the starter. See **Fig. 2**.

If the starter relay does operate, replace the starter.

If the starter relay still does not operate, replace the starter relay.



1. Battery
2. Starter "B" Terminal
3. Starter "S" Terminal
4. Jumper

Fig. 2, Starter Operation Test

Hold-In Winding Continuity Test

1. Disconnect both cables from the starter and the wire between the cranking motor and the solenoid.

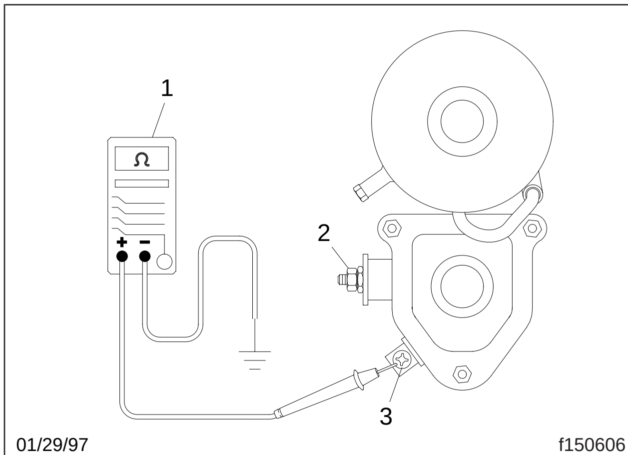
WARNING

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 one lead of a digital ohmmeter to the starter "S" (solenoid) terminal. Connect the other lead of the ohmmeter to a good source of ground. See **Fig. 3**. Check for continuity.

   If there is continuity (less than 5 ohms resistance), replace the starter.

   If there is no continuity (very high resistance), replace the starter relay.



1. Digital Ohmmeter
2. Starter "B" Terminal
3. Starter "S" Terminal

Fig. 3, Hold-In Winding Continuity Test

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 ring gear teeth are damaged, replace the ring gear.

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

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

Cold Weather Voltage Test

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

IMPORTANT: Make sure that the brakes are applied and the vehicle is in the neutral position.

1. Check the starter mounting bolts for tightness.
2. With the ignition keyswitch on, clamp a heavy battery jumper cable on one of the two large

Troubleshooting

studs on the starter relay. Then touch the other end of the jumper to the other large stud.

3. If the starter engages, remove the jumper cable and do the "Starter Operation Test." Repair/replace the wire connections, terminals, and/or starter relay as necessary.
4. If the engine now starts properly, check the starter mounting bolts for tightness and do the "Alternator Wiring Test." See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
5. If the engine still does not start properly, go to "Available Cranking Voltage Test."

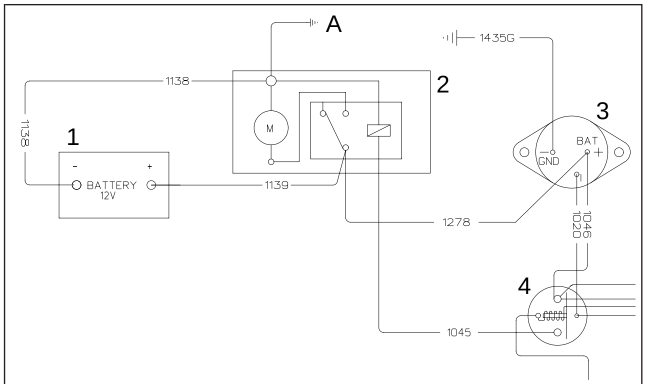
Specifications

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

For a charging circuit wiring diagram, 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	—	26 (300)
Starter Relay Mounting Capscrews	5	1/4-20 x 0.5	—	84 (940)

Table 1, Fastener Torque Values



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A. To Ground
1. Battery
2. Starter
3. Alternator
4. Starter Relay

Fig. 1, Charging Circuit Wiring

Troubleshooting Tables

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.

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 oil cooler aftercooler.	Do the repairs necessary to stop the leaks. Fill to the surge tank sight glass with the correct mixture of antifreeze and water. Refer to the chassis 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, aftercooler, or condenser fins are clogged.	Clean the outside of the core and the condenser with compressed air directed from the fan side, or with water and a mild laundry soap. Straighten bent fins.
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, aftercooler, and condenser to the fan clutch sensor. Check that the radiator core is getting hot in front of the fan clutch (core is not internally clogged in that area) so that the sensor is getting a correct reading. If no radiator problems exist, refer to the viscous fan clutch section in this group for fan clutch inspection procedures and operation tests.
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 aftercooler for leaks. Repair or replace parts, as necessary.
The aftercooler is internally plugged or damaged.	Repair or replace the aftercooler.
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.

Radiator Removal and Installation, Rear Engine

NOTICE

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

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

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

Removal (Rear-Mounted Radiator)

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. From inside the vehicle, raise the bed, then the engine access hatch.

WARNING

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

3. Drain the radiator.
4. Remove the rear engine compartment access door.
5. Remove the rubber baffles from the top and sides of the radiator.
6. Remove the metal air dam from the rear bumper.
   - 6.1 Drill out the rivets holding the metal air dam to the top and bottom edges of the rear bumper.
   - 6.2 Move the air dam down and out of the way so the radiator can be removed.
7. Disconnect the engine oil fill tube and dipstick tube from the bracket on top of the right side of the radiator.
8. Disconnect the radiator struts from the radiator support brackets on top of the radiator.
9. Mark, then disconnect the transmission oil cooler hoses from the right side of the radiator.
10. Drain the coolant surge tank on the left side of the radiator, then disconnect the hose from it.
11. Remove the coolant surge tank from the left-side radiator support bracket.
12. Remove the left-side radiator support bracket from the radiator.
13. Remove the right-side radiator support bracket from the radiator. Leave the transmission fluid reservoir attached to the bracket, and put the bracket to the side. Keep it upright so the transmission fluid doesn't leak out of the reservoir.
14. From inside the vehicle, disconnect the upper radiator hose from the engine.
15. Remove the five bolts holding the fan shroud to the radiator. The upper center bolt is accessible only from inside the vehicle.
16. Mark, then disconnect the rubber hoses from the charge air cooler (CAC).
17. From underneath the vehicle, remove the two mounting nuts holding the radiator studs to the frame crossmember.
18. Separate the fan shroud from the radiator.
19. Lift the radiator and CAC assembly out through the rear engine compartment opening.

Installation (Rear-Mounted Radiator)

1. Make sure all of the hoses are removed from the radiator, except the rubber section of the lower coolant hose.
2. If not already done, put the fan shroud into the engine compartment, making sure it fits over the fan blade.

Radiator Removal and Installation, Rear Engine

3. Put the radiator and CAC assembly into the engine compartment, making sure the lower mounting studs line up with the holes in the crossmember.
4. Install the right radiator support bracket onto the radiator.
5. Install the transmission fluid reservoir onto the right radiator support bracket.
6. Attach the fan shroud to the radiator. The upper center bolt is accessible only from inside the vehicle.
7. Connect the lower transmission oil cooler hose to the right side of the radiator.
8. Connect the rubber section of the lower coolant hose to the metal tubing attached to the front engine mount. Tighten the radiator hose clamps. See **Table 1** for proper torque values.

Hose Clamp Torque Values		
Clamp Type	**Size**	**Torque**
T-bolt	All	55 lbf·in (621 N·cm)
Breeze Constant-Torque	5/16-inch tightening screw hex	90 lbf·in (1017 N·cm)
	3/8-inch tightening screw hex	90 lbf·in (1017 N·cm)
ABA	1.26-inch Diameter	31 lbf·in (350 N·cm)
	1.50-inch Diameter	35 lbf·in (395 N·cm)
	1.73-inch Diameter	35 lbf·in (395 N·cm)
	1.97-inch Diameter	35 lbf·in (395 N·cm)
	2.28-inch Diameter	35 lbf·in (395 N·cm)
	2.68-inch Diameter	40 lbf·in (452 N·cm)
	3.03-inch Diameter	40 lbf·in (452 N·cm)

Table 1, Hose Clamp Torque Values

NOTE: Hose clamps can be either T-bolt clamps, Breeze Constant-Torque clamps, or ABA clamps. See **Fig. 1**, **Fig. 2** and **Fig. 3**.

All hose clamps will lose torque after installation due to "compression set." However, when correctly installed, Breeze Constant-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.

9. Connect the upper transmission oil cooler hose.

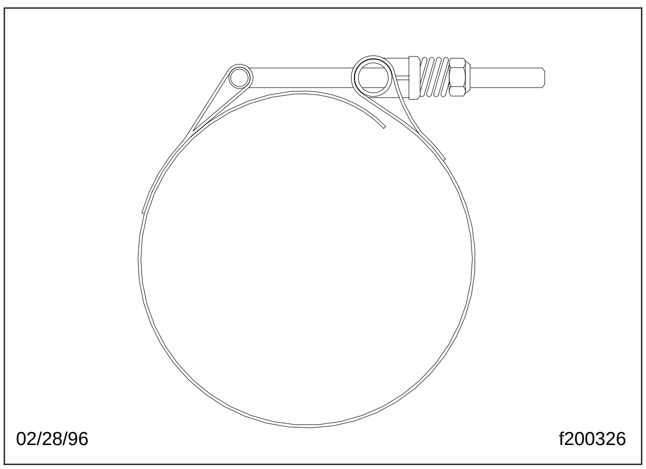
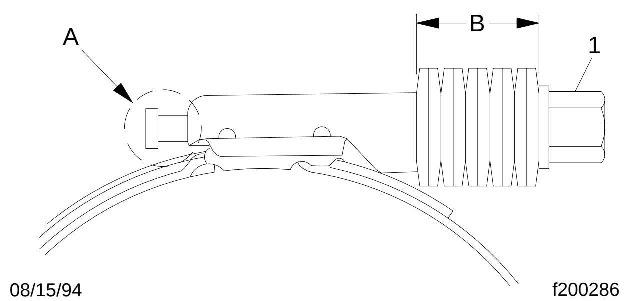


Fig. 1, T-Bolt Type Hose Clamp

Radiator Removal and Installation, Rear Engine



A. The screw tip must extend about 1/4 inch (6 mm)
B. The belleville washer stacks must be collapsed almost flat.

1. Tightening Screw Hex

Fig. 2, Breeze Constant-Torque Hose Clamp

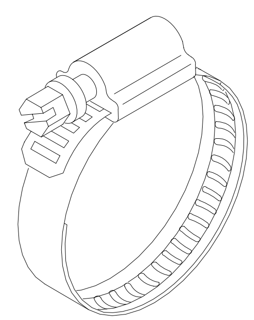


Fig. 3, ABA Radial-Worm-Drive Hose Clamp (typical)

10. Connect the upper coolant hose to the radiator and to the engine.
11. Starting with the topmost rear bolt, install the left radiator support bracket.
12. Install the coolant surge tank onto the left radiator support bracket.
13. Install the radiator stud nuts and shims (if needed). Tighten the nuts securely.
14. Install the oil filler tube and the dipstick tube.
15. Attach the radiator struts to the radiator support brackets. Tighten the nuts securely.
16. Attach the air cleaner bracket to the left side of the radiator.
17. Attach the coolant system air bleed tube to the left side of the radiator.
18. Connect the charge air cooler hoses. See **Table 1** for proper torque values.
19. Using a suitable riveting tool, install the metal air dam to the top and bottom edges of the bumper.
20. Install the rubber wind baffles around the edges of the radiator.

NOTICE

When filling the radiator, air must be vented from the engine coolant passages. Any air trapped in the system can cause severe engine damage.

21. Fill the cooling system, using the applicable procedure below.
22. *If equipped with a Cummins B Series or a 275 hp Caterpillar 3126 engine:*

    22.1 If not already done, open the drain petcocks on the right side of the radiator and at the water pump.

    22.2 Open the engine venting petcock.

    22.3 Slowly add a 50/50 mixture of coolant and water to the surge tank until the system is filled. See **Subject 400** for approved coolants.

    22.4 Start the engine and run it at low idle for 10 seconds; then at high idle for one minute. Return to low idle.

    22.5 Close the lower radiator petcock when a steady stream of water is flowing from it. Don’t let more than 1.5 quarts (1.4 L) of coolant escape.

    22.6 Run the engine, with the radiator cap removed, until the upper radiator hose is hot. With the engine idling, add coolant to the radiator until it is at the bottom of the filler neck. Install the radiator cap, making sure the arrows on the cap line up with the overflow tube on the radiator filler neck.

    22.7 Fill the surge tank to or above the "Full Hot" mark. Put the surge tank cap back on.

    22.8 Go to the step for topping off the transmission fluid reservoir.

23. *If equipped with a Cummins ISB engine:*

23.1 Close the heater inlet valve at the rear of the engine cylinder head.

23.2 Open the drain petcock at the heater outlet valve (at the inside rear of the left frame rail).

23.3 Open the drain petcock at the top left side of the radiator, where the identification plate is located.

23.4 Fill the system with a 50/50 mixture of coolant and water through the surge tank. See **Subject 400** for approved coolants.

23.5 Start the engine and run it at low idle for 10 seconds; then at high idle for one minute. Return to low idle.

23.6 Open the heater inlet valve at the rear (toward the front of the vehicle) of the engine cylinder head.

23.7 Close the drain petcock at the heater outlet valve (at the inside rear of the left frame rail) when a steady stream of coolant begins flowing from it. Do not let more that 1.5 quarts (1.4 L) of coolant escape.

23.8 Open the heater outlet gate valve.

23.9 Close the drain petcock at the top left side of the radiator when a steady stream of coolant begins flowing from it. Do not let more that 1.5 quarts (1.4 L) of coolant escape.

23.10 Top off the surge tank.

23.11 Go to the step for topping off the transmission fluid reservoir.

24. *If equipped with a 300 hp Caterpillar 3126 engine:*

24.1 Close the heater inlet valve (on the engine cylinder head) and heater outlet valve (at the water pump.)

24.2 Open the drain petcock at the heater outlet valve (on the water pump).

24.3 Slowly add a 50/50 mixture of coolant and water to the surge tank until the system is filled.

24.4 Start the engine and run it at low idle for 10 seconds; then at high idle for one minute. Return to low idle.

24.5 Open the heater inlet valve (on the engine cylinder head).

24.6 Close the drain petcock on the heater outlet valve when a steady stream of water is flowing from it. Don’t let more than 1.5 quarts (1.4 L) of coolant escape.

24.7 Open the heater outlet valve.

24.8 Top off the surge tank.

24.9 Go to the step for topping off the transmission fluid reservoir.

25. If needed, top off the transmission fluid reservoir.
26. Start the engine and check for leaks. Repair any leaks. After idling the engine for 15 to 20 minutes, add more coolant if necessary.
27. From inside the vehicle, lower the engine access hatch, then the bed.
28. Install the exterior engine access door.
29. Remove the chocks from the tires.

Removal (Side-Mounted Radiator)

1. Park the vehicle, apply the parking brakes, and chock the front tires.
2. Open the left-side engine access panel and secure it open.

DANGER

Before jacking up the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle should fall, severe injury, death, and substantial property damage could result.

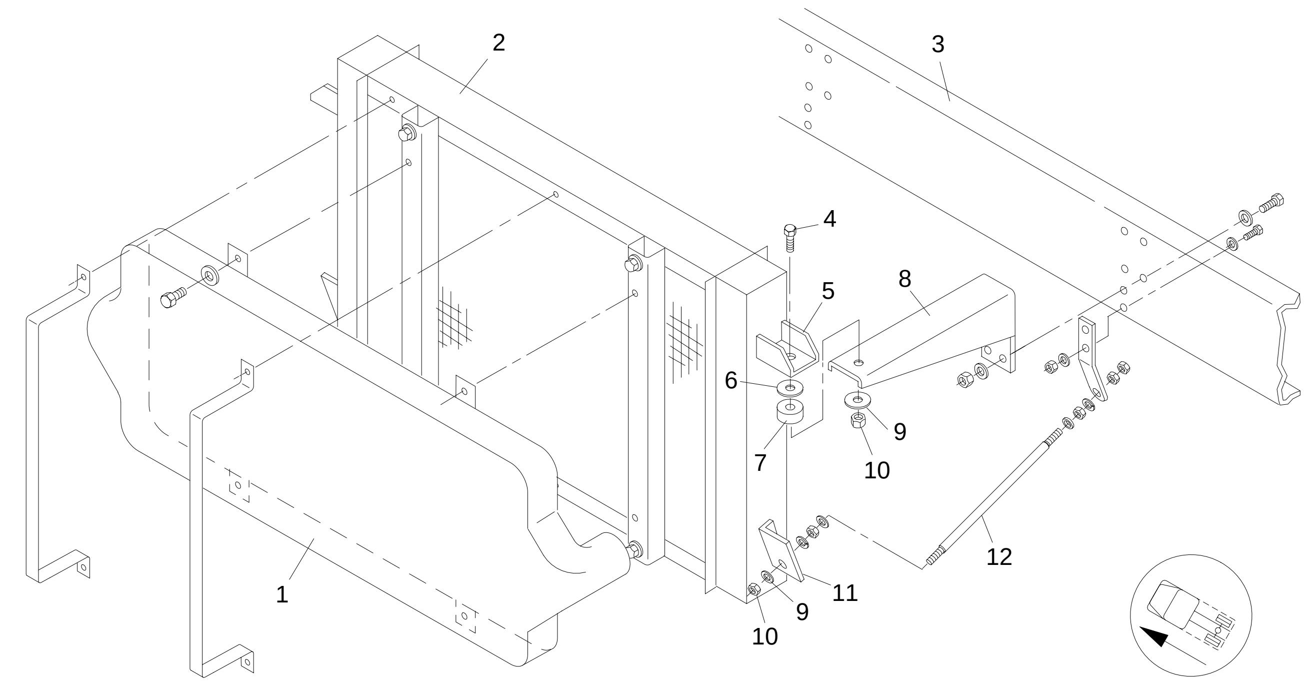
3. Jack up the rear of the vehicle and place jackstands under the frame rails, just behind the rear wheels.
4. Remove the oil cooler (if equipped) and the charge air cooler (CAC). For instructions, see **Group 09**.

WARNING

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

5. Drain the coolant from the radiator.
6. At the top back-side of the radiator, loosen the breather-hose clamp and disconnect the breather hose from the radiator.
7. Remove the nut and washer from the rear lower radiator mounting tab to gain access to the hose clamp on the lower (outlet) radiator hose. See **Fig. 4**.
8. Remove the hose clamp, disconnect the lower (outlet) hose, and allow the radiator to drain completely.
9. Remove the two hose clamps from the upper (inlet) radiator hose and remove the hose.
10. Remove the nut and washer from the forward lower radiator mounting tab.
11. Remove the mounting nuts and washers from the bottoms of the two upper radiator mounting brackets, which sit on top of the upper radiator mounts, attached to the frame rails. See **Fig. 1**.

NOTE: Four washers are used as spacers at each upper radiator mounting point. The



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1. Charge Air Cooler (CAC)
2. Side Radiator
3. Frame Rail
4. Bolt
5. Upper Radiator Mounting Bracket
6. Spacers (washers)
7. Rubber Bushing
8. Upper Radiator Mount
9. Washer
10. Nut
11. Lower Radiator Mounting Tab
12. Threaded Rod

Fig. 4, Side Radiator Mounting

washers are positioned between the bottoms of

Radiator Removal and Installation, Rear Engine

the upper radiator mounting brackets and the rubber bushings in the upper radiator mounts.

12. Remove the two upper mounting bolts and the washers.
13. If present, remove the tie straps temporarily holding the lower ends of the oil cooler brackets to the access panel framework.
14. Position a floor jack or other supporting device below the radiator.

WARNING

Exercise caution when removing the radiator from the mounts. It is heavy and if dropped serious personal injury and significant property damage could result.

15. With the help of an assistant, pull the radiator outward at the bottom and free it from the lower mount threaded rods. See **Fig. 1**.
16. Lift the radiator off of the upper mounts and place it on the floor jack or supporting device and place it safely out of the way.

Installation (Side-Mounted Radiator)

WARNING

Exercise caution when placing the radiator in position on the mounts. It is heavy and if dropped serious personal injury and significant property damage could result.

1. With the help of an assistant, raise the radiator into position and let the upper radiator mounting brackets rest on the rubber bushings in the radiator mounts attached to the frame rails. See **Fig. 1**.
2. Carefully insert the four washers on each side, between the bottoms of the upper radiator brackets and the rubber bushings in the upper mounts.
3. Insert the two top mounting bolts through the radiator brackets, spacers, bushings, and frame mounts. See **Fig. 1**.
4. Attach the lower (outlet) radiator hose to the radiator. Install the hose clamp at the radiator end of the hose and tighten it securely.
5. Attach the upper (inlet) radiator hose to the inlet pipe and the radiator. Install the two hose clamps and tighten them securely. 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. 1**, **Fig. 2**, and **Fig. 3**.

All hose clamps will lose torque after installation due to "compression set." However, when correctly installed, Breeze Constant-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.

6. Push the radiator inward at the bottom, so that the lower radiator mounting tabs slide over the threaded rods. See **Fig. 1**.
7. Install the washer and nut at each of the four mounting points and tighten 68 lbf·ft (92 N·m).
8. At the top back-side of the radiator, connect the breather hose to the radiator and tighten the hose clamp securely.
9. Install the charge air cooler (CAC) and the oil cooler (if equipped). For instructions, see **Group 09**.
10. Slowly add a 50/50 mixture of coolant and water to the surge tank until the system is filled. See **Subject 400** for approved coolants.
11. Start the engine and check for leaks. Repair any leaks. After idling the engine for 15 to 20 minutes, add more coolant if necessary.
12. Close the left-side engine access door.

DANGER

Before jacking up the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking. If the vehicle should fall, substan-

tial property damage, severe injury, and death could result.

13. Jack up the rear of the vehicle. Remove the jackstands and lower the vehicle.
14. Remove the chocks from the front tires.

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

Do not 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 the testing gauge. If necessary, repair the radiator.
3. Install the radiator. For instructions, see **Subject 100**.

Specifications

Hose Clamp Torque Values		
Clamp Type	**Size**	**Torque**
T-bolt	All	55 lbf·in (621 N·cm)
Breeze Constant-Torque	5/16-inch tightening screw hex	90 lbf·in (1017 N·cm)
	3/8-inch tightening screw hex	90 lbf·in (1017 N·cm)
ABA	1.26-inch Diameter	31 lbf·in (350 N·cm)
	1.50-inch Diameter	35 lbf·in (395 N·cm)
	1.73-inch Diameter	35 lbf·in (395 N·cm)
	1.97-inch Diameter	35 lbf·in (395 N·cm)
	2.28-inch Diameter	35 lbf·in (395 N·cm)
	2.68-inch Diameter	40 lbf·in (452 N·cm)
	3.03-inch Diameter	40 lbf·in (452 N·cm)

Table 1, Hose Clamp Torque Values

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

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

Table 2, Approved Coolants

General Information

The Horton VMaster® Direct Sensing Viscous Fan Drive is managed by the engine's electronic control module (ECM) for precision fan control, improved fuel economy, and less noise. The fan drive is operated in an on/off control configuration, providing a low fan speed under most operating conditions and full fan speed when requested by the ECM.

The front-engine diesel chassis uses the Horton VMaster® Air Sensing Viscous Fan Drive that monitors the air temperature coming across the radiator. When the air temperature reaches a preset value, a bimetal spring on the front of the fan drive opens a valve inside the fan drive and causes the fan to rotate at full speed. This fan drive is attached to the engine with an M30 left-hand bolt that must be turned clockwise to remove and counterclockwise to tighten.

Horton VMaster® Direct Sensing Viscous Fan Drive Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Remove the fan from the fan drive. Place it out of the way of the fan drive mounting bolts.
3. Remove the fan drive from the vehicle.
4. Check the belts for any wear and replace them if necessary.
5. Check the fan for any damage and clean the radiator before installing the fan drive.

Installation

1. Install the fan drive on the engine. Torque the bolts 28 lbf·ft (38 N·m).

NOTE: The holes on the fan drive may not be fully threaded.

2. Use the fasteners and self-tapping bolts included with the fan drive to attach the fan to the fan drive. Torque the bolts 18 lbf·ft (24 N·m).
3. Remove the chocks from the tires.

Horton VMaster® Air Sensing Viscous Fan Drive (front-engine diesel chassis) Removal and Installation

Removal

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

NOTE: Depending on the vehicle design, it may be necessary to remove the radiator and shroud in order to install the fan drive. If so, see **Section 20.01, Subject 100** for instructions.

2. Using a 1-15/16 inch wrench, remove the fan drive from the vehicle. The fan drive is mounted with a left-hand-thread bolt. To loosen the bolt, turn it clockwise.
3. Remove the fan from the fan drive.
4. Check the belts for any wear and replace them if necessary.
5. Check the fan for any damage, and clean the radiator before installing the fan drive.

Installation

1. Use the fasteners and self-tapping bolts included with the fan drive to attach the fan to the fan drive. Torque the bolts 18 lbf·ft (24 N·m).

NOTE: The holes on the fan drive may not be fully threaded.

2. Using a 1-15/16 inch wrench, install the fan drive on the engine. Torque the bolt 40 lbf·ft (38 N·m). The bolt has a left-hand thread, and must be turned counterclockwise to tighten.
3. Remove the chocks from the tires.

General Information

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

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

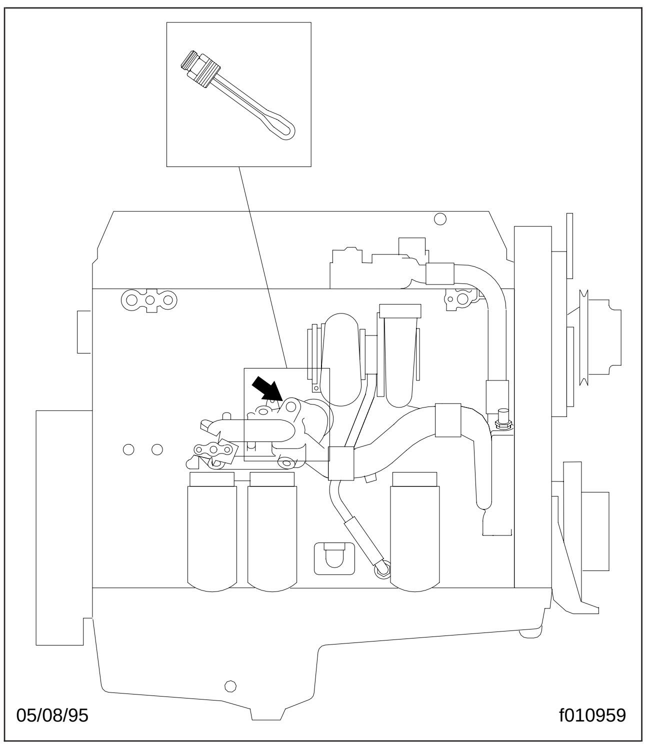


Fig. 1, Block Heater Element Installation (typical)

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

Block Heater Element Removal and Installation

Removal

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

WARNING

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

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

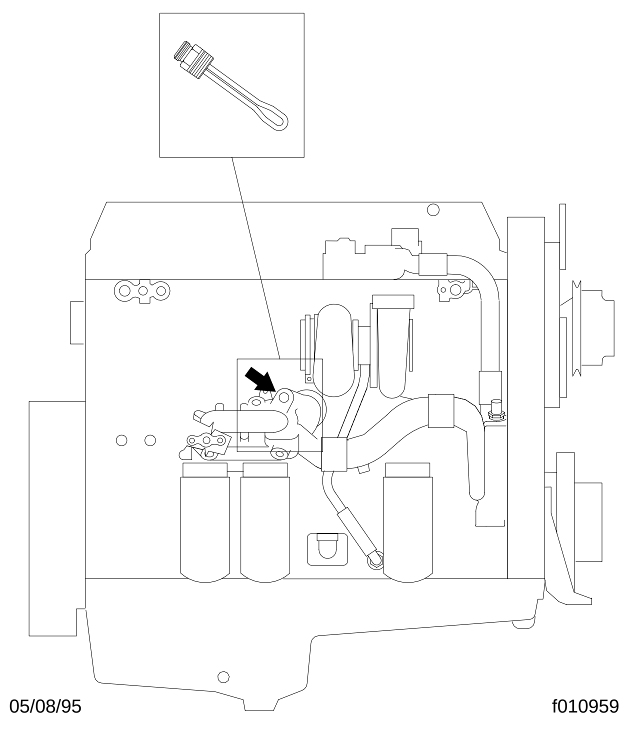


Fig. 1, Block Heater Element Installation (typical)

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

Installation

1. Position the heater element in the engine block.

   Coat the threads of the element with a small amount of sealant. For the approved sealants, refer to **Specifications, 400**.
2. Secure the heater element in the engine block by screwing the element into the engine block hand tight, then use a wrench to turn the element 1-1/2 turns more.
3. Plug the cord into the element and (if applicable) secure it by screwing the threaded cord cover in place.
4. Fill the cooling system. For instructions, refer to **Section 20.01**.
5. 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.
6. To test the heater, plug a wattmeter into a power source, and connect the heater cord to the meter. A reading on the meter will indicate the heater is working.
7. Return the hood to the operating position and remove the chocks from the tires.

Troubleshooting Procedures

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

Wiring Problems

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element.
4. Using an ohmmeter, check the continuity between the two poles of the element. The resistance should be very low, typically between 9 and 10 ohms. If there is no reading, the element has burned out, 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.
6. Using an ohmmeter at the receptacle, check the continuity between the two power terminals. The resistance should be low, typically between 9 and 10 ohms. If there is no reading or a very high reading, the cord is damaged; replace the cord.
7. Check the continuity between each power terminal and the ground terminal. There should be no ohmmeter reading. If there is a reading, replace the cord.
8. Check the ohmmeter reading between the ground terminal and a good vehicle ground. The reading should be zero. If not, replace the cord.

Fouled Element

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

WARNING

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

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

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

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

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

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

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

Specifications

Approved Sealants

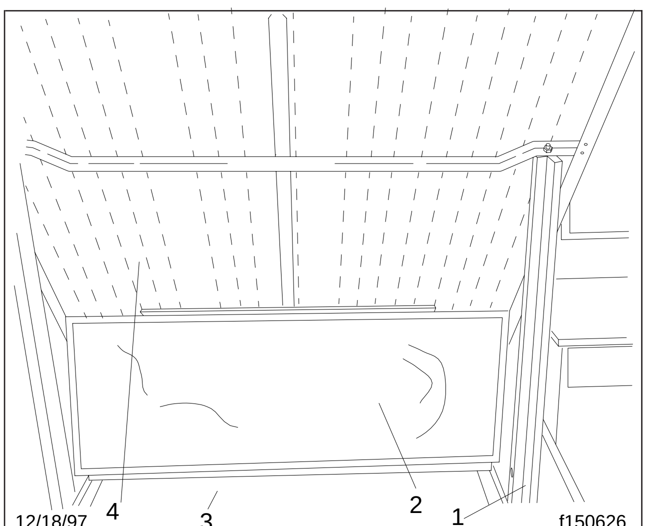
- Loctite 567
- Henkel 790 Pipegrip
- Perma-Loc LH-150

Automatic Transmission Removal and Installation, MD Models

IMPORTANT: Since the engine is located in the rear of the vehicle with the fan pointing backwards, references to the front of the engine or transmission refer to aft on the vehicle. Likewise, references to the rear of the engine, or output yoke of the transmission, refer to forward on the vehicle.

Removal

1. Apply the parking brake and chock the tires.
2. Lift up the bed. Disconnect the support links and prop up the bed using a piece of sturdy metal stock about 3-1/2 feet long (1.1 meter). See **Fig. 1**.



1. Metal Stock, 3-1/2 ft (1.1 meter)
2. Engine Compartment Cover
3. Engine Compartment
4. Bed

Fig. 1, Prop Up the Bed

NOTE: The bed must be propped up to gain access to the transmission.

3. Fold up the engine compartment cover to expose the engine and transmission.

NOTE: Because of the shortness of the driveline and the angle it makes with the drive axle, you may find it easier to disconnect the driveline before jacking the vehicle.

4. Disconnect the driveline from the transmission.
   - 4.1 Remove the transmission yoke U-joint end caps or lock straps.
   - 4.2 Slide the front of the driveshaft out of the transmission output yoke.
   - 4.3 Set the disconnected driveshaft aside.

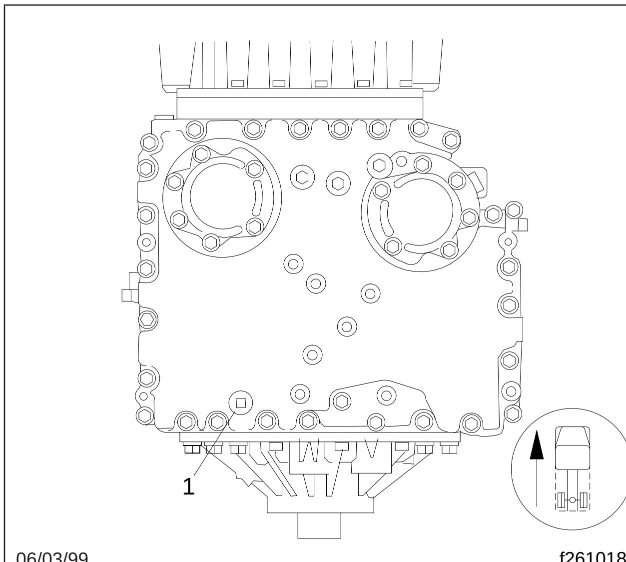
WARNING

Do not work under a vehicle that is only supported by jacks. Jacks can slip, causing the vehicle to fall, resulting in possible serious personal injury. Always support the vehicle with safety stands.

5. Jack up the vehicle to gain better access to the transmission from below. Position safety stands around the vehicle until it is solidly supported.
6. Disconnect the batteries.

NOTE: For better drainage, do the next step when the transmission is warm.

7. Remove the transmission drain plug and drain the automatic transmission fluid. See **Fig. 2**. Install the drain plug and tighten it 18 to 24 lbf·ft (25 to 32 N·m).

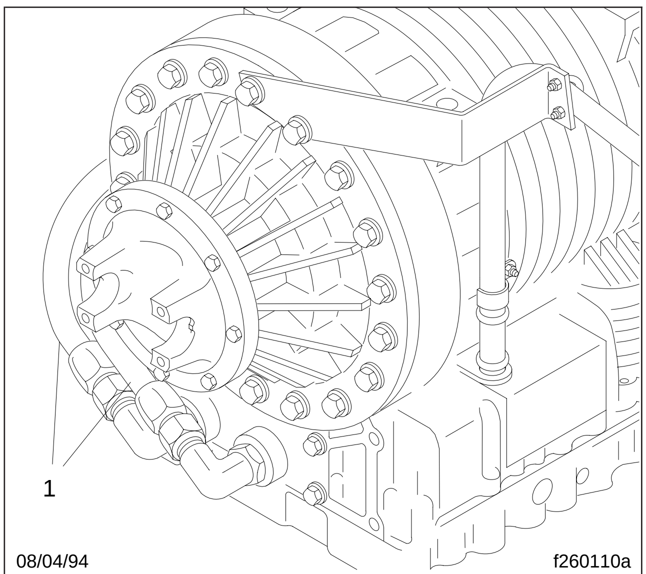


1. Drain Plug

Fig. 2, Transmission Drain Plug (bottom view)

Automatic Transmission Removal and Installation, MD Models

8. Remove the piping from the exhaust brake to the muffler.
9. Remove the turbocharger outlet piping.
10. Disconnect the three electrical connections to the transmission.
    - 10.1 Disconnect the transmission control connector.
    - 10.2 Disconnect the electrical cable to the output speed sensor.
    - 10.3 Disconnect the cable to the engine speed sensor.
11. Disconnect the transmission fluid cooler lines from the transmission and drain the remaining automatic transmission fluid (ATF). See **Fig. 3**.



1. Cooler Lines

Fig. 3, ATF Cooler Lines

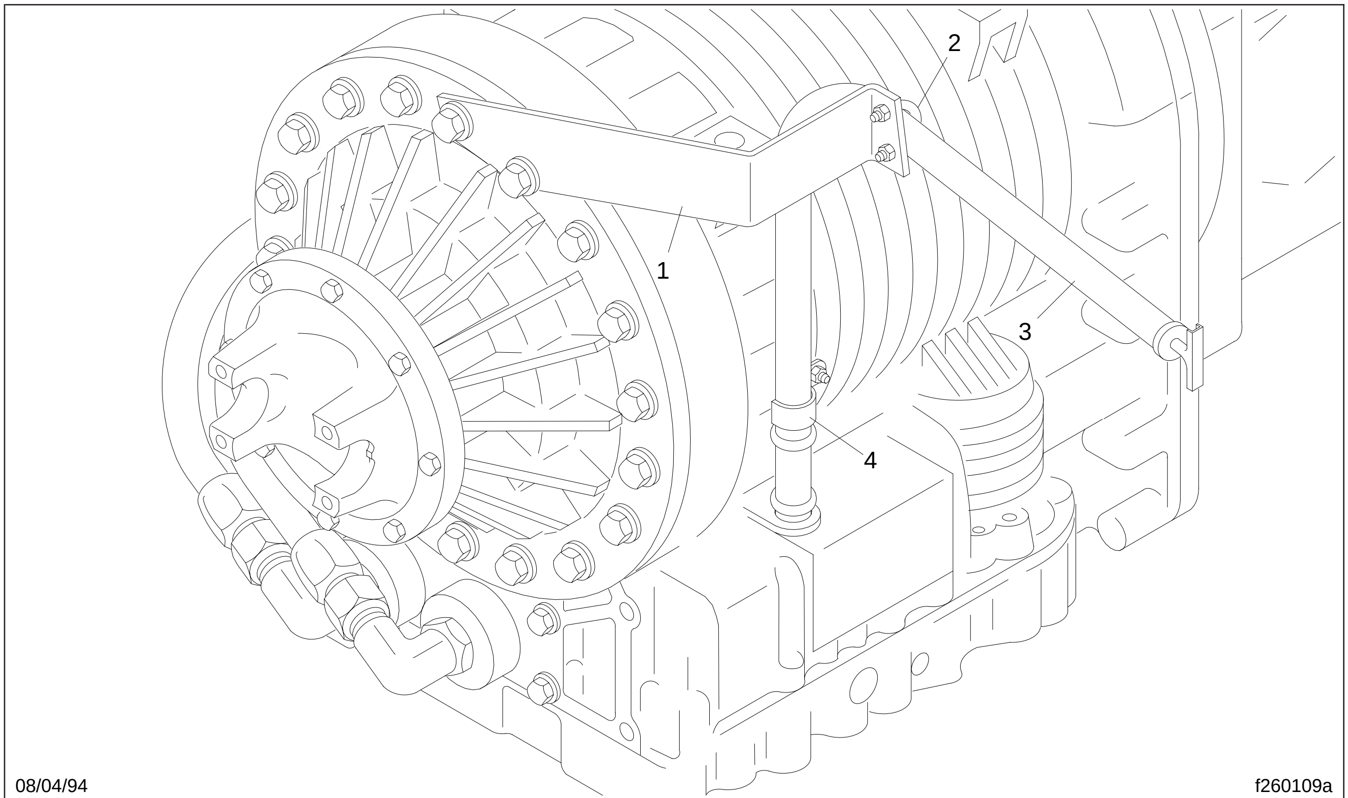
12. Remove the ATF fill/dipstick tube. See **Fig. 4**.
    - 12.1 Remove the U-bolt holding the fill/dipstick tube to its support bracket.
    - 12.2 Remove the bolt and metal strap holding the fill/dipstick tube.
    - 12.3 Pull the fill/dipstick tube out of the transmission case.
    - 12.4 Plug the hole with a clean rag to prevent entry of foreign material.
13. Disconnect the flexplate from the transmission.
    - 13.1 Remove the capscrews holding the ring gear access cover. Then, remove the cover. See **Fig. 5**.
    - 13.2 Using a prybar, turn the ring gear until one of the capscrews holding the flexplate adapter to the torque converter can be removed. Continue turning the ring gear and removing the capscrews through the access hole until all are removed.
14. Place a piece of plywood on a transmission jack to support the transmission.
15. 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**.
16. Remove the transmission flange bolts. See **Fig. 7**.
17. Move the transmission jack to the rear of the vehicle. Lower the jack and lift the vehicle as needed, so the transmission clears the frame rail and any attached components.
18. 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 vehicle frame with a hydraulic jack to obtain adequate clearance for installing the transmission. Place safety stands under the vehicle.
2. With the transmission on a jack, roll the transmission into place behind the flexplate.
3. Raise the jack until the transmission lines up with the flexplate.
4. Push the transmission toward the engine until it seats squarely against the engine flywheel housing with the bolt holes in the transmission housing aligned with those in the flywheel housing.

Automatic Transmission Removal and Installation, MD Models



1. Support Bracket
2. U-Bolt
3. ATF Fill/Dipstick Tube
4. Metal Strap

Fig. 4, Removing the Fill/Dipstick Tube

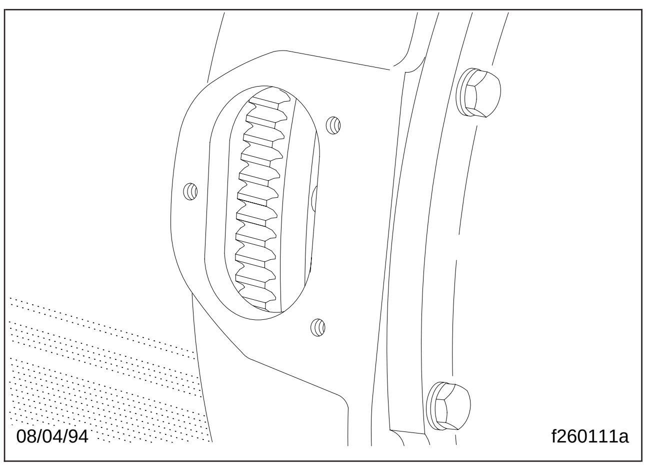


Fig. 5, Ring Gear Access Cover

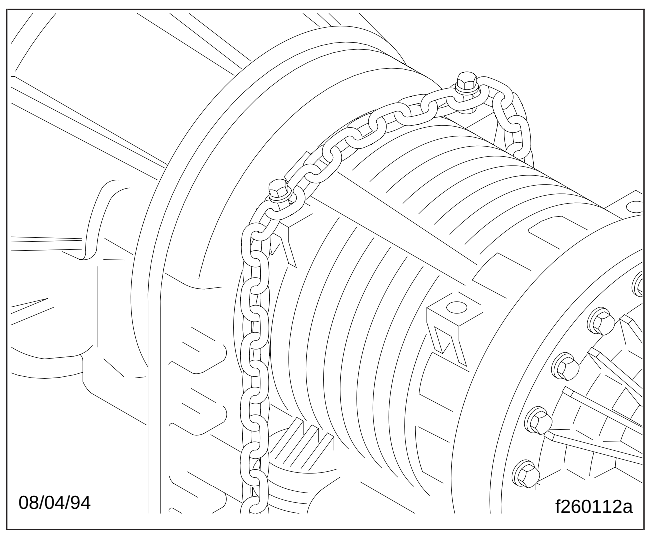


Fig. 6, Securing the Transmission With Chain

Automatic Transmission Removal and Installation, MD Models

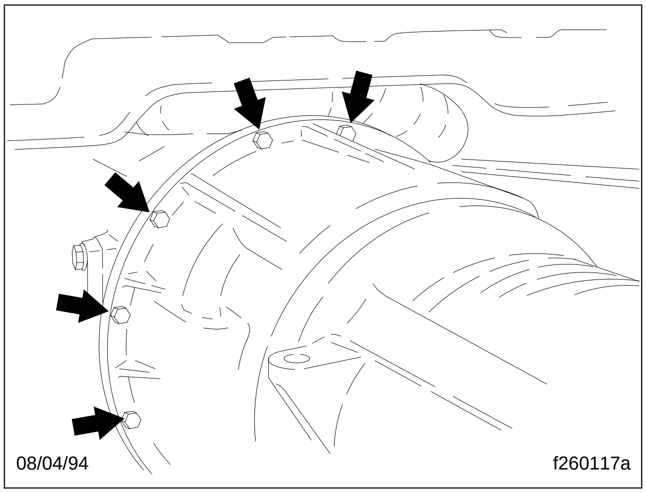


Fig. 7, Transmission Flange Bolts

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

5. Install the transmission flange bolts finger-tight.
6. Remove the chain holding the transmission to the transmission jack.
7. Lower the transmission jack and remove it.
8. Install the 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.

   8.1 Turning the ring gear for access, install all the capscrews through the access hole. Don't tighten them now.

   IMPORTANT: Install all the capscrews before tightening any of them to prevent cocking of the flexplate adapter.

   8.2 Using a star pattern, tighten the capscrews 48 lbf·ft (65 N·m).

   8.3 Install the access cover and its capscrews.
9. Tighten the M10 transmission flange bolts 41 lbf·ft (56 N·m), using a star pattern. See **Fig. 7**.
10. Install the ATF fill/dipstick tube.

    10.1 Install the fill/dipstick tube support bracket. Tighten the two capscrews 80 lbf·ft (108 N·m).

    10.2 Inspect the fill/dipstick tube seal. Replace it if damaged.

    10.3 Install the fill/dipstick tube and metal strap. Tighten the capscrew 12 lbf·ft (16 N·m).

    10.4 Install the U-bolt and nuts holding the fill/dipstick tube to the bracket. Tighten the U-bolt nuts 8 lbf·ft (11 N·m).
11. Connect the transmission fluid cooler lines to the transmission. Tighten the fittings 45 lbf·ft (61 N·m). See **Fig. 3**.
12. Connect all electrical lines to the transmission.

    12.1 Connect the transmission control connector.

    12.2 Connect the electrical cable to the output speed sensor.

    12.3 Connect the cable to the engine speed sensor.

    12.4 Using tie straps, secure the cables where necessary.
13. Install the turbocharger outlet piping.
14. Install the piping between the exhaust brake and the muffler.
15. Remove the safety stands and lower the vehicle with a hydraulic jack.
16. Connect the driveshaft.

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

    16.2 Install the transmission yoke U-joint end caps or lock straps. For torque values, see **Section 41.00, Specifications 400**.
17. Fill the transmission with ATF. Add 17.5 quarts (16.5 liters). See **Specifications 400** in this subject for a list of approved fluids.
18. Close the engine compartment cover and reattach the support links to the bed. Lower the bed.
19. Connect the batteries and remove the chocks from the tires.

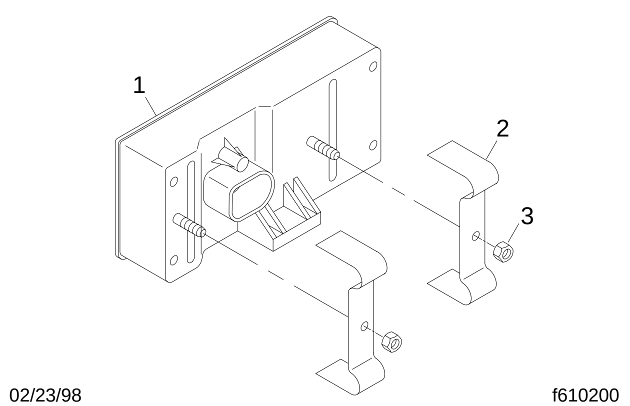
Automatic Transmission Removal and Installation, MD Models

20. Start the engine, and check for any leaks. Repair leaks as needed.
21. Check the ATF level. Add fluid as needed.
22. Remove the chocks from the tires.
23. Road test the vehicle, and check for correct transmission operation.

Transmission Shift Controller Removal and Installation

Removal

1. Apply the parking brake, chock the tires, and disconnect the batteries.
2. From underneath the shift controller panel, remove the locknut attaching each of the two brackets to the shift controller remote (control box). See **Fig. 1**.



1. Remote
2. Bracket
3. Locknut

Fig. 1, Shift Controller, Remote Mounting

3. Disconnect the electrical connector from the back of the remote.
4. Remove the remote from the panel. Pull the remote out through the top of the panel.

Installation

1. Position the shift controller remote on the panel. See **Fig. 2**.
2. From underneath the panel, attach the electrical connector.
3. Install the two brackets on the back of the remote. Install a locknut in each bracket and tighten until the remote is firmly fixed in the panel.
4. Connect the batteries and remove the chocks from the tires.
5. Use the shift controller to select several gears, both forward and reverse, and check for correct operation.

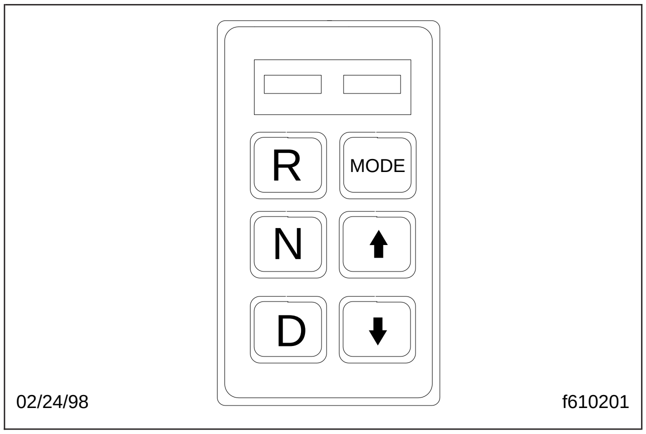


Fig. 2, Shift Controller

Specifications

Torque Values, Automatic Transmission, MD Models	
Description	Torque: lbf·ft (N·m)
ATF Cooler Hoses	45 (61)
Drain Plug	18–24 (25–32)
Fill/Dipstick Tube Clamp Capscrews	12 (16)
Fill/Dipstick Tube Support Bracket Capscrews	80 (108)
Fill/Dipstick Tube Support Bracket U-Bolt Nuts	8 (11)
Flexplate Adapter Capscrews	48 (65)
Transmission Flange Bolts	41 (56)

Table 1, Torque Values, Automatic Transmission, MD Models

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

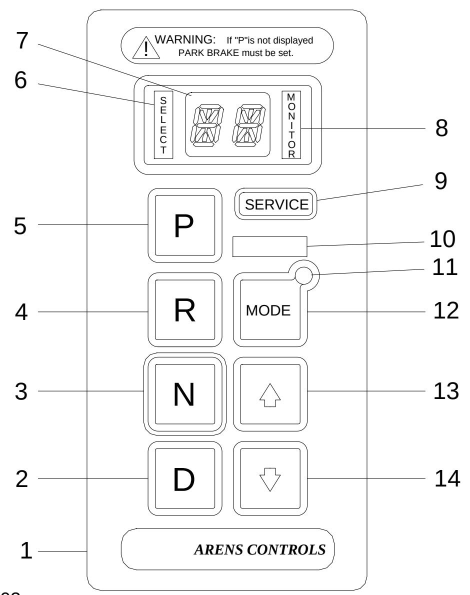
* To check the latest Allison approved fluids, go to www.allisontransmission.com. Lubricants listed in order of preference. Do not mix types of oil.

Table 2, Approved Allison Transmission Lubricants

General Information

The Arens Shift-by-Wire (SBW) system is an electronic shift control device used with Allison 1000/2000/2400 5-speed automatic transmissions. The system consists of two main components, a push button shift selector and a transmission-mounted electronic actuator.

Allison 1000/2400 series transmissions have a park pawl and the SBW selector for these transmissions has a Park (P) position. The 2000 series transmissions do not have a park pawl and there is no Park (P) position button on this selector. Otherwise, the two selectors are identical. See **Fig. 1**.



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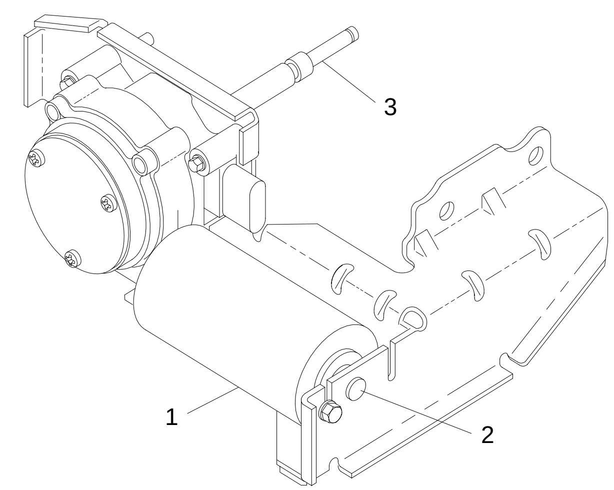
1. SBW Shift Selector
2. Drive (D) Button
3. Neutral (N) Button
4. Reverse (R) Button
5. Park (P) Button
6. Select Display
7. Select/Monitor Display Window
8. Monitor Display
9. Service Display
10. Mode Function Label
11. Mode Light
12. Mode Button
13. Upshift Button
14. Downshift Button

Fig. 1, SBW Push-Button Shift Selector (1000/2400 series)

The selector is a self-contained electronic control that contains the push button system, the interface control module, and the actuator control module. The interface control module communicates electronically with the Allison transmission control module (TCM) and the neutral start-backup (NSBU) switch. The actuator control communicates with the Arens actuator and the integrated position sensor (IPS).

The actuator is mounted on the Allison transmission. See **Fig. 2**. The actuator shifts the transmission via commands from the selector, within the operating guidelines of the Allison transmission. The SBW system components employ a redundant electronic system, intended to prevent single-point electrical system failures. If an SBW vehicle needs to be towed and the system cannot be activated to take the transmission out of Park (P), see Chapter 10 of the *Recreational Vehicle Chassis Operator's Manual*. See **Subject 100** in this Section for actuator adjustment (calibration) information and **Subject 300** for troubleshooting procedures.



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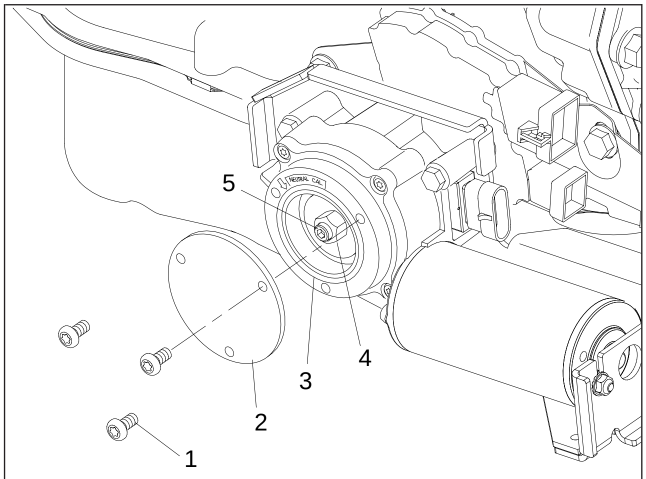
1. SBW Actuator
2. Access Hole Plug
3. Shift Selector Shaft (part of Allison transmission)

Fig. 2, SBW Actuator (on transmission)

Adjustment

NOTE: The following procedure is for adjusting or calibrating a shift-by-wire (SBW) actuator already installed on a vehicle. This procedure does not pertain to the first-time installation of an SBW actuator.

1. Park the vehicle on level surface. Shut down the engine, set the parking brake, and chock the tires.
2. Remove the three cover plate screws and the cover plate from the actuator. See **Fig. 1**.



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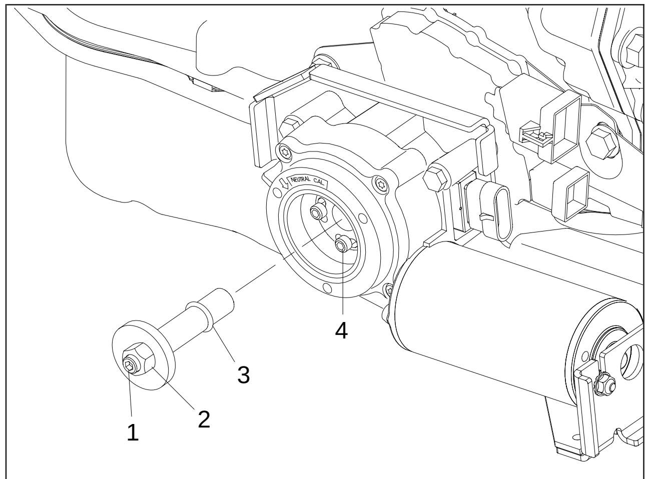
1. Cover Screw
2. Cover Plate
3. O-ring
4. Capnut
5. Socket Head Capscrew (inside capnut)

Fig. 1, Cover Plate and Capnut

3. Hold the capnut securely with a box-end wrench and loosen (but don’t remove) the socket head capscrew inside of the capnut. See **Fig. 1**.
4. Fully loosen and remove the capnut. See **Fig. 2**.



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1. Socket Head Capscrew (inside capnut)
2. Capnut
3. O-ring
4. Socket Head Capscrew (adapter)

Fig. 2, Capnut and Adapter

Type A Shift Shaft Adaptor

NOTE: Follow this procedure if the shift shaft adaptor face has four long slots and no holes in it. See **Fig. 3**.

1. Turn the ignition switch to the ON position and place the transmission in Neutral (N).

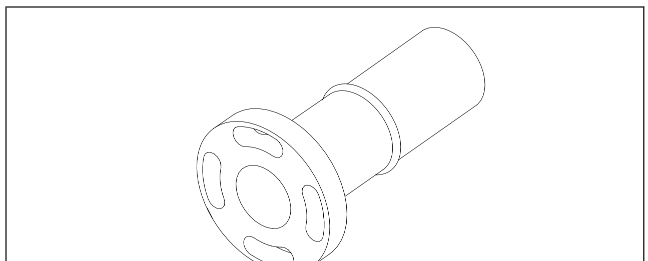

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Fig. 3, Type A Adaptor

2. Turn the ignition switch to the OFF position.

NOTE: The shift selector will continue supplying power to the actuator, holding the transmission in Neutral (N). On 1000 and 2400 series transmissions (with a Park [P] position), it is normal for the shift selector display to be active and for the buzzer to sound during the calibration procedure. When the procedure is completed, turn the ignition switch to the ON position, place the transmission in Park (P), and then turn the ignition switch to the OFF position. The display and the buzzer will both go off.

Actuator Adjustment

There is an alternate method (different from that described in the steps below) to determine if the transmission is in Neutral (N). Momentarily engage the starter. If the transmission is not in Neutral (N) the starter won't engage (except on vehicles with a Park [P] position). Check and determine if the parking pawl is or is not engaged. If the pawl is not engaged and the starter can be momentarily activated, the transmission is in Neutral (N). The actuator is now calibrated.

3. Loosen (but do not remove) the four socket head capscrews securing the shift shaft adaptor. See **Fig. 2**.

NOTE: Back the screws out 1/8 to 3/16 of an inch (3 to 9 mm).

4. Now, remove two of the four 1/2-inch (12-mm) long socket head adaptor capscrews that are opposite each other. See **Fig. 2**.

5. Thread two 1 to 1-1/2 inch (25 to 37-mm) long #10-32 screws into the two empty adaptor slots.

6. Pull outward on the two screws.

NOTE: This will place the actuator in the calibration position. Leave the adaptor capscrews loose.

7. Turn the ignition switch to the ON position and, using the selector, cycle the actuator through the following gear positions. Shift from Neutral (N) into Reverse (R), then shift from Reverse (R) into Drive (D), and then shift from Drive (D) back into Neutral (N). Turn the ignition switch to the OFF position.

8. Remove the two long #10-32 screws from the adaptor.

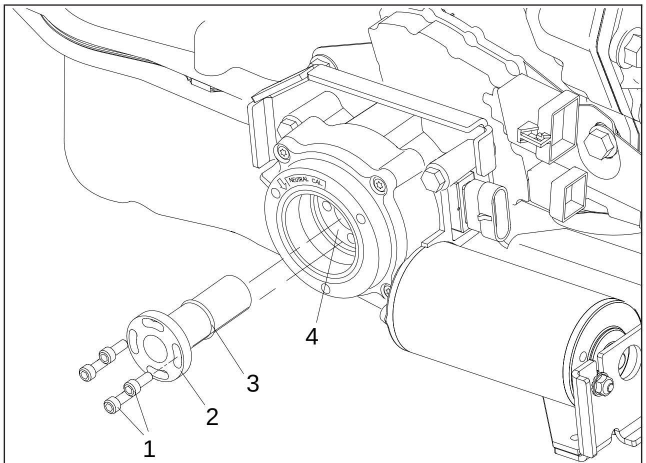
9. Install the two 1/2-inch (12-mm) long adaptor capscrews removed earlier. See **Fig. 4**.

10. Tighten all four of the adaptor capscrews 20 lbf·in (225 N·cm).

11. Install the capnut and tighten it.

NOTE: As the capnut is tightened, the actuator parts will draw down into the operation position.

12. Back the capnut off 1/16 to 1/8 of a turn.



1. Capscrew (adapter)
2. Adaptor
3. O-ring
4. Lost Motion Wheel

Fig. 4, Adaptor (type A) and Lost Motion Wheel

13. Hold the capnut securely with a box-end wrench and tighten the inner socket head capscrew 20 lbf·in (225 N·cm).

14. Install the cover plate and the three cover plate screws. Tighten the screws securely.

15. Turn the ignition switch to the ON position, place the transmission in Park (P), and then turn the ignition switch to the OFF position.

16. Remove the chocks from the tires.

Type B Shift Shaft Adaptor

NOTE: Follow this procedure if the shift shaft adaptor face has four short slots and two holes in it. See **Fig. 5**.

1. Turn the ignition switch to the ON position and place the transmission in Neutral (N).

2. Turn the ignition switch to the OFF position.

NOTE: The shift selector will continue supplying power to the actuator, holding the transmission in Neutral (N). On 1000 and 2400 series transmissions (with a Park [P] position), it is normal for the shift selector display to be active and for the buzzer to sound during the calibration pro-

Actuator Adjustment

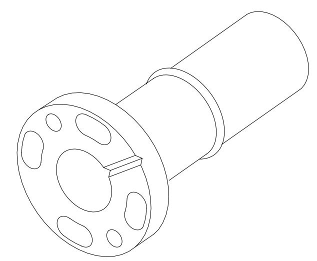


Fig. 5, Type B Adaptor

cedure. When the procedure is completed, turn the ignition switch to the ON position, place the transmission in Park (P), and then turn the ignition switch to the OFF position. The display and the buzzer will both go off.

There is an alternate method (different from that described in the steps below) to determine if the transmission is in Neutral (N). Momentarily engage the starter. If the transmission is not in Neutral (N) the starter won't engage (except on vehicles with a Park [P] position). Check and determine if the parking pawl is or is not engaged. If the pawl is not engaged and the starter can be momentarily activated, the transmission is in Neutral (N). The actuator is now calibrated.

3. Remove the four socket head capscrews securing the shift shaft adaptor. See **Fig. 4**.
4. Thread two 1-3/4 to 2-1/2 inch (43 to 62-mm) long #10-32 screws into the empty holes (not the slots) of the adaptor.
5. Position a long, sturdy screwdriver between the two screws so that the adaptor may be rotated in a clockwise direction.

CAUTION

Do not force the selector shaft when it reaches the end of its travel. This could damage the transmission.

6. Carefully rotate the adaptor fully in a clockwise direction. The transmission is now in the Park (P) position.
7. Now, slowly and carefully, rotate the adaptor counter-clockwise two positions to Neutral (N).

NOTE: When rotating counter-clockwise, you will engage two detents. The second detent will be Neutral (N).

IMPORTANT: The transmission must be in Neutral (N) to calibrate it properly. Rotate the adaptor slowly so that you don't go beyond the Neutral (N) position.

8. Remove the adaptor from the actuator and remove the two long #10-32 screws used to rotate the adaptor. See **Fig. 4**.
9. Thread a long #10-32 screw partially into one of the holes in the lost motion wheel. See **Fig. 4**.
10. Grasp the screw with pliers and pull the lost motion wheel outward, into the calibration position.
11. Turn the ignition switch to the ON position, press the Reverse (R) button on the shift selector, then press the Neutral (N) button. Turn the ignition switch to the OFF position.
12. Install the adaptor and the four adaptor socket head capscrews. See **Fig. 4**.
13. Position your thumb over the center of the adaptor and press inward while tightening the adaptor screws 20 lbf·in (225 N·cm). See **Fig. 4**.
14. Install the capnut and tighten 20 lbf·in (225 N·cm). See **Fig. 2**.
15. Hold the capnut securely with a box-end wrench and tighten the inner socket head capscrew 20 lbf·in (225 N·cm).
16. Install the cover plate and the three cover plate screws. Tighten the screws securely.
17. Turn the ignition switch to the ON position, place the transmission in Park (P), and then turn the ignition switch to the OFF position.
18. Remove the chocks from the tires.

Troubleshooting Tables

SBW System Troubleshooting

Problem—Display Doesn’t Illuminate With Ignition Switch ON

Problem—Display Doesn’t Illuminate With Ignition Switch ON	
Possible Cause	**Remedy**
Electrical Problem	See "Electrical Troubleshooting"

Problem—Display Doesn’t Indicate P or NN With Ignition Switch ON

Problem—Display Doesn’t Indicate P or NN With Ignition Switch ON	
Possible Cause	**Remedy**
Park (P) or Neutral (N) Selector Position Not Selected	Press P on a Park-Equipped Transmission or Press N on a non-Park-Equipped Transmission

Problem—Display Doesn’t Indicate P or NN After Pressing P or N on Selector

Problem—Display Doesn’t Indicate P or NN After Pressing P or N on Selector	
Possible Cause	**Remedy**
Electrical Problem	See "Electrical Troubleshooting"

Problem—Display Indicates P or NN but Engine Doesn’t Start

Problem—Display Indicates P or NN but Engine Doesn’t Start	
Possible Cause	**Remedy**
Actuator not Adjusted (calibrated) Correctly	Adjust the Actuator
Transmission was not in Neutral (N) When Actuator was Adjusted (calibrated)	Ensure That the Transmission is in Neutral (N) and Adjust the Actuator
Neutral Start-Backup (NSBU) Switch Incorrectly Calibrated or Defective	See the *Allison Electronic Troubleshooting Manual*

Problem—Engine Starts but Display Doesn’t Indicate P or NN After Pressing P or N on Selector

Problem—Engine Starts but Display Doesn’t Indicate P or NN After Pressing P or N on Selector	
Possible Cause	**Remedy**
Electrical Problem	See "Electrical Troubleshooting"

Problem—Display Doesn’t Indicate RR After Pressing R on Selector

Problem—Display Doesn’t Indicate RR After Pressing R on Selector	
Possible Cause	**Remedy**
Electrical Problem	See "Electrical Troubleshooting" *

* If the vehicle is equipped with a back-up warning beeper and the beeper sounds, the transmission has shifted into Reverse (R).

Troubleshooting

Problem—Display Indicates DD After Pressing D on Selector

Problem—Display Indicates DD After Pressing D on Selector	
Possible Cause	**Remedy**
J1939 CAN not Working or Poor Contact at Connector	Ensure a Good Contact at the CAN Connector *

* The CAN (controller area network) connector is located behind the instrument panel, to the left of the steering column.

Problem—Display Indicates D3 After Pressing D on Selector

Problem—Display Indicates D3 After Pressing D on Selector	
Possible Cause	**Remedy**
Transmission Control Module (TCM) is in the Limp-Home Mode	See the *Allison Electronic Troubleshooting Manual*

Problem—Correct Drive Positions do not Display as Transmission is Downshifted and Upshifted While in the Drive (D) Range

Problem—Correct Drive Positions * do not Display as Transmission is Downshifted and Upshifted While in the Drive (D) Range	
Possible Cause	**Remedy**
Transmission and/or Transmission Control Module (TCM) Problem	Contact FCCC Customer Support at (800) 385-4357
SBW System Problem	Contact Arens at (847) 844-4716

* Press D and D1 should display; press down arrow and 41 should display, down arrow (31), down arrow (21), down arrow (11); press up arrow and 21 should display, up arrow (31), up arrow (41), up arrow (D1).

Electrical Troubleshooting

Problem—Display Doesn't Illuminate or no Power to SBW System With Ignition Switch ON

Problem—Display Doesn't Illuminate or no Power to SBW System With Ignition Switch ON	
Possible Cause	**Remedy**
Blown Fuse	Replace Blown Fuse *
Bad Connection at Fuse Panel	Ensure a Good Connection †
Bad Ground at Fuse Panel	Ensure a Good Ground ‡
Shift Selector Connector not Making Good Connection	Ensure Good Shift Selector Connector Connection §
Open Circuit or too Much Resistance in any of the Wiring Described in This Table	Check Continuity of all Wires Described in This Table and Repair Wiring as Necessary ¶

* The main power location is the V-Bat terminal at the fuse panel in the lower right corner of the operator's compartment, near the door. There are two 10-amp in-line fuses.

† Check the ignition locations (12 and 13) at the fuse panel.

‡ Check the two grounds at the ground post at the right side of the far-right fuse panel.

§ Two U-brackets underneath the selector secure it. Remove the selector to check the connector.

¶ If, after making all of the checks in this table the display still doesn't illuminate, replace the shift selector.

Troubleshooting

Problem—Display Illuminates but Transmission Doesn’t Shift

Problem—Display Illuminates but Transmission Doesn’t Shift	
Possible Cause	**Remedy**
Actuator Assembly Connectors Damaged (Pushed-out Pins) or Poorly Connected	Repair Connectors and Ensure Good Connections *
Wheel Chair Lift (if so equipped) not Properly Stowed	Ensure That the Wheel Chair Lift is Properly Stowed †
Open Circuit or too Much Resistance Between Selector Connector/Actuator Connectors/Sensor and Motor Wiring	Check Continuity Between Selector Connector/Actuator Connectors/Sensor And Motor Wiring and Repair or Replace Wiring and/or Connectors as Necessary
Transmission and/or Transmission Control Module (TCM) Problem	Contact FCCC Customer Support at (800) 385-4357
Other Non-Determined Problem	Contact Arens at (847) 844-4716

* There are two connectors at the actuator assembly, on the left side of the transmission. One is a pigtail and the other is plugged into the position sensor.

† The SBW system will not allow the transmission to shift if the wheel chair lift (if so equipped) is deployed.

Problem—Transmission Will not Hold Fourth (4) Gear

Problem—Transmission Will not Hold Fourth (4) Gear	
Possible Cause	**Remedy**
Wrong Shift Schedule Programmed Into the Transmission Control Module (TCM)	Program the TCM With the 1235 Shift Schedule With Overdrive Defeat Enabled (See the *Allison Electronic Troubleshooting Manual*)
Poor Connection at Overdrive Defeat Wire/Pin	Ensure a Good Connection at the Overdrive Defeat Wire/Pin

Specifications

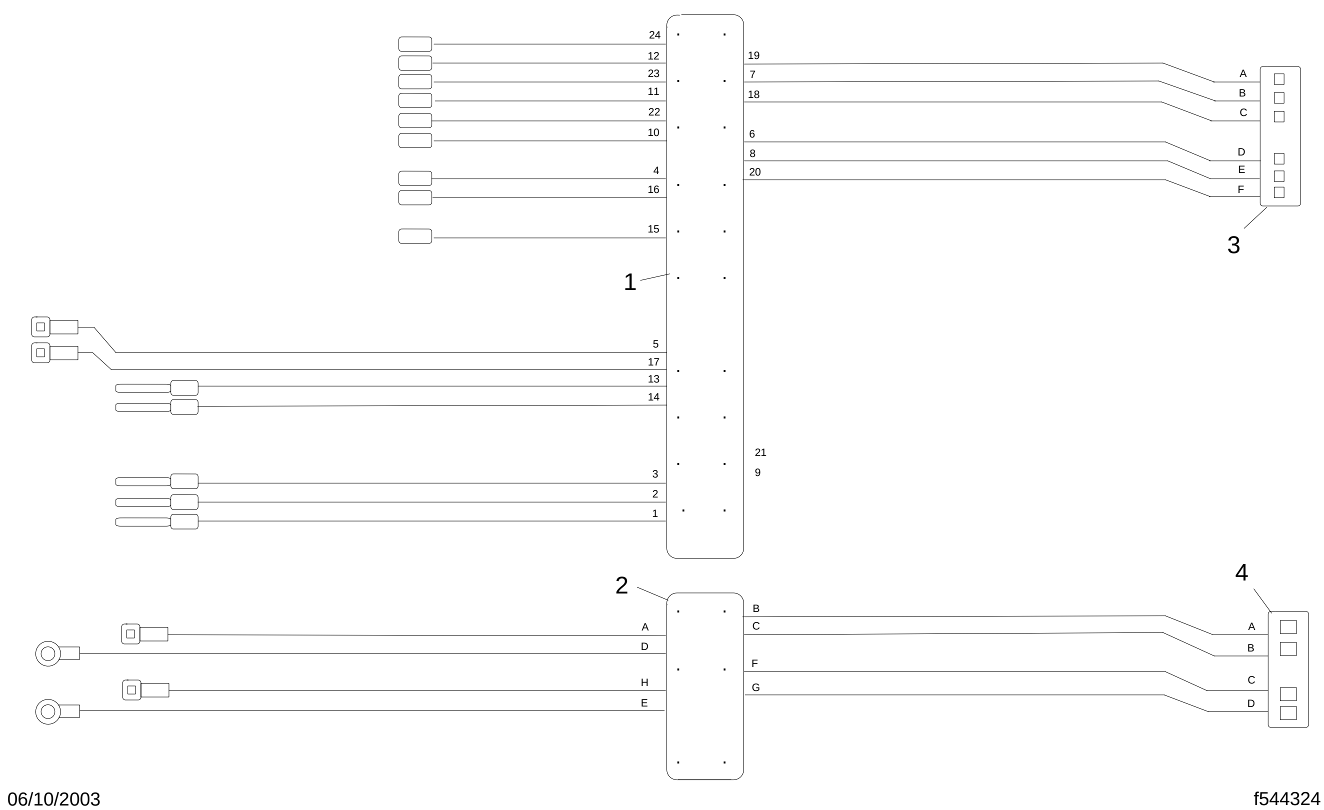
See **Table 1** for SBW wiring information and **Fig. 1** for an SBW wiring diagram.

Shift-by-Wire (SBW) Wire Harness Connectors				
Wire	**Selector Signal Connector (1)**	**Selector High-Power Connector (2)**	**Position Sensor Connector (3)**	**Motor Connector (4)**
VBATT 1	—	A	—	—
VBATT 2	—	H	—	—
GND 1	—	D	—	—
GND 2	—	E	—	—
SHIELD	3	—	—	—
CAN H	2	—	—	—
CAN L	1	—	—	—
VIGN	17	—	—	—
USER INPUT 1	24	—	—	—
USER INPUT 2	12	—	—	—
USER INPUT 3	23	—	—	—
USER INPUT 4	11	—	—	—
USER OUTPUT 1	4	—	—	—
USER OUTPUT 2	16	—	—	—
SHIFT INHIBIT	13	—	—	—
OVERDRIVE DEFEAT	14	—	—	—
MODE OUT	15	—	—	—
DIM	5	—	—	—
POSITION 1A POWER	19	—	A	—
POSITION 1C GND	7	—	B	—
POSITION 1B	18	—	C	—
POSITION 2B	6	—	D	—
POSITION 2C GND	8	—	E	—
POSITION 2A POWER	20	—	F	—
MOTOR 1A	—	B	—	A
MOTOR 1B	—	C	—	B
MOTOR 2B	—	F	—	C
MOTOR 2A	—	G	—	D
USER INPUT 5	22	—	—	—
USER INPUT 6	10	—	—	—
RESERVED	21	—	—	—

Specifications

Shift-by-Wire (SBW) Wire Harness Connectors				
Wire	**Selector Signal Connector (1)**	**Selector High-Power Connector (2)**	**Position Sensor Connector (3)**	**Motor Connector (4)**
RESERVED	9	—	—	—

Table 1, Shift-by-Wire (SBW) Wire Harness Connectors



1. Shift Selector Connector (24 pin)
2. Shift Selector Connector (8 pin)
3. Position Sensor Connector (6 pin)
4. Actuator Connector (4 pin)

Fig. 1, Shift-by-Wire (SBW) Wiring Diagram

General Description

The Cummins B Series engines in the recreational vehicles use a manual throttle pedal, and a throttle cable that connects the throttle pedal to the throttle lever on the engine. The cable runs from the pedal, through the floorboard, 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 upward 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 upward or releases it downward, the lever rotates the shaft to increase or decrease fuel delivery to the fuel injectors.

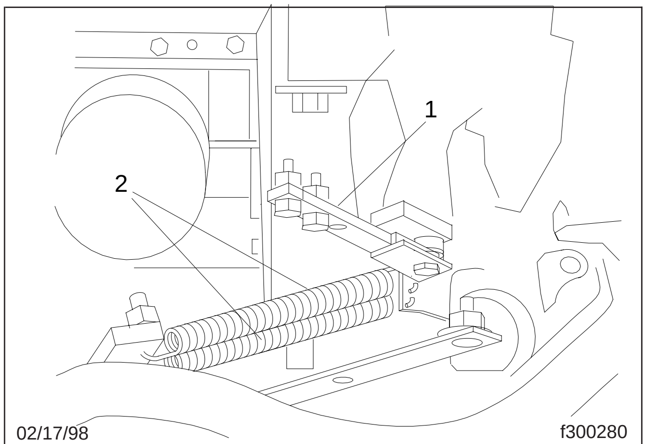
When the throttle cable pulls the rear half of the throttle lever as far upward as the injection pump shaft will rotate, additional force applied at the throttle pedal overcomes the breakover spring in the throttle lever. This allows the rear portion of the throttle lever to continue rotating upward as the throttle cable pulls, but the injection pump shaft is not forced to rotate beyond its rotational limit.

A throttle pedal stop prevents the cable from pulling the throttle lever beyond the breakover range.

Non-Adjustable Throttle Control Cable Operation Checking

Operation Checking

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Gain access to the throttle lever and linkage.
3. Check the linkage attachment fasteners for tightness; tighten any that are loose.
4. Operate the throttle lever by hand, from idle to full throttle, while checking that nothing interferes with movement of the throttle lever or the throttle pedal. Reposition any parts that interfere.
5. Operate the throttle lever by hand, from idle to full throttle, while checking that the return springs pull the throttle lever back to idle when the lever is released. See **Fig. 1** and **Fig. 2**.

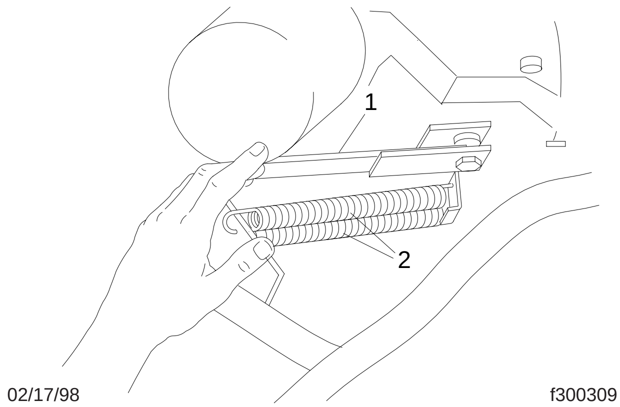


1. Throttle Lever
2. Return Springs

Fig. 1, Throttle Lever in Idle Position

NOTE: There are three return springs—two short springs and one long, narrow spring. The long, narrow spring is inside one of the short springs.

6. Inspect the return springs as follows:
   - 6.1 Disconnect the anchor hooks of the outer spring first. Then disconnect the anchor hooks of the inner spring from the return spring brackets.

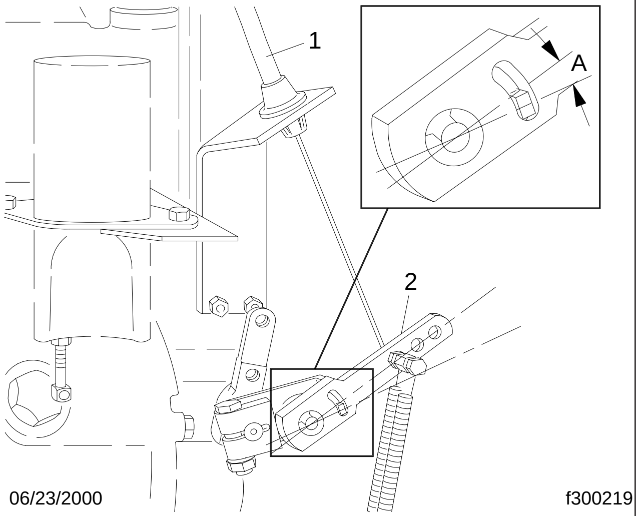


1. Throttle Lever
2. Return Springs

Fig. 2, Throttle Lever in Full Throttle Position

   - 6.2 Inspect the springs, especially in the area of the anchor loops, for wear, nicks, or other damage that might cause breakage.
   - 6.3 Measure the springs for stretching. The short springs, when relaxed, should be no longer than 1.4 inches (36 mm) from one end of the coil to the opposite end of the coil. The long spring, when relaxed, should be no longer than 1.7 inches (43 mm) from one end of the coil to the opposite end of the coil.
   - 6.4 If the springs are worn, damaged, or stretched, install new springs.
   - 6.5 Place the long, narrow spring inside one of the short springs. Attach the anchor hooks of the inner spring to the small diameter holes on the return spring brackets. Attach the anchor hooks of the outer spring to the larger diameter holes next to the small holes on the return spring brackets.
7. Operate the pedal, from idle to the pedal stop, while checking that the throttle cable pulls the throttle lever into the breakover range. See **Fig. 3**.
8. Remove the chocks from the tires.
9. Test drive the vehicle and ensure that the throttle system operates properly.

Non-Adjustable Throttle Control Cable Operation Checking



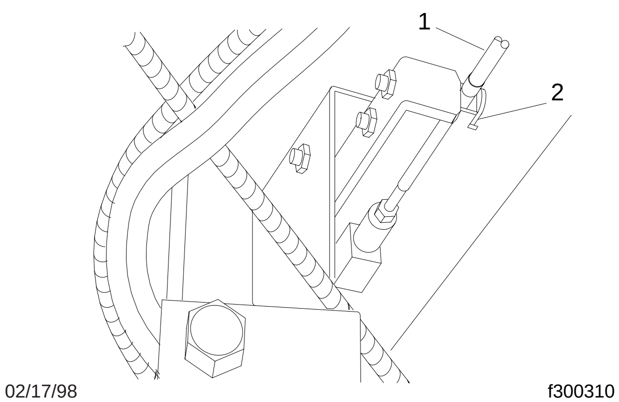
A. Breakover Range
1. Throttle Cable
2. Throttle Lever

Fig. 3, Breakover Range

Throttle Cable Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. From beneath the vehicle, from under the throttle pedal, remove the cotter pin from the clevis pin. Then remove the clevis pin that attaches the lever and pushrod assembly to the throttle cable.
3. Turn the tab on the throttle cable bracket, and remove the throttle cable from the bracket. See **Fig. 1**.



1. Throttle Cable
2. Tab

Fig. 1, Throttle Cable Bracket

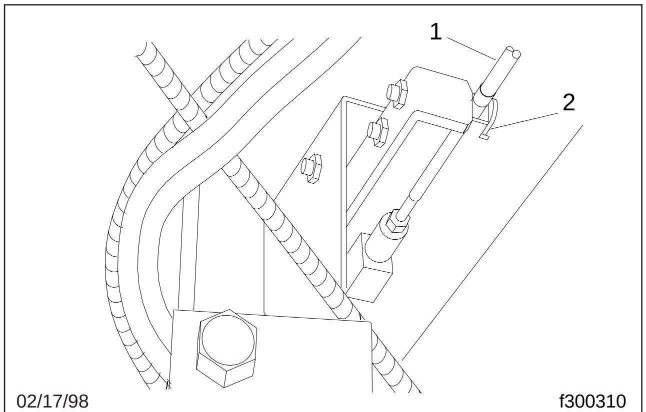
4. Remove all of the tie straps attaching the throttle cable to the cable bundle, inside of the left frame rail.
5. At the engine, loosen the nut that attaches the throttle cable to the throttle injection block linkage.
6. Turn the tab on the throttle cable bracket and remove the throttle cable from the bracket.
7. Remove the throttle cable.

Installation

1. Route the throttle cable from the throttle injection block linkage, across the transmission, to the inside-left frame rail.
2. Tighten the nut that attaches the throttle cable to the throttle injection block linkage.
3. Place the throttle cable on the throttle cable bracket. Turn the tab to secure the cable to the bracket.
4. At the opposite end of the throttle cable, attach the lever and pushrod assembly to the throttle cable. Secure them with the clevis pin. Attach the cotter pin to the clevis pin.
5. Place the throttle cable on the throttle cable bracket. Turn the tab to secure the cable to the bracket.
6. Tie strap the throttle cable to the cable bundle, inside of the left frame rail.
7. Remove the chocks from the tires.
8. Test drive the vehicle and ensure that the throttle system operates properly.

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. From beneath the vehicle, from under the throttle pedal, remove the cotter pin from the clevis pin. Then remove the clevis pin that attaches the lever and pushrod assembly to the throttle cable.
3. Turn the tab on the throttle cable bracket and remove the throttle cable from the bracket. See **Fig. 1**.



1. Throttle Cable Bracket
2. Tab

Fig. 1, Throttle Cable Bracket

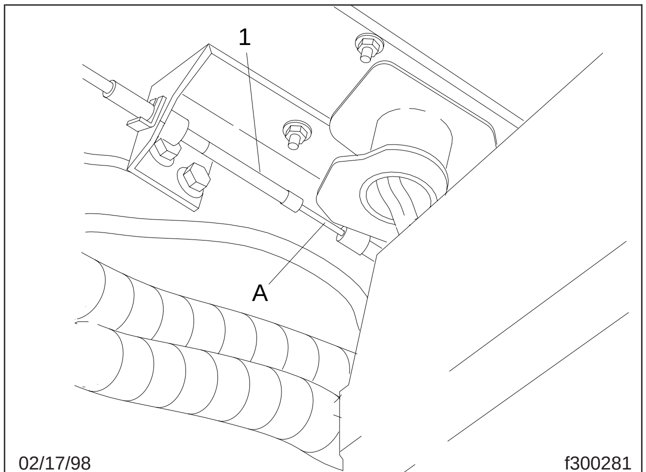
4. Inside the vehicle, remove the carpet from around the pedal mounting.
5. Remove the nuts, bolts, and washers that attach the throttle pedal to the floorboard.
6. Pull the throttle pedal assembly up through the floorboard.

Installation

1. Inside the vehicle, place the throttle pedal assembly in position on the floorboard. Install the bolts, washers, and nuts and tighten 60 to 96 lbf·in (678 to 1085 N·cm).
2. From beneath the vehicle, from under the throttle pedal, attach the lever and pushrod assembly to the throttle cable. Secure them with the clevis pin. Attach the cotter pin to the clevis pin.
3. Install the carpet around the pedal mounting.
4. Remove the chocks from the tires.
5. Test drive the vehicle and ensure that the throttle system operates properly.

Lubrication

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. From under the front of the vehicle, lubricate the throttle cable with silicone spray. See **Fig. 1**.



A. Apply lubricant here.
1. Throttle Cable

Fig. 1, Throttle Cable Lubrication

3. Remove the chocks from the tires.

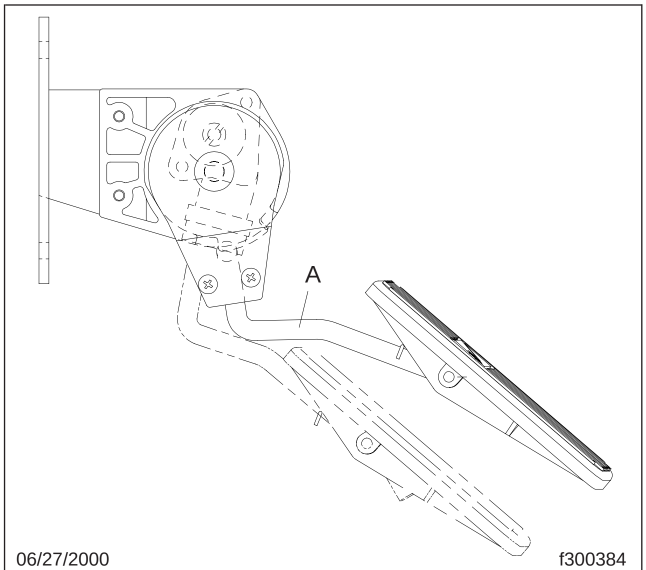
General Information

The Williams electronic suspended throttle pedal assembly is used with Cummins ISB Series engines. The throttle pedal assembly mounts to the inside of the driver's compartment frontwall 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 downward and rotates the pinion gear, the sensor, attached to the right-hand 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. See **Fig. 1**, **Fig. 2**, and **Fig. 3**.

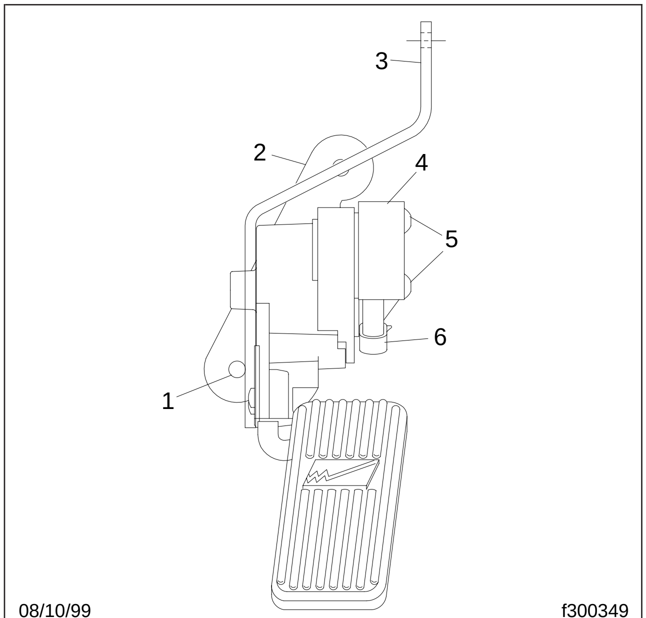
When the driver stops pressing the pedal, return springs within the pedal assembly lift the pedal back to the original idle position.

Only the pedal sensor is serviceable. If any other part of the pedal malfunctions, replace the entire pedal assembly.



A. Idle Position

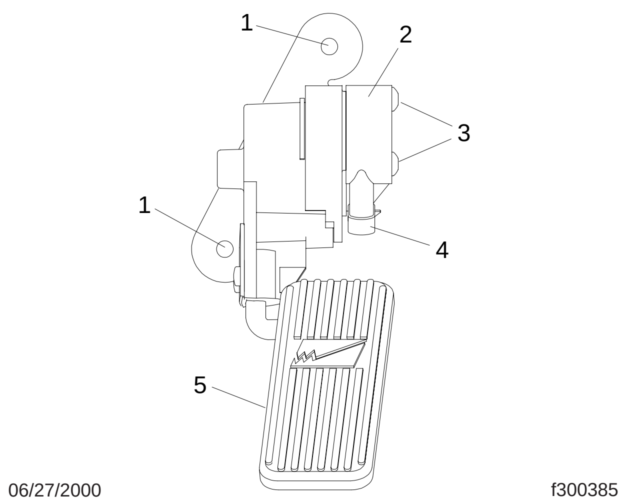
Fig. 1, Williams Electronic Throttle Pedal (side view)



1. Pedal Assembly Mounting Bolt Hole
2. Pedal Assembly Mounting Bracket
3. Kick-Down Modulator Cable Bracket
4. Throttle Sensor
5. Throttle Sensor Mounting Screws
6. Wiring Harness Connector

Fig. 2, Throttle Pedal Assembly (with a non-electronic automatic transmission)

General Information

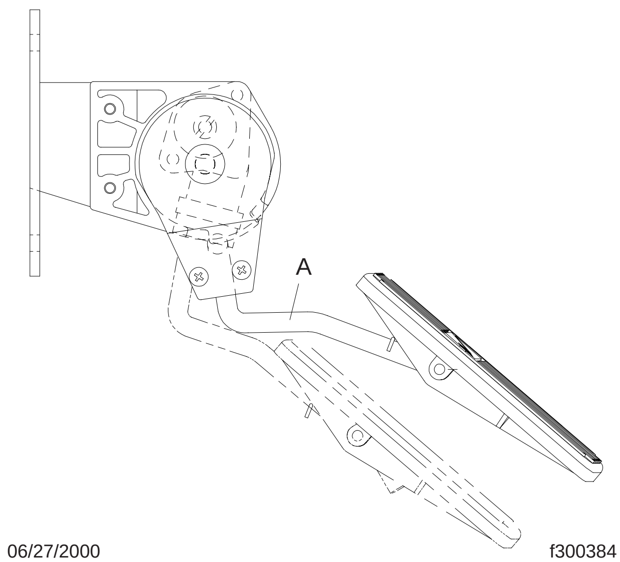


1. Pedal Assembly Mounting Bolt Hole
2. Throttle Sensor
3. Throttle Sensor Mounting Screws
4. Wiring Harness Connector
5. Throttle Pedal

Fig. 3, Throttle Pedal Assembly (with an electronic automatic transmission)

Throttle Pedal Removal and Installation

Removal



A. Idle Position

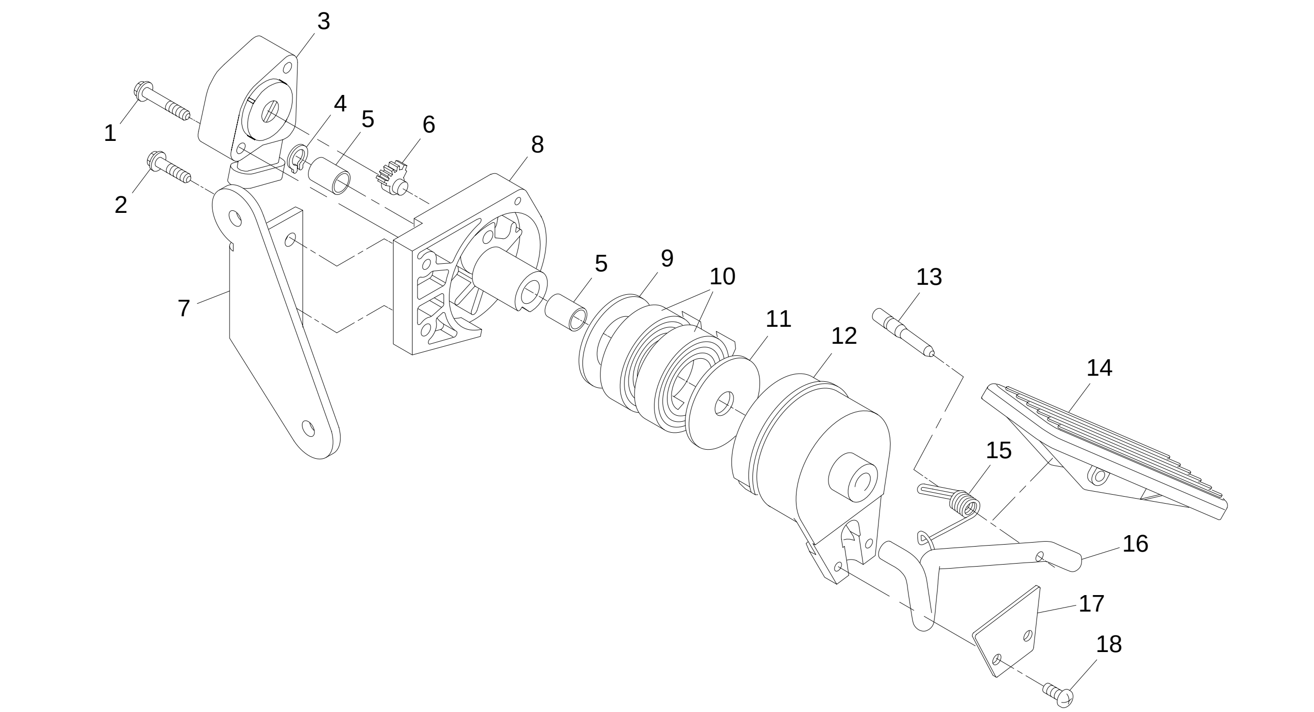
Fig. 1, Electronic Throttle Pedal (side view)

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the throttle pedal. See **Fig. 1** and **Fig. 2**.
   - 3.1 Remove the carpeting from around the pedal mounting.
   - 3.2 Disconnect the wiring harness from the pedal sensor connector.
   - 3.3 Remove the fasteners securing the pedal assembly to the frontwall.
   - 3.4 Remove the pedal assembly from the vehicle.

Installation

1. Install the pedal. See **Fig. 1** and **Fig. 2**.
   - 1.1 Place the pedal assembly in position on the frontwall. Install the mounting fasteners and tighten 15 lbf·ft (20 N·m).
   - 1.2 Connect the wiring harness to the pedal sensor connector.
   - 1.3 Position the carpet around the pedal mounting.
2. Check the operation of the throttle pedal.
3. Connect the batteries.
4. Remove the chocks from the tires.
5. Test drive the vehicle and ensure that the throttle pedal assembly operates properly.

Throttle Pedal Removal and Installation



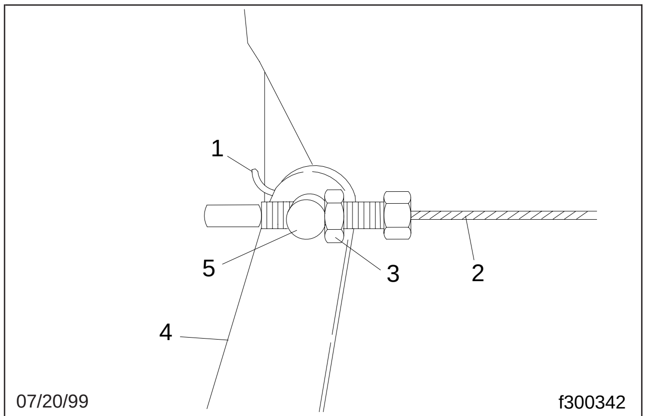
1. Screw, #10–32 UNF-2A x 1.25"
2. Screw, Hex 1/4–20 x 0.75"
3. Sensor
4. Grip Ring
5. Bushing
6. Pinion Gear
7. Mounting Plate
8. Throttle Base
9. Spacer Washer
10. Throttle Spring
11. Spacer Washer
12. Housing
13. Pedal Pin
14. Pedal
15. Pedal Return Spring
16. Pedal Lever
17. Saddle Clamp
18. Screw, #10–32 UNF-2A x 0.50"

Fig. 2, Electronic Throttle Pedal Assembly (exploded view)

Throttle Sensor Replacement

Replacement

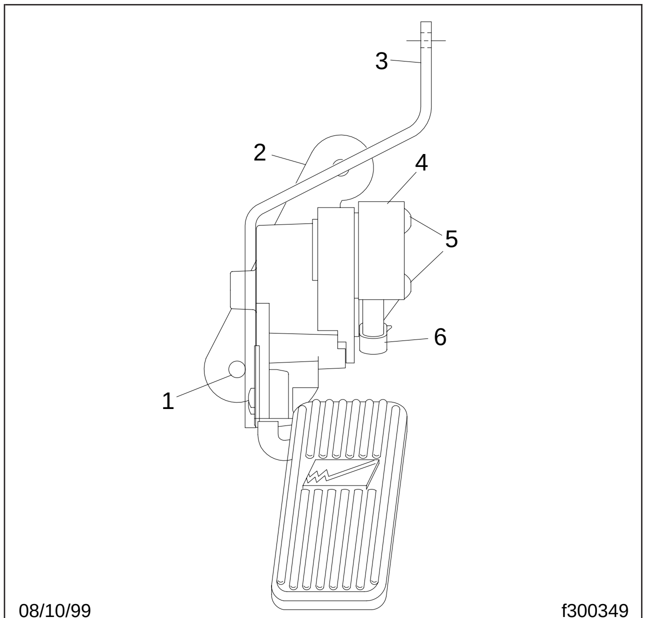
1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the negative battery cable.
3. On vehicles with a non-electronic automatic transmission, remove the cotter pin and disconnect the transmission kick-down modulator cable adjusting pivot from the pedal bracket. See **Fig. 1**.



1. Cotter Pin
2. Kick-Down Modulator Cable
3. Jam Nut
4. Pedal Bracket
5. Adjusting Pivot

Fig. 1, Kick-Down Modulator Cable Pedal Connection (with non-electronic automatic transmission)

4. Remove the two mounting fasteners attaching the pedal assembly to the frontwall. See **Fig. 2** or **Fig. 3**.
5. Disconnect the wiring connector from the electronic throttle control sensor. See **Fig. 2** or **Fig. 3**.
6. Remove the two retaining screws attaching the electronic throttle sensor to the pedal and remove the sensor from the pedal assembly. See **Fig. 2** or **Fig. 3**.
7. Place the throttle sensor in position by sliding it onto the accelerator pedal shaft. Install the two retaining screws. Tighten the screws 15 lbf·in (20 N·cm).

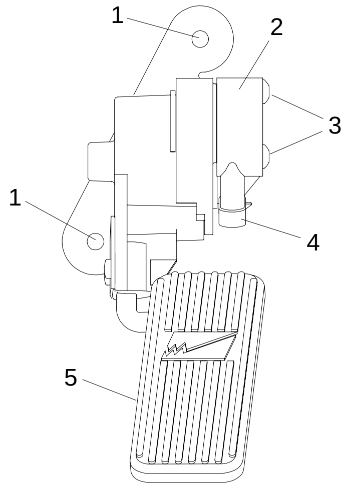


1. Pedal Assembly Mounting Bolt Hole
2. Pedal Assembly Mounting Bracket
3. Kick-Down Modulator Cable Bracket
4. Throttle Sensor
5. Throttle Sensor Mounting Screws
6. Wiring Harness Connector

Fig. 2, Throttle Pedal Assembly (with non-electronic automatic transmission)

8. Connect the wiring connector to the pedal sensor.
9. Place the pedal in position on the frontwall and install the two mounting fasteners. Tighten the mounting fasteners 15 lbf·ft (20 N·m).
10. On vehicles with a non-electronic automatic transmission, insert the adjusting pivot into the hole at the top of the pedal bracket and secure it with a new cotter pin. Check for proper cable end play after connecting the modulator cable to the bracket. For instructions, see **Section 30.03**, Subject 110.
11. Connect the negative battery cable.
12. Remove the chocks from the tires.
13. Test drive the vehicle and ensure that the throttle control sensor operates properly.

Throttle Sensor Replacement



1. Pedal Assembly Mounting Bolt Hole
2. Throttle Sensor
3. Throttle Sensor Mounting Screws
4. Wiring Harness Connector
5. Throttle Pedal

Fig. 3, Throttle Pedal Assembly (with an electronic automatic transmission)

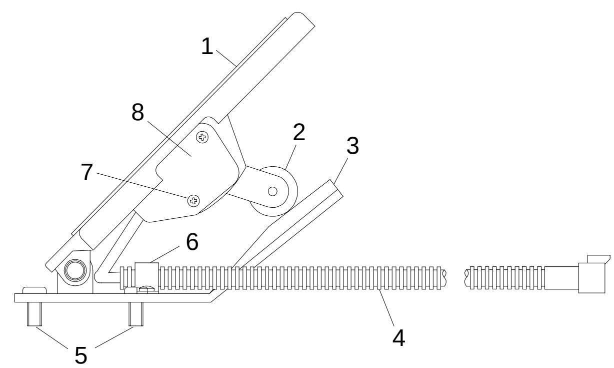
General Information

The Felsted electronic throttle pedal is mounted on a throttle pedal base which is mounted to the driver's compartment floor. It 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 rotates the pinion gear, the sensor, attached to the right-hand 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. See **Fig. 1** and **Fig. 2**.

When the driver stops pressing the pedal, return springs within the pedal assembly lift the pedal back to the original idle position.

NOTE: None of the individual parts of the pedal assembly are serviceable. If any part of the assembly malfunctions, replace the entire pedal assembly.



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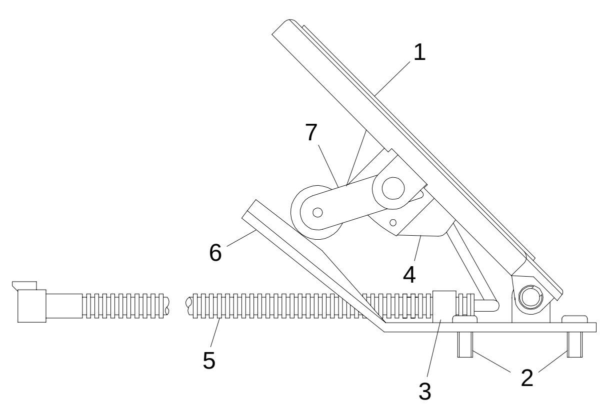
1. Throttle Pedal
2. Roller Assembly
3. Throttle Pedal Base
4. Wire Harness
5. Mounting Fasteners
6. Wire Harness Clamp
7. Sensor Screw
8. Throttle Sensor

Fig. 2, Felsted Electronic Throttle Pedal (right-side view)



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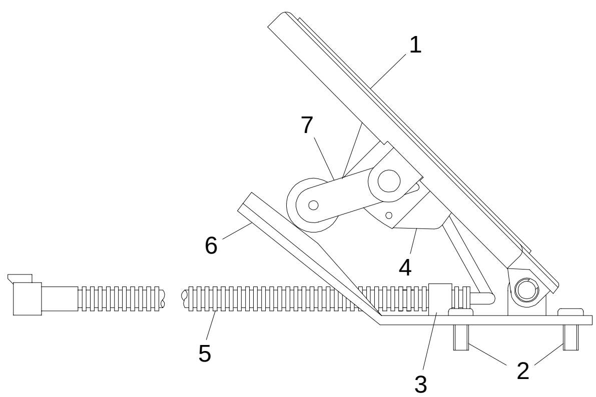
1. Throttle Pedal
2. Mounting Fasteners
3. Wire Harness Clamp
4. Throttle Sensor
5. Wire Harness
6. Throttle Pedal Base
7. Roller Assembly

Fig. 1, Felsted Electronic Throttle Pedal (left-side view)

Throttle Pedal Removal and Installation

Removal



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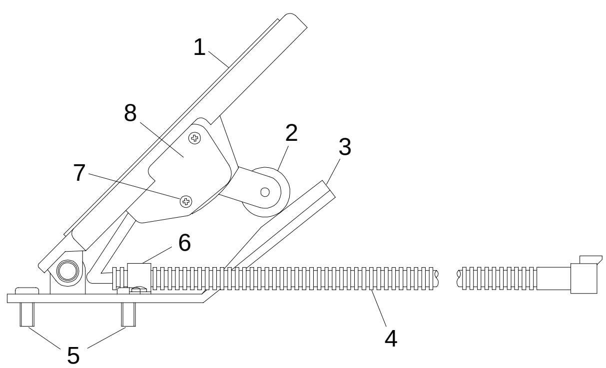
1. Throttle Pedal
2. Mounting Fasteners
3. Wire Harness Clamp
4. Throttle Sensor
5. Wire Harness
6. Throttle Pedal Base
7. Roller Assembly

Fig. 1, Felsted Electronic Throttle Pedal (left-side view)



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1. Throttle Pedal
2. Roller Assembly
3. Throttle Pedal Base
4. Wire Harness
5. Mounting Fasteners
6. Wire Harness Clamp
7. Sensor Screw
8. Throttle Sensor

Fig. 2, Felsted Electronic Throttle Pedal (right-side view)

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the throttle pedal. See **Fig. 1** and **Fig. 2**.

   NOTE: None of the individual parts of the pedal assembly are serviceable. If any part of the assembly malfunctions, replace the entire pedal assembly.

   3.1 Remove the carpeting from around the pedal mounting.

   3.2 Remove the three fasteners that secure the pedal base to the driver's compartment floor.

   3.3 Disconnect the throttle pedal sensor wiring harness connector from the main wiring harness.

   3.4 Remove the pedal assembly from the vehicle.

Installation

1. Install the pedal.

   1.1 Place the pedal assembly in position on the driver's compartment floor. Install the three fasteners and tighten them securely.

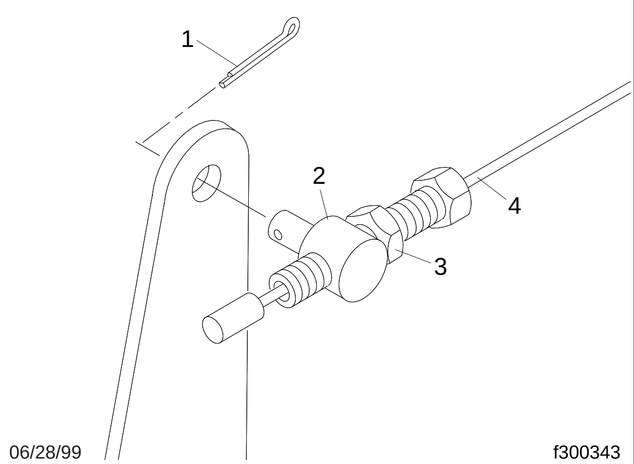
   1.2 Connect the throttle pedal sensor wiring harness connector to the main wiring harness.

   1.3 Position the carpet back around the pedal mounting.
2. Connect the batteries.
3. Check the operation of the throttle pedal assembly. See **Fig. 1** and **Fig. 2**.
4. Remove the chocks from the tires.
5. Test drive the vehicle and ensure that the throttle pedal assembly operates properly.

Throttle Kick-Down Cable Removal And Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Gain access to the throttle kick-down cable adjusting pivot, at the top of the throttle pedal assembly.
3. Remove the cotter pin from the pivot and disconnect the cable from the throttle pedal assembly. See **Fig. 1**.



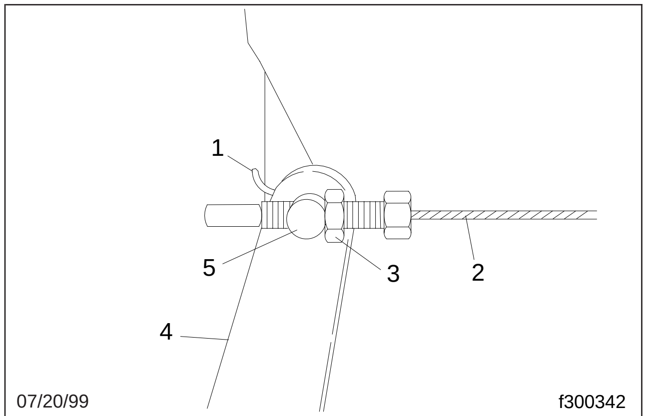
1. Cotter Pin
2. Adjusting Pivot
3. Jam Nut
4. Throttle Kick-Down Cable

Fig. 1, Throttle Kick-Down Cable Adjusting Pivot

4. Remove the engine cover and remove the two cable-to-engine mounting bracket fasteners and the brackets.
5. From the inside of the engine compartment, disconnect the kick-down cable bracket from the charge air tube.
6. From the driver's side of the operator's station, remove the jam nut. See **Fig. 2**.

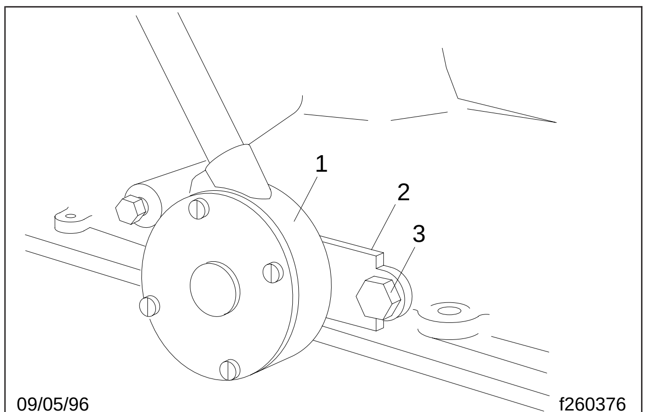
NOTE: The cable nut on the forward side of the operator's station is secured with Loctite® and cannot be turned.

7. Remove the capscrew securing the modulator retaining bracket to the left side of the transmission. Remove the retaining bracket and discard the O-ring. See **Fig. 3**.



1. Cotter Pin
2. Kick-Down Cable
3. Jam Nut
4. Throttle Pedal Bracket
5. Adjusting Pivot

Fig. 2, Kick-Down Cable Mounting



1. Mechanical Modulator
2. Modulator Retaining Bracket
3. Capscrew

Fig. 3, Mechanical Modulator

8. Remove the kick-down cable assembly from the vehicle.

IMPORTANT: Note the routing of the cable to ensure proper installation.

Throttle Kick-Down Cable Removal And Installation

Installation

NOTE: The bulkhead seal washer must be on the forward side of the operator's station and the internally toothed lock washer must be on the driver's side.

1. Route the new kick-down cable assembly in the same manner as the one removed. Insert the cable slip-link end into the front panel of the operator's station. Tighten the jam nut on the driver's side of the operator's station securely.

IMPORTANT: Before installing the modulator neck in the transmission, lubricate a new O-ring with Dexron® transmission fluid.

2. Place the new O-ring on the neck of the modulator control.
3. Insert the neck of the modulator control into the transmission opening, being careful not to damage the O-ring.
4. Place the modulator retaining bracket in position on the transmission. Install the capscrew and tighten 15 to 20 lbf·ft (20 to 27 N·m).
5. From the inside of the engine compartment, connect the kick-down cable bracket to the charge air tube.
6. Install the two cable-to-engine mounting brackets. Install the bracket fasteners and tighten them securely.

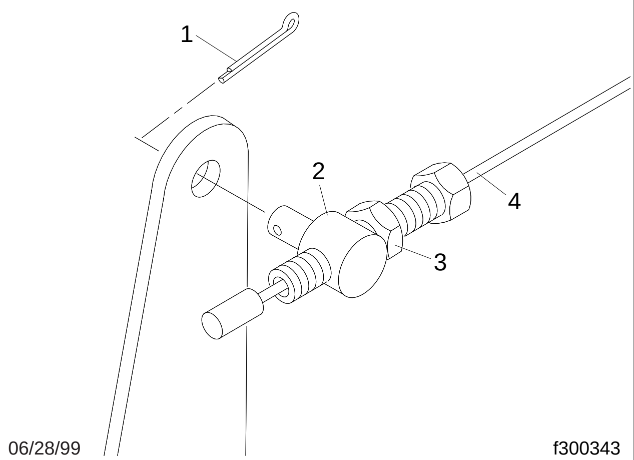
IMPORTANT: Adjust the kick-down cable pivot so that it will insert easily into the throttle pedal bracket, with no pull on the cable.

7. With the cable pivot installed on the threaded end of the cable, adjust the pivot.
8. Secure the pivot to the pedal bracket with a new cotter pin.
9. Adjust the cable. For instructions, see **Subject 110**.
10. Tighten the jam nut on the threaded end of the cable securely.
11. Install the engine cover.
12. Remove the chocks from the tires.
13. Test drive the vehicle and ensure that the throttle kick-down cable assembly operates properly.

Throttle Kick-Down Cable Adjustment

Adjustment

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Gain access to the throttle kick-down cable adjusting pivot, at the top of the throttle pedal assembly.
3. Remove the cotter pin from the pivot and remove the cable from the throttle pedal assembly. See **Fig. 1**.



1. Cotter Pin
2. Adjusting Pivot
3. Jam Nut
4. Throttle Kick-Down Cable

Fig. 1, Throttle Kick-Down Cable Adjusting Pivot

IMPORTANT: Adjust the kick-down cable pivot so that it will insert easily into the throttle pedal bracket, with no pull on the cable.

4. Adjust the position of the pivot on the threaded end of the cable by screwing the pivot either up or down the cable.
5. After installing the pivot in the throttle pedal bracket, ensure that there is no slack in the cable.
6. Secure the pivot to the pedal bracket with a new cotter pin.
7. Push the throttle pedal to the wide open throttle position. Pull the cable end away from the pivot and measure the clearance between the cable end and the threaded end of the cable.

IMPORTANT: Clearance between the cable end and the threaded end of the cable must be 0.02 inch (3 mm). If the clearance is not 0.02 inch (3 mm), adjust the pivot on the threaded end of the cable until the proper clearance is achieved.

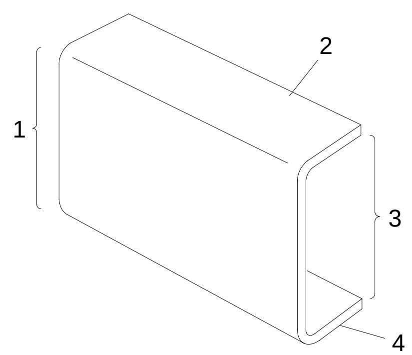
8. Tighten the jam nut on the threaded end of the cable securely.
9. Remove the chocks from the tires.
10. Test drive the vehicle and ensure that throttle kick-down cable assembly operates properly.

General Description

IMPORTANT: This service manual *does not cover* the procedures and calculations necessary to perform frame modifications. For basic information, refer to the vehicle body builder's manual.

The main body of the frame is two non-heat-treated steel frame rails secured together by cross members. The frame assembly is supported on the front and rear axles, and supports the rest of the chassis and body.

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. 1**.



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

Fig. 1, Frame Terminology

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.

FRAME STATIONS

A frame station is a reference point along each frame rail from which the location of each component (mounted on that frame rail) is measured. There are two frame stations along the frame rails: station zero and station 1000.

There is no identifying mark for station zero; it is located about 1.6 inches (40 mm) forward of the forward end of the frame rail, and about 11.4 inches (290 mm) forward of the centerline of the front suspension's forward spring pin. Station 1000 is located about 39.4 inches (1000 mm) to the rear of station zero, and is directly above the centerline of the front axle.

Station 1000 is used when station zero is not accessible because of vehicle assembly. Station 1000 is identified by a 1-1/16 inch (27 mm) diameter hole near the bottom third of the frame rail web. A bulkhead fitting for the air or hydraulic brake lines is installed in the hole.

The vehicle's frame drilling chart lists the location of each frame rail component. For example: if a component is given a location of 850, then that component is installed on the frame rail 33-15/32 inches (850 mm) aft of station zero, or 5-29/32 inches (150 mm) forward of station 1000.

In addition to frame stations zero and 1000, each frame rail has six manufacturing holes along the centerline of the frame rail web. All six holes are 5/8-inch (16-mm) diameter. These holes can be used for location and measurement in the same manner as the hole at frame station 1000.

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

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

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 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.

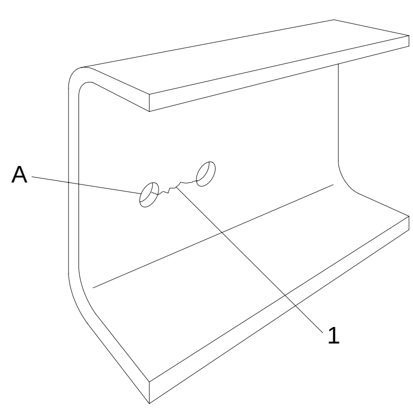
CAUTION

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**.



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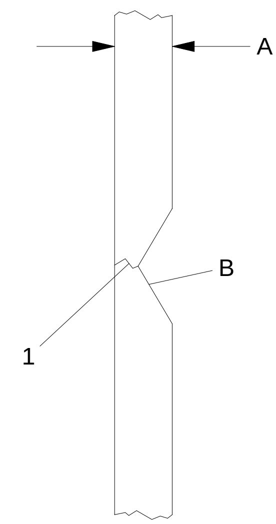
A. 1/8 inch (3 mm) Diameter Hole
1. Crack

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**.



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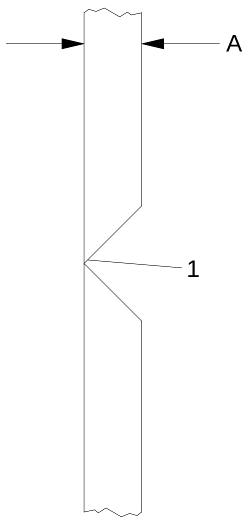
A. Frame Rail Thickness
B. Grind a v-groove to two-thirds the depth of the stock thickness.
1. Crack

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



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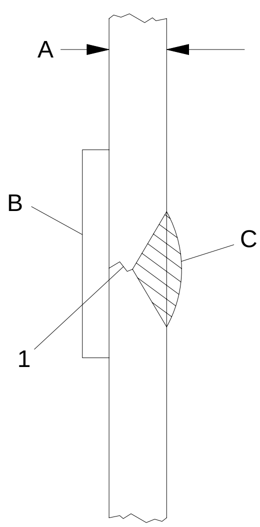
A. Frame Rail Thickness
1. V-groove (full depth)

Fig. 3, Full Depth Groove



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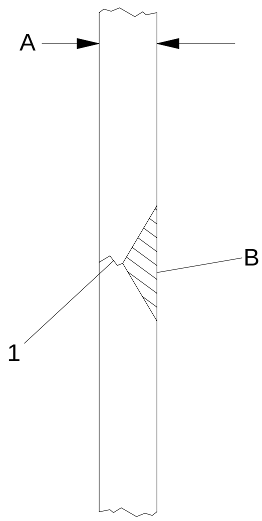
A. Frame Rail Thickness
B. Clamp the "chill" strip on the opposite side of the groove.
C. Deposit weld material.
1. Crack

Fig. 4, Using a Chill Strip



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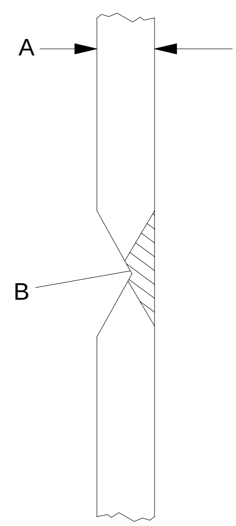
A. Frame Rail Thickness
B. Grind the weld flush with the frame rail.
1. Crack

Fig. 5, Weld Ground Flush



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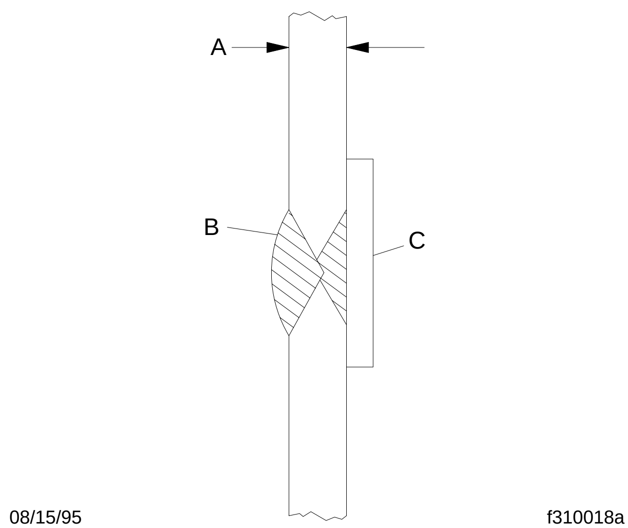
A. Frame Rail Thickness
B. Grind a v-groove deep enough to reach the weld.

Fig. 6, Cross-Section View

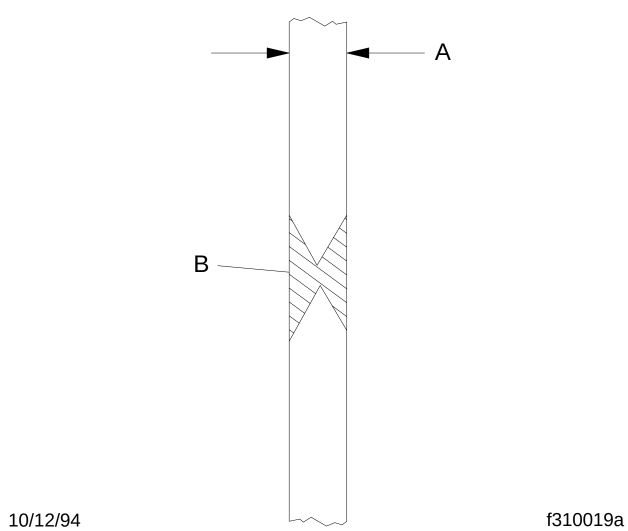
Filling Unused Holes

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.

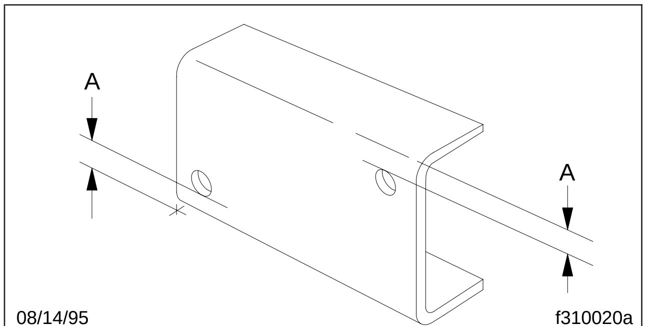
3. Tighten the fasteners to the applicable torque value. For proper frame fastening instructions, refer elsewhere in this group.

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

Frame Fasteners

Either Huckbolts® or grade 8 hexhead bolts and grade C prevailing torque locknuts are used for frame attachments. See **Fig. 1** and **Fig. 2**. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. For some components, grade 8.2 flanged hexhead bolts and grade G prevailing torque locknuts are used for frame attachments. See **Fig. 3**. Prevailing torque locknuts of all three bolt types have distorted sections of threads to provide torque retention.

When nonflanged hexhead bolts and locknuts are used on an attached aluminum 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 frame rails, and for the engine rear supports, rear suspension brackets, and fifth wheel mountings. They are cadmium-or zinc-plated, and have a hardness rating of 38 to 45 HRC.

Flanged hexhead bolts and locknuts have integral flanges which eliminate the need for washers on steel and aluminum surfaces. The fasteners are placed directly against the frame where the part is attached.

HEXHEAD BOLT REPLACEMENT

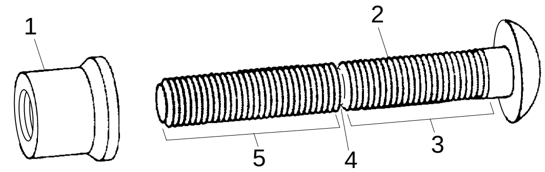
Replace hexhead bolts and locknuts with identical fasteners. See the vehicle parts book for fastener specifications.

Apply Alumilastic® compound, or an equivalent, to all bolts, nuts, and washers that contact aluminum parts.

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 three threads and a maximum of 3/4-inch (19 mm) bolt length.



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1. Collar
2. Huckbolt
3. Locking Grooves
4. Breakneck
5. Pulling Grooves

Fig. 1, Huckbolt Fastener

HUCKBOLT REMOVAL

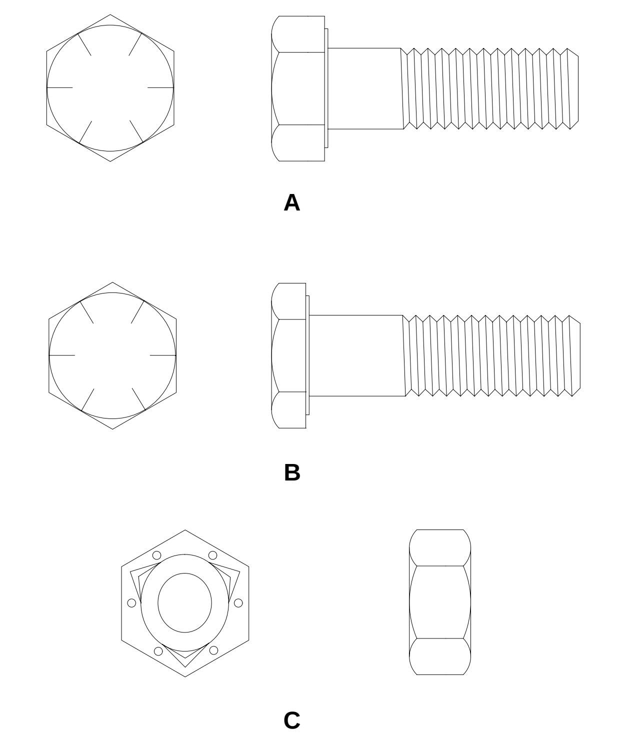
Huckbolt HP 8® frame fasteners see have parallel locking grooves on the lockbolt pintail. See **Fig. 1**. The swaged collar cannot be unscrewed. Use the Huck Collar Cutter to remove HP8 fasteners. If the Collar Cutter isn't available, split the collar with an air chisel while supporting the opposite side of the collar with an anvil. See **Fig. 4**. Then, drive out the lockbolt with a punch. Discard the fastener after removing it.

HUCK-FIT® frame fasteners have locking threads instead of grooves; the collar can be removed using a standard impact wrench and sockets. Discard the fastener after removing it.

CAUTION

Never attempt to reuse any Huck fastener that has been removed. Even though HUCK-FIT fasteners can be removed with a socket wrench, they cannot be correctly installed again. Reusing any Huck frame fastener can result in damage to the vehicle frame or components attached to the frame.

Frame Fasteners



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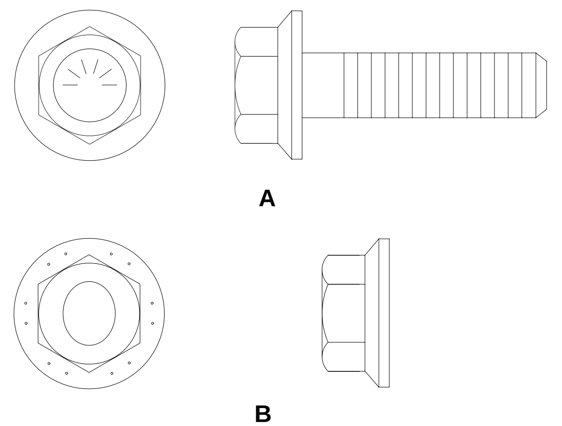
A. Grade 8 Hexbolt
B. Grade 8 Low-Profile Hexbolt
C. Grade C Prevailing Torque Locknut

Fig. 2, Hexhead Fasteners



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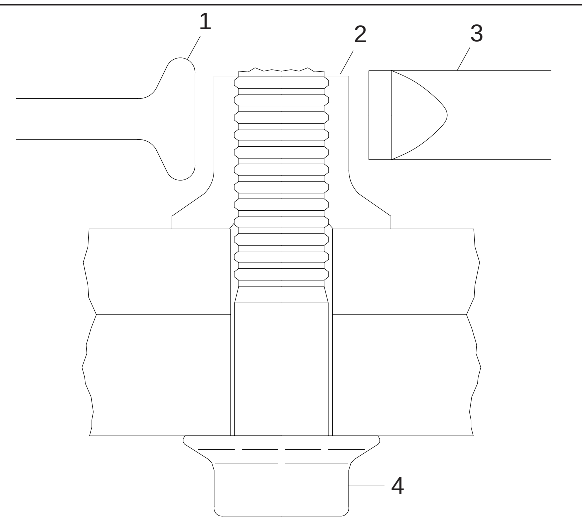
A. Grade 8.2 Flanged Bolt
B. Grade G Prevailing Torque Locknut

Fig. 3, Flanged Hexhead Fasteners



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1. Anvil
2. Lockbolt Collar
3. Chisel
4. Lockbolt

Fig. 4, Huckbolt Removal

HUCKBOLT INSTALLATION

NOTE: Huckbolts cannot be installed without the proper Huckbolt installation equipment.

1. Insert the pintail through the prepared hole in the frame or other component. See **Fig. 5**.
2. Place the collar over the pintail.
3. Place the Huck installation tool nose assembly over the pintail. See **Fig. 6**. The pintail pulling grooves ratchet into the chuck jaws, which securely grip the pintail.
4. As the installation tool trigger is pulled, the tool piston and chuck jaws move rearward, pulling on the pintail, seating the bolt head, and closing the gap between the work surfaces. As pulling on the pintail continues, the collar is swaged into the locking grooves on the pintail; and the collar is lengthened, developing clamping force. See **Fig. 7**.
5. The pintail breaks, freeing the nose assembly anvil from the swaged collar. See **Fig. 8**.

NOTE: Most Huck fasteners have a constriction, the breakneck, which determines the point

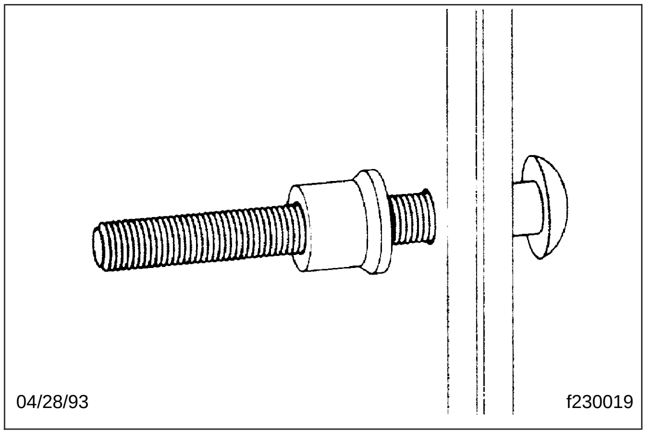


Fig. 5, Positioning the Collar

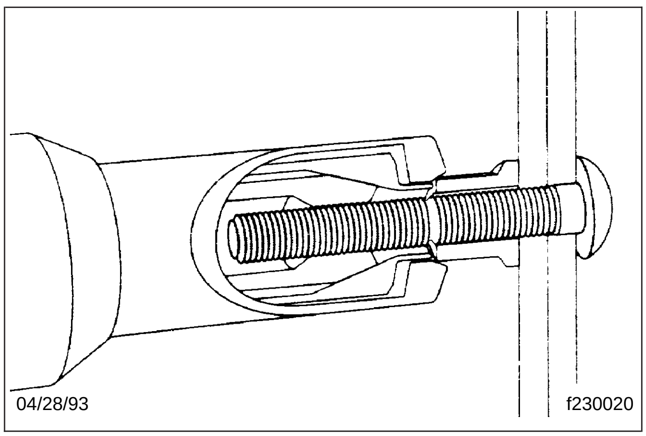


Fig. 6, Positioning the Tool

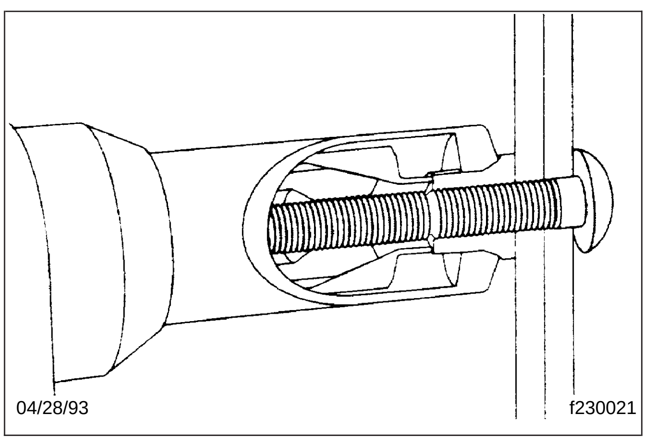


Fig. 7, Securing the Pintail

where the pintail breaks free. See Fig. 1. MAGNA-GRIP® fasteners do not have this

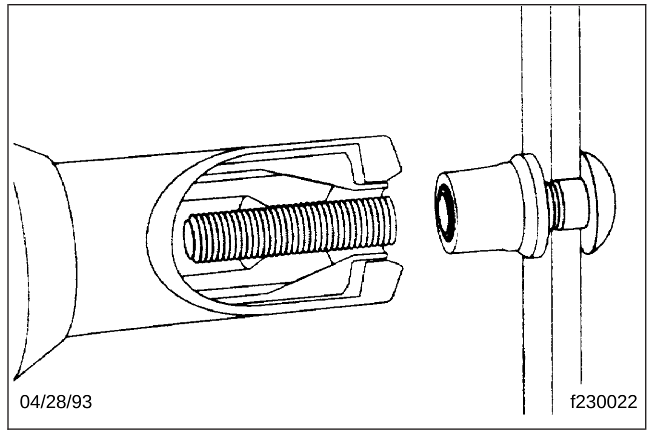


Fig. 8, Installed Huckbolt Fastener

breakneck; the pintail should break flush with the top of the collar. No more than two grooves should be visible on the collar after installation. See Fig. 9 for examples of acceptable and unacceptable MAGNA-GRIP pintail breaks.

FRAME FASTENER TIGHTENING

CAUTION

Tighten standard frame fasteners periodically. Continued vehicle operation with loose fasteners could result in component, bracket, and frame damage.

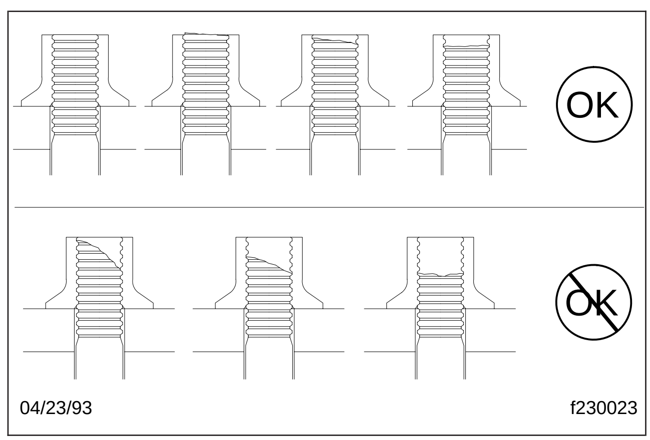


Fig. 9, Pintail Breaks

Tighten hexhead bolts and locknuts periodically to offset the effects of "bedding in" (seating). See the

Frame Fasteners

Maintenance Schedule in Group 00 and the frame section in Group 31 of the vehicle maintenance manual for intervals.

When tightening the fasteners, tighten the nut, not the bolt head. This will give a true torque reading by eliminating bolt body friction. For torque specifications, see the general information section in Group 00 of the vehicle maintenance manual.

NOTE: Huck fasteners do not require periodic tightening.

Replacement

The placement of crossmembers affects the overall stability of the frame. If a crossmember is being eliminated, added, or relocated, dealers must contact their regional service office for instructions and approval. All others must contact a 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.

Rear Closing Crossmember Removal and Installation

REMOVAL

1. Park the vehicle, set the parking brake, and chock the tires.
2. Loosen the fasteners that hold the engine to the rear engine mount.

WARNING

Do not get under a vehicle or engine supported only by jacks. Securely support it with engine stands before going under it. A vehicle or engine supported only by jacks can fall, causing severe personal injury or property damage.

3. Place a jack under the engine and lift it slightly. Place engine stands under the engine to hold it.

NOTE: If necessary, use a jack or the built-in coach jacks to lift the rear of the vehicle enough to place a jack under the engine.

4. Remove the fasteners that hold the engine to the rear engine mount.
5. Place engine stands under the radiator and brace it in place.

   Remove the fasteners that hold the radiator to the rear closing crossmember.
6. Remove the hitch assembly.
   - 6.1 Remove the tie straps that secure the trailer electrical hook up harness along the underside of the hitch assembly.
   - 6.2 Remove the fasteners that hold the hitch assembly to the frame rails, and move the assembly aside
7. Remove the 5/8–11, grade 8 capscrews and nuts that hold the crossmember to the frame rails, and remove it.

INSTALLATION

1. With engine stands securely supporting the engine and radiator, position the rear closing crossmember between the two frame rails.
2. Install the 5/8–11, grade 8 capscrews and nuts that hold the crossmember, and torque them 190 lbf·ft (258 N·m).
3. Install the hitch assembly.
   - 3.1 Position the hitch assembly, and install the fasteners that hold the hitch assembly to the frame rails. Torque them 190 lbf·ft (258 N·m).
   - 3.2 Route the trailer electrical hook up harness along the underside of the hitch assembly, and secure it with tie straps.
4. Install the fasteners that hold the engine, and torque them 136 lbf·ft (184 N·m).
5. Install the fasteners that hold the radiator, and torque them 136 lbf·ft (184 N·m).
6. Remove the chocks from the tires.

Front Crossmember Removal and Installation

REMOVAL

1. Park the vehicle, set the parking brake, and chock the tires.
2. Remove the eight 1/2-inch, grade 8 fasteners that hold the crossmember in place.

INSTALLATION

1. Position the crossmember between the frame rails, and align the fastener holes.

Crossmember Replacement, Model XC

2. Install the eight 1/2-inch, grade 8 fasteners, and torque them 95 lbf·ft (129 N·m).
3. Remove the chocks from the tires.

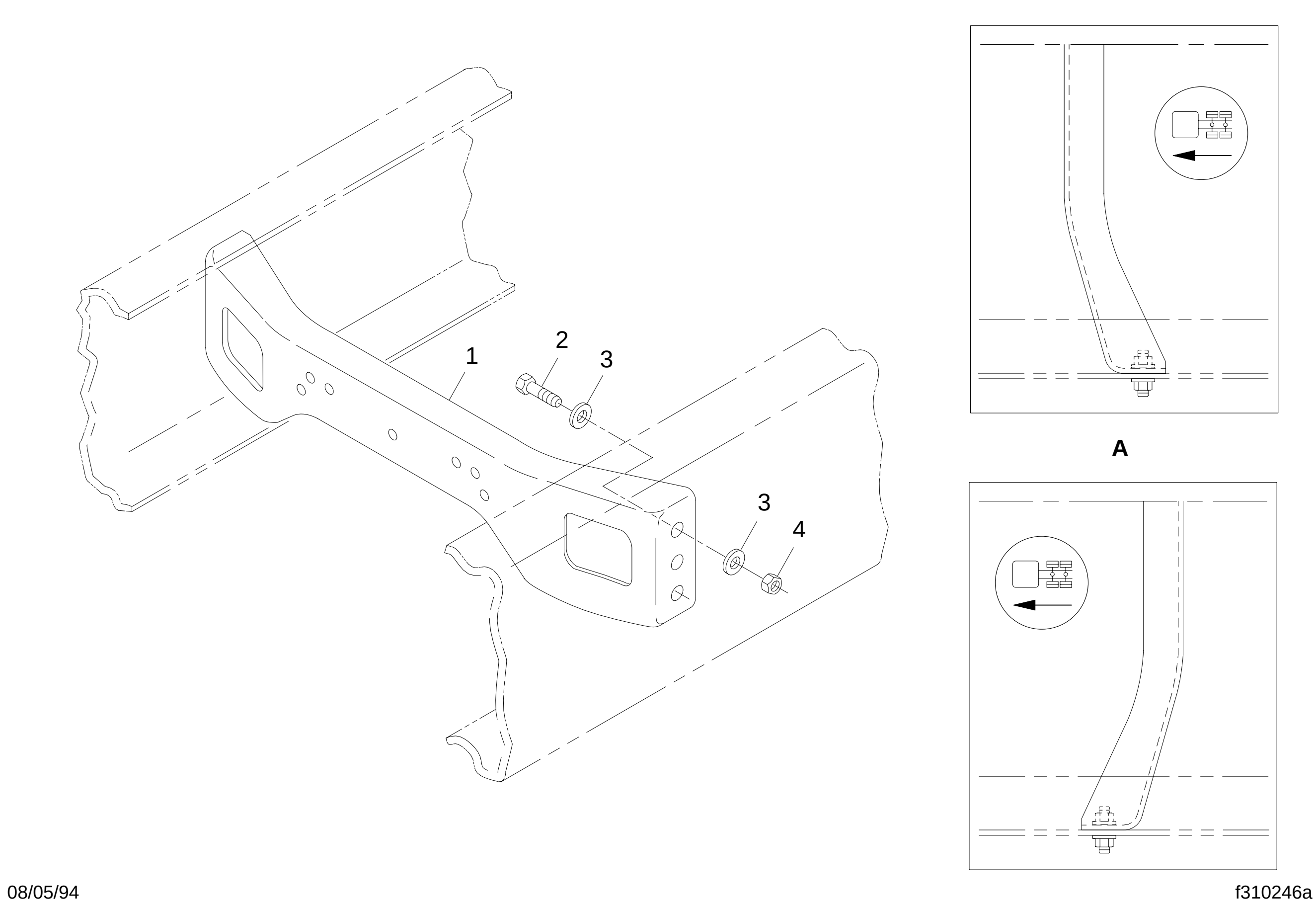
Midship Crossmember Removal and Installation

REMOVAL

1. Park the vehicle, set the parking brake, and chock the tires.
2. Disconnect from the crossmember any valves, hoses, or wiring attached to it.
3. Leave the hoses and wiring routed through the crossmember intact, and cut out the existing crossmember. See **Fig. 1**.

INSTALLATION

1. Position the new crossmember, making sure to route the existing, intact, wiring and hoses either above or below the crossmember, whichever way will best prevent chafing.
2. Install the new crossmember with 1/2-inch, grade 8 fasteners, and torque them 95 lbf·ft (129 N·m).
3. Remove the chocks from the tires.



A. Top Views

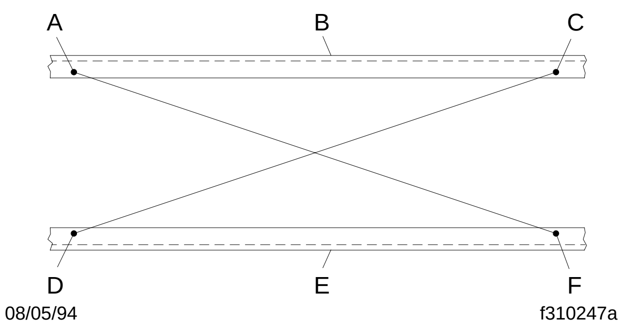
1. Splayed Midship Crossmember
2. 1/2–13 Grade 8 Bolt
3. Hardened Steel Flatwasher
4. 1/2–13 Locknut

Fig. 1, Midship Crossmember Installation

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.

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, Checking Frame Rail Alignment

IMPORTANT: Use a pencil or soapstone to make all lines, points, or other marks. Do not use any marker or tool that will scratch the surface of the frame rail. Use a machinist's square to project all points from the webs to the upper (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.

   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.

   If the values differ by more than 1/8 inch (3 mm), proceed with 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.
8. Loosen *all* of the frame fasteners enough to allow movement of the parts when force is applied.

Frame Rail Alignment

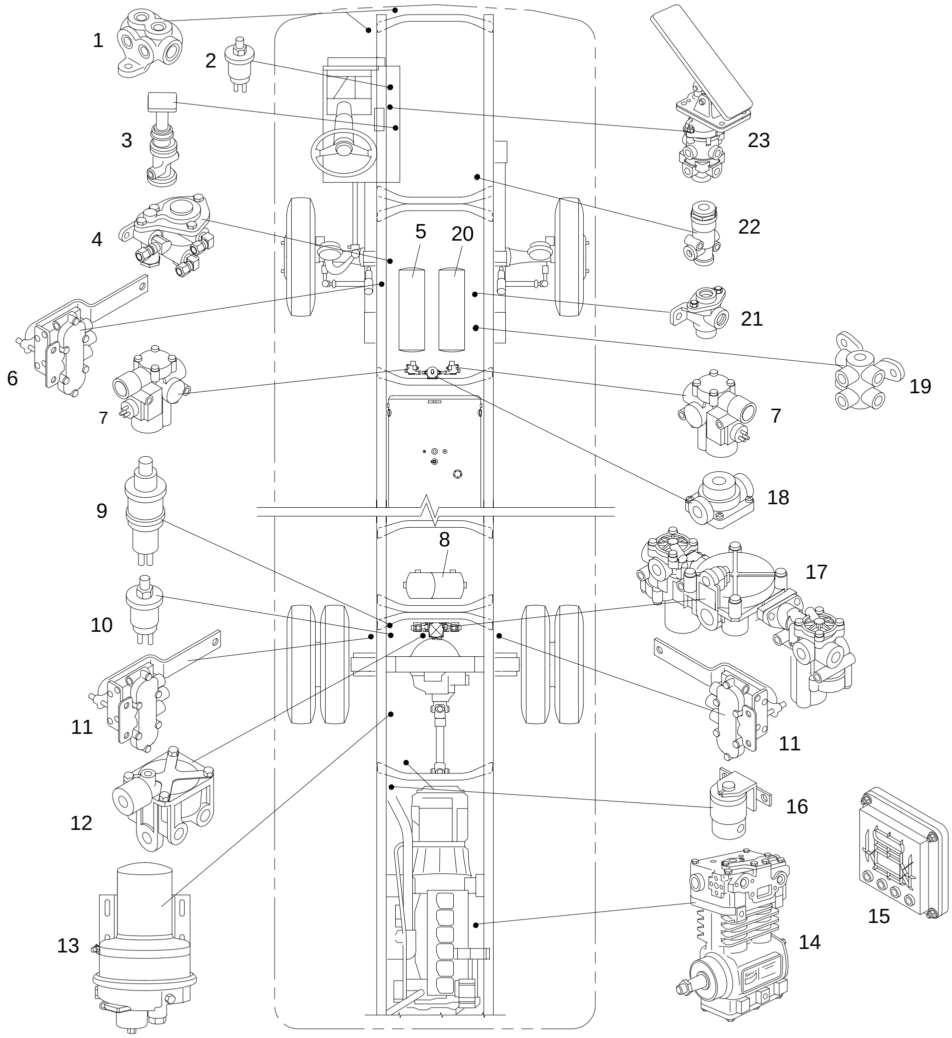
IMPORTANT: To align the frame rails, the frame must have all of the crossmembers in place, but the attachment fasteners should *not* be tightened.

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 00.04** in this manual.
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.

General Information

The chassis layout diagrams below are not specific to a particular RV body builder or model. They represent the general locations of the air plumbing components and of the electrical connectors and components on a generic RV chassis. On most chassis, the components and connectors described should be found within 2 to 3 feet (61 to 91 cm) of where they are shown. See **Fig. 1** and **Fig. 2**.

General Information



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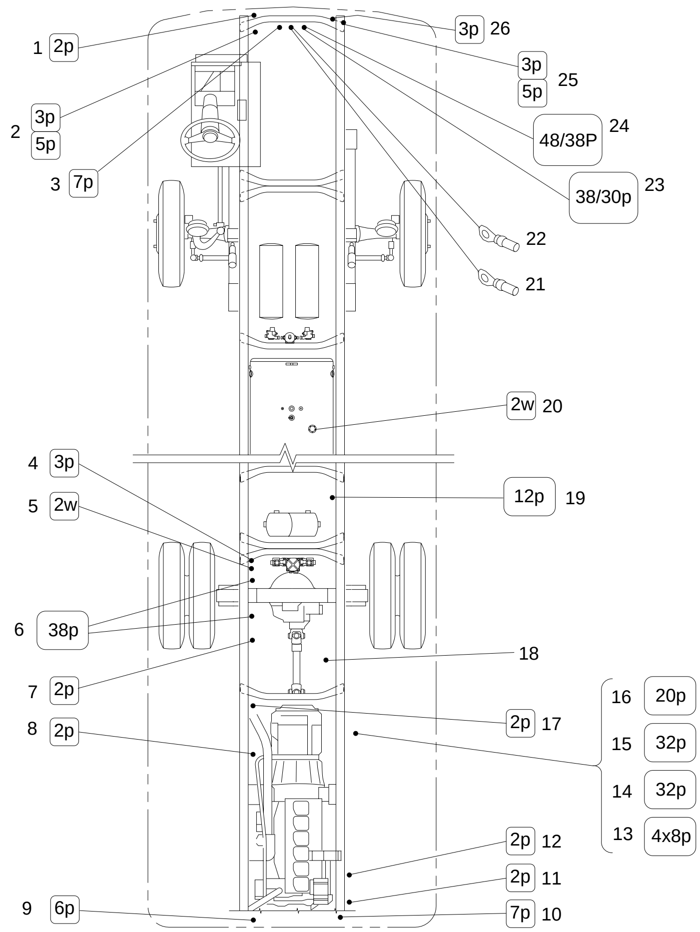
1. Customer Air Manifold (2 possible locations)
2. Stop Light Switch
3. Park Brake Control Valve
4. Spring Brake Valve
5. Secondary Air Tank
6. Front Height Control Valve
7. Front ABS Valves
8. Ping Tank (optional)
9. Park Brake Switch
10. Park Brake Warning Sensor
11. Rear Height Control Valves
12. Rear R-14 Relay Valve
13. Air Dryer
14. Air Compressor/Governor
15. VDC (located by body builder at rear of coach)
16. Exhaust Brake Air Solenoid (2 possible locations)
17. WABCO ABS Combo Valve
18. Front Quick-Release Valve
19. Air Suspension Manifold
20. Primary Air Tank
21. Double Check Valve
22. Inversion Valve
23. Foot Valve

Fig. 1, Air Plumbing Component Locations

General Information



1. Electric Horn (2-pin)
2. Body Builder Interface Connector (LH-side lights, 3/5-pin)
3. Wiper/Washer Connector (7-pin)
4. Park Brake Buzzer Switch (3-pin)
5. Park Brake Switch (2-wire)
6. Chassis/Engine Interface (38-pin)
7. Air-Dryer Heater (2-pin)
8. ABS Interrupt (2-pin)
9. Body Builder Interface Connector (rear lights, 6-pin)
10. Body Builder Interface Connector (rear lights, 7-pin)
11. Back-Up Alarm (2-pin)
12. Fuel/Water Separator (2-pin)
13. VIM-V Connectors (green, blue, gray, black, four 8-pin connectors)
14. ECU-S Connector (black, 32-pin)
15. ECU-V Connector (gray, 32-pin)
16. VIM-V Connector (round, 20-pin)
17. Exhaust Brake Air Solenoid (2-pin)
18. Battery Location (power/ground cables)
19. WABCO ABS ECU (12-pin)
20. Fuel Level Sender (2-wire)
21. Battery Negative Feed to Cab (ring terminal)
22. Battery Positive Feed to Cab (ring terminal)
23. 38/30 Way Connector (38 or 30-pin)
24. 48/38 Way Connector (48 or 38-pin)
25. Body Builder Interface Connector (RH-side lights, 3/5-pin)
26. Air Brake Option Connector (3-pin)

NOTE: Connectors 13 through 16 and the batteries (#18) are located by the body builder.

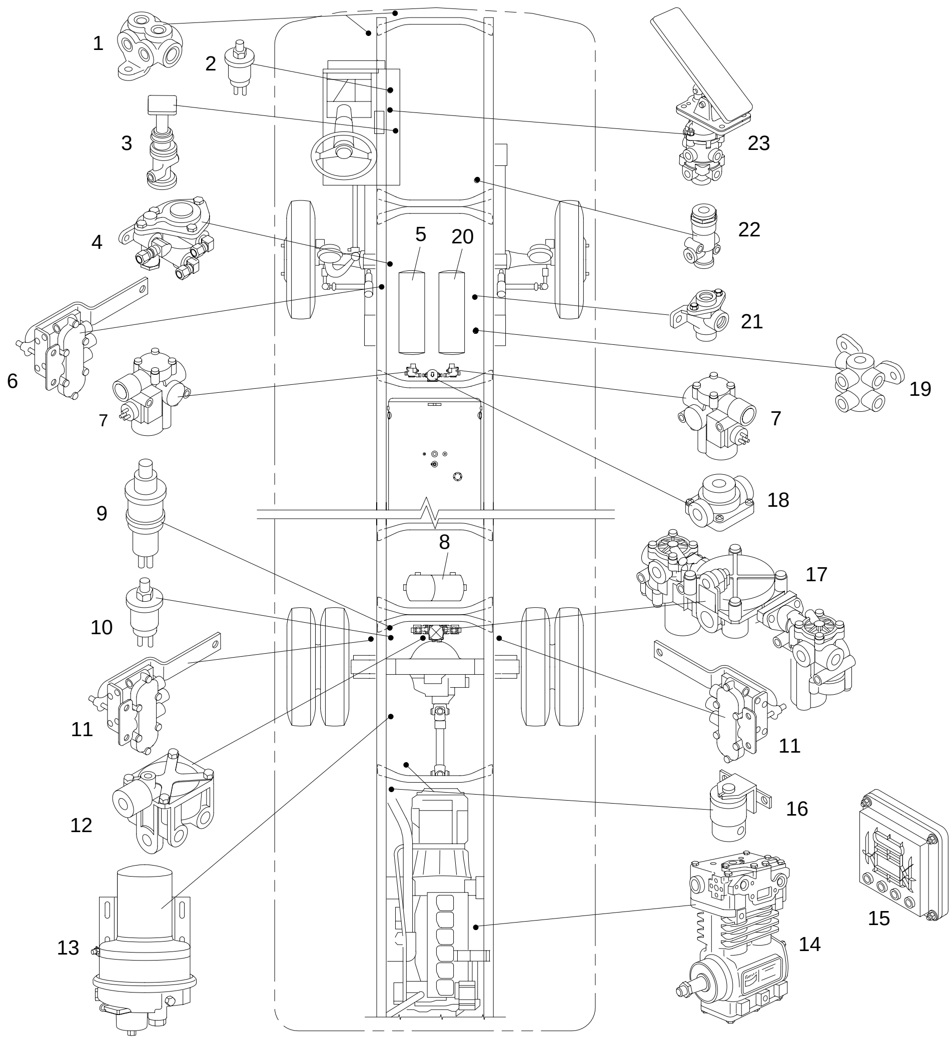
Fig. 2, Electrical Connector and Component Locations

Air Plumbing and Electrical Component Locations

Component Locations

The following chassis layout diagrams are not specific to a particular RV body builder or model. They represent the general locations of the air plumbing components and of the electrical connectors and components on a generic RV chassis. On most chassis, the components and connectors described should be found within 2 to 3 feet (61 to 91 cm) of where they are shown. See **Fig. 1** and **Fig. 2**.

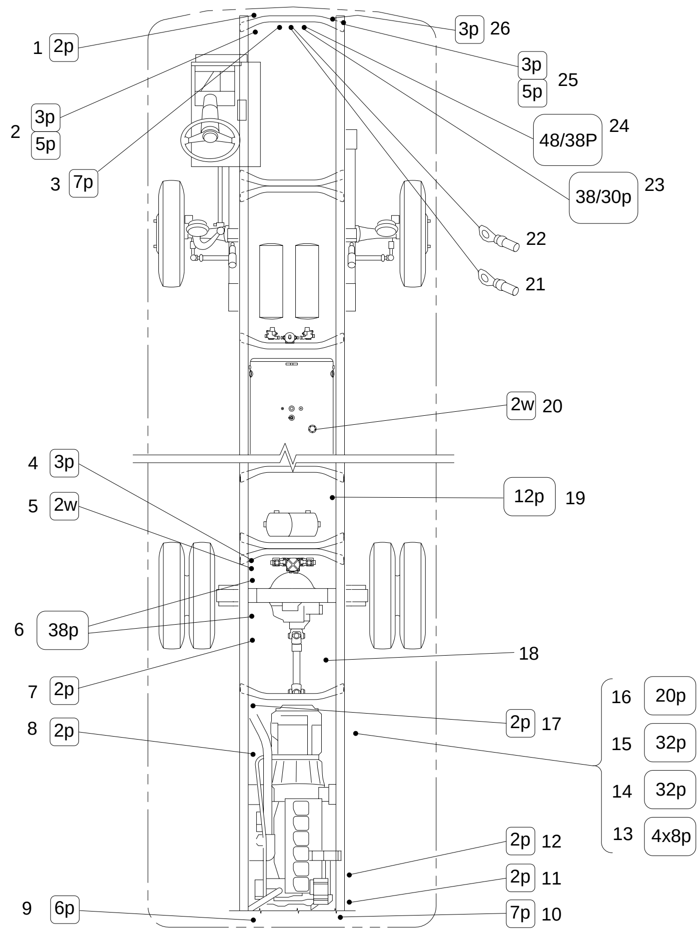
Air Plumbing and Electrical Component Locations



1. Customer Air Manifold (2 possible locations)
2. Stop Light Switch
3. Park Brake Control Valve
4. Spring Brake Valve
5. Secondary Air Tank
6. Front Height Control Valve
7. Front ABS Valves
8. Ping Tank (optional)
9. Park Brake Switch
10. Park Brake Warning Sensor
11. Rear Height Control Valves
12. Rear R-14 Relay Valve
13. Air Dryer
14. Air Compressor/Governor
15. VDC (located by body builder at rear of coach)
16. Exhaust Brake Air Solenoid (2 possible locations)
17. WABCO ABS Combo Valve
18. Front Quick-Release Valve
19. Air Suspension Manifold
20. Primary Air Tank
21. Double Check Valve
22. Inversion Valve
23. Foot Valve

Fig. 1, Air Plumbing Component Locations

Air Plumbing and Electrical Component Locations



NOTE: Connectors 13 through 16 and the batteries (#18) are located by the body builder.

1. Electric Horn (2-pin)
2. Body Builder Interface Connector (LH-side lights, 3/5-pin)
3. Wiper/Washer Connector (7-pin)
4. Park Brake Buzzer Switch (3-pin)
5. Park Brake Switch (2-wire)
6. Chassis/Engine Interface (38-pin)
7. Air-Dryer Heater (2-pin)
8. ABS Interrupt (2-pin)
9. Body Builder Interface Connector (rear lights, 6-pin)
10. Body Builder Interface Connector (rear lights, 7-pin)
11. Back-Up Alarm (2-pin)
12. Fuel/Water Separator (2-pin)
13. VIM-V Connectors (green, blue, gray, black, four 8-pin connectors)
14. ECU-S Connector (black, 32-pin)
15. ECU-V Connector (gray, 32-pin)
16. VIM-V Connector (round, 20-pin)
17. Exhaust Brake Air Solenoid (2-pin)
18. Battery Location (power/ground cables)
19. WABCO ABS ECU (12-pin)
20. Fuel Level Sender (2-wire)
21. Battery Negative Feed to Cab (ring terminal)
22. Battery Positive Feed to Cab (ring terminal)
23. 38/30 Way Connector (38 or 30-pin)
24. 48/38 Way Connector (48 or 38-pin)
25. Body Builder Interface Connector (RH-side lights, 3/5-pin)
26. Air Brake Option Connector (3-pin)

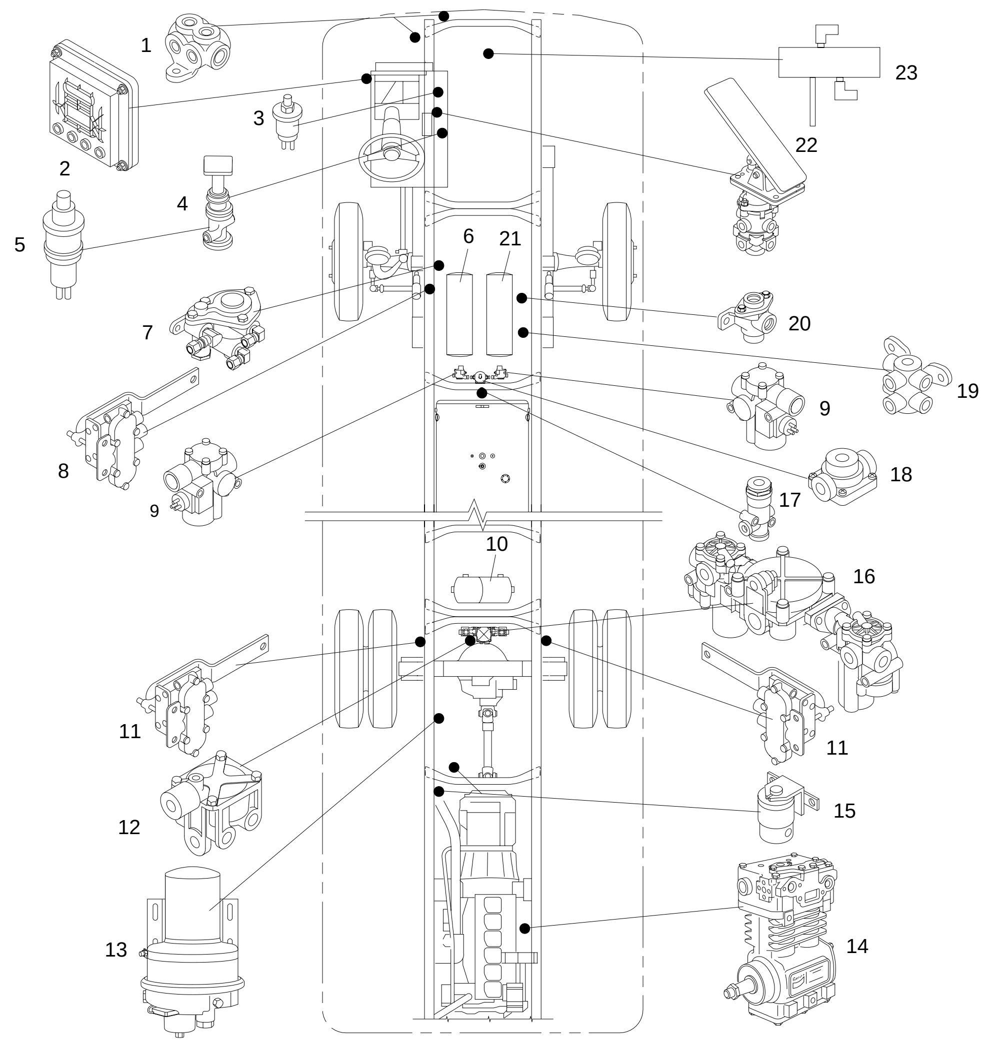
Fig. 2, Electrical Connector and Component Locations

MMDC Air Plumbing and Electrical Component Locations

Component Locations

NOTE: The following chassis layout diagrams are not specific to a particular RV body builder or model. They represent the general locations of the air plumbing components and of the electrical connectors and components on a generic RV chassis with the Multiple Module Data Computer (MMDC) instrument system. On most chassis, the components and connectors described should be found within 2 to 3 feet (61 to 91 cm) of where they are shown. See **Fig. 1** and **Fig. 2**.

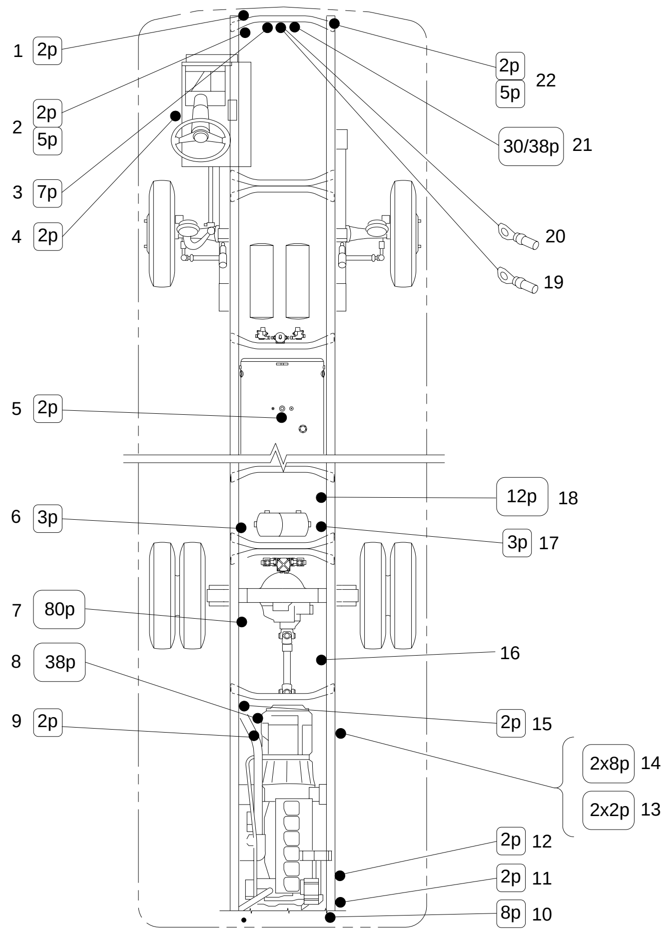
MMDC Air Plumbing and Electrical Component Locations



1. Customer Air Manifold (2 possible locations)
2. MMDC (located by body builder at front of coach)
3. Stop Light Switch
4. Park Brake Control Valve
5. Park Brake Switch
6. Secondary Air Tank
7. Spring Brake Valve
8. Front Height Control Valve
9. Front ABS Valves
10. Ping Tank (optional)
11. Rear Height Control Valves
12. Rear R-14 Relay Valve
13. Air Dryer
14. Air Compressor/Governor
15. Exhaust Brake Air Solenoid (2 possible locations)
16. WABCO ABS Combo Valve
17. Inversion/Auto Dump Valve
18. Front Quick-Release Valve
19. Air Suspension Manifold
20. Double Check Valve
21. Primary Air Tank
22. Foot Valve
23. Auto Dump/Norgren Valve with ZEDF IFS

Fig. 1, Air Plumbing Component Locations, MMDC Chassis

MMDC Air Plumbing and Electrical Component Locations



NOTE: Connectors 7, 13, 14, 17 and the batteries (#16) are located by the body builder.

1. Electric Horn (2 pin)
2. Body Builder Interface Connector (LH-side lights, 2/5 pin)
3. Wiper/Washer Connector (7 pin)
4. Park Brake Switch (2 pin)
5. Fuel Level Sender (2 pin)
6. Body Builder Interface Connector (left-hand marker light, turn signal 3 pin)
7. TCM Connector (black, 80 pin)
8. Chassis/Engine Interface (38 pin; 3 pin J1939)
9. Air-Dryer Heater (2 pin)
10. Body Builder Interface Connector (rear lights, 8 pin)
11. Back-Up Alarm (2 pin)
12. Fuel/Water Separator (2 pin)
13. VIM-V Connectors (black, two 2-pin connectors)
14. VIM-V Connectors (gray, black, two 8-pin connectors)
15. Exhaust Brake Air Solenoid (2 pin)
16. Battery Location (power/ground cables)
17. Body Builder Interface Connector (right-hand marker light, turn signal 3 pin)
18. WABCO ABS ECU (12 pin)
19. Battery Negative Feed to Cab (ring terminal)
20. Battery Positive Feed to Cab (ring terminal)
21. 30/38 Way Connector (30 or 38 pin; 3 pin J1939)
22. Body Builder Interface Connector (RH-side lights, 2/5 pin)

Fig. 2, Electrical Connector and Component Locations, MMDC Chassis

General Description

The air (bag) springs are mounted on a leaf spring, which is attached to the front axle. The leaf spring is equipped with rubber bushings.

If an air spring is damaged or is leaking, it should be replaced.

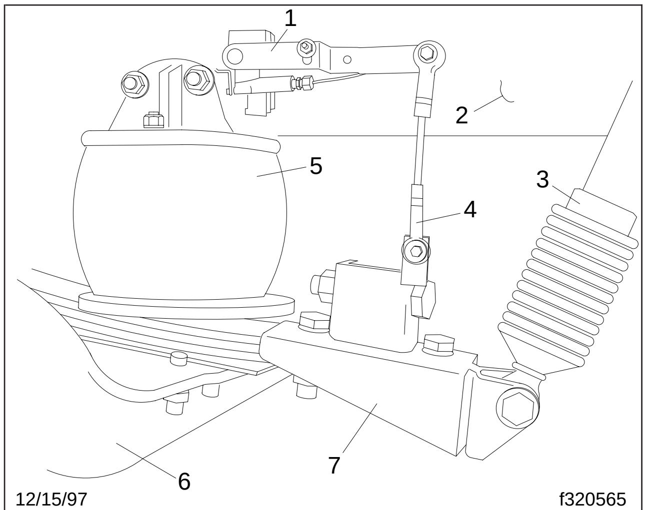
If a leaf spring has taken a set, that is, lost significant height, it should be replaced.

The front suspension system is equipped with a sway bar and shock absorbers. The hydraulic shock absorbers are of the direct double-acting type. They provide a continuous dampening effect both on compression and rebound. These shock absorbers are of telescopic design with rubber grommets at the mounting points for quiet operation. The shock absorbers are sealed, non-adjustable units, and must be replaced as complete assemblies.

Air Spring Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake, and chock the rear tires. Raise the vehicle frame until the weight is off the front suspension with the wheels still touching the floor. Place jack stands under the frame rails.
2. If equipped, remove the front hub caps from the vehicle.
3. Remove the tires and wheels from the vehicle. See **Group 40** for instructions.
4. Support the front axle with jacks.
5. Disconnect the height control valve linkage rod. See **Fig. 1**. If removing both air springs, disconnect the height control valve linkage rod on each side of the vehicle.
6. Disconnect the shock absorber from the leaf spring mounting.



1. Height Control Valve
2. Frame Rail
3. Shock Absorber
4. Height Control Valve Linkage Rod
5. Air Spring Bag
6. Front Axle
7. Leaf Spring Mounting Bracket

Fig. 1, Typical Front Spring Assembly

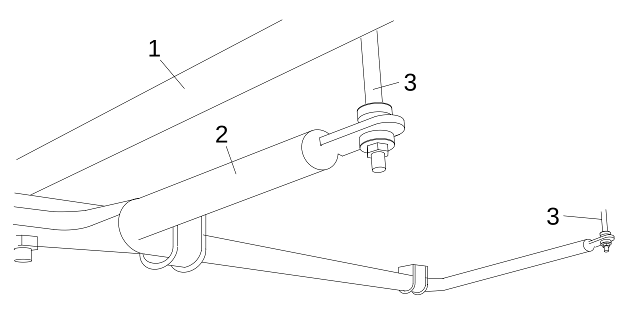
7. Remove the nut, washer, and capscrew that attaches the leaf spring to the front hanger bracket.
8. Remove the leaf spring and the air spring assemblies.
9. Inspect, remove, and replace the front spring hanger bracket, as necessary.

Installation

1. Position the leaf spring at the spring seat over the axle and align the spring eye with the front spring hanger.
2. Install the leaf spring capscrew, washer, and nut, and tighten 140 lbf·ft (190 N·m).
3. Install the air spring (with four capscrews and nuts) to the leaf spring/front axle, and attach the nut to the bolt at the top of the air spring. See **Fig. 1**. Tighten 220 lbf·ft (298 N·m).
4. Install the shock absorber to the leaf spring, and tighten nut 100 lbf·ft (136 N·m).
5. Install the tires and wheels on the vehicle. See **Group 40** for instructions. Install the hub caps, if removed.
6. Remove the jack stands and lower the vehicle.
7. Remove the chocks.

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake, and chock the rear tires.
2. Raise the vehicle frame until the weight is off the front suspension assembly with the wheels still touching the floor. Place jack stands under the frame rails.
3. If equipped, remove the front hub caps from the vehicle.
4. Remove the front tires and wheels from the vehicle. See **Group 40** for instructions.
5. Support the front axle with jacks.
6. Remove the sway bar end nut, the capscrew, and the bracket that attaches the sway bar ends to the rod attached to the frame rail. See **Fig. 1**.



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1. Frame Rail
2. Sway Bar
3. Sway Bar Mounting Rods

Fig. 1, Swaybar Assembly

7. Remove the two fasteners (per side) attaching the sway bar bracket to the axle.
8. Remove the sway bar and bushing and slide clear of the vehicle.
9. Inspect, remove and replace the sway bar and bracket, if necessary.
10. To install the sway bar, install the sway bar links and bracket, if removed. Tighten capscrews and nuts 25 lbf·ft (34 N·m).
11. Position the sway bar assembly on the axle seat. Position the shim in place and raise the axle into position.
12. Install the sway bar link capscrew and nut, and tighten 100 lbf·ft (136 N·m).
13. Install the two fasteners (per side) that attach the sway bar to the axle. Install the nuts and tighten 100 lbf·ft (136 N·m).
14. Install the front tires and wheels on the vehicle. See **Group 40** for instructions. Install the hub caps, if removed.
15. Remove the support jacks and lower the vehicle.
16. Remove the chocks.

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake, and chock the front and rear tires.
2. Remove the prevailing torque nut and steel washer at the upper end of the shock absorber.
3. Remove the prevailing torque nut, capscrew, washers, and spacers at the lower mounting bracket of the shock absorber at the end of the leaf spring.
4. Remove the shock absorber.
5. Inspect, remove, and replace any other shock mounting components that require replacement.
6. Install any shock mounting components that were removed.
7. Position the shock absorber on the mounting brackets.
8. Install the shock absorber on the upper mounting bracket. Install the outside steel washer and prevailing torque nut. Tighten 100 lbf·ft (136 N·m).
9. Install the capscrew through the steel washers, spacer, shock absorber at the lower mounting bracket. Install the prevailing torque nut. Tighten 100 lbf·ft (136 N·m).

Leaf Spring Bushing Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires. Raise the vehicle frame until the weight is off the front suspension with the wheels still touching the floor. Place jack stands under the frame rails.
2. If equipped, remove the front hub caps from the vehicle.
3. Remove the necessary wheel and tire for access to the leaf spring. See **Group 40** for instructions.
4. Remove the leaf spring/air spring assembly from the vehicle. See **Subject 100** in this manual for instructions.
5. Using a press, remove the worn or damaged bushing.
6. 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.

7. Install the leaf spring/air spring assembly. See **Subject 100** in this manual for instructions.
8. Install the wheel and tire. See **Group 40** for instructions. Install the hub caps, if necessary.
9. Remove the jack stands, lower the vehicle and remove the chocks from the tires.

Troubleshooting Tables

Problem—Vehicle Leans to One Side

Problem—Vehicle Leans to One Side	
Possible Cause	**Remedy**
A leaf spring or an air spring is broken.	Replace the leaf spring or the air spring.
The leaf spring/air spring assembly is weak or fatigued.	Replace the leaf spring/air spring assembly.
Unmatched spring-design/load-capacity suspension assemblies are installed.	Install the correct suspension 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**
A leaf spring or an air spring is broken.	Replace the leaf spring or the air spring.
The wheels are out of alignment.	Adjust the wheel alignment using the instructions in **Group 33**.
Caster is incorrect.	Install correct caster shims. See **Group 33** for specifications.
Steering gear is not centered.	Adjust steering using the instructions in **Group 46**.
Drive axle is out of alignment.	Align the drive axle using the instructions in **Group 35**.

Problem—Vehicle Bottoms Out

Problem—Vehicle Bottoms Out	
Possible Cause	**Remedy**
Excessive weight on the vehicle is causing an overload.	Reduce the loaded vehicle weight to the maximum suspension capacities.
A leaf spring or an air spring is broken.	Replace the leaf spring or the air spring.
The suspension assembly is weak or fatigued.	Replace the suspension assembly.

Problem—Frequent Spring Breakage

Problem—Frequent Leaf Spring Breakage	
Possible Cause	**Remedy**
The vehicle is overloaded or operated under severe conditions.	Reduce the loaded vehicle weight to the maximum suspension capacities. Caution the driver on improper vehicle handling.
There is insufficient torque on the suspension fasteners.	Torque the suspension fasteners to the value listed in the torque table in **Specifications, 400**.
Worn or damaged leaf spring bushings are allowing spring end-play.	Replace the leaf spring bolt and bushing.
A loose leaf spring bolt is allowing spring end-play.	Replace the leaf spring bolt and bushing.

Front Suspension Fastener Torque Values	
Description	**Torque lbf·ft (N·m)**
Rear U-Bolts	150 (203)
Front U-Bolts	150 (203)
Spring Center Bolt	30 (41)
Front Shock Absorbers	100 (136)
Rear Drag Link to Front Axle Control Arm	80 (108)
Drag Link Castle Nut	80 (108)
Front Sway Bar Mounting Rods to Sway Bar Brackets	25 (34)
Front Sway Bar to Axle Seats	100 (136)
Front Sway Bushing Fasteners	100 (136)
Front Spring Eye Bolts	140 (190)
Air Spring Height Control Valve Rods to Bracket	65 (88)
Track Bar to Brackets	260 (352)
Axle Mounting Plate to Beam	280 (380)
Front Air Springs to Frame Rail	220 (298)
Front Air Beams to Front Hangers	480 (651)

Table 1, Front Suspension Fastener Torque Values

General Description

The Neway Air Ride suspension is a single-axle suspension that uses air springs. See **Fig. 1**. The top of each air spring is bolted to a frame-rail bracket, and the bottom of each spring is attached to a suspension crossmember. The suspension crossmember is attached to the rear ends of two equalizing beams which carry the axle. The forward ends of the equalizing beams are journaled to brackets bolted on the frame rail.

The suspension allows for vertical travel. The maximum loading capacity is 22,500 pounds (10 000 kg).

The Neway suspension maintains a stable, level ride by adjusting the air spring height according to vehicle load and road conditions. A height control valve mounted inside the frame rail is linked to the suspension crossmembers and monitors ride height in relation to the crossmember. If the load is riding too high, the suspension crossmember pulls the valve's control lever down, and the valve lowers the load by venting air from the springs. See **Fig. 2**. If the load rides too low, the suspension crossmember pushes the valve's control lever up, and the valve raises the load by delivering air to the springs. The air springs and the shocks mounted between the axle and the frame rails absorb road shock.

The design of the height control valve allows a several second delay between delivering air to and venting air from the air springs. This prevents the valve from reacting to abrupt axle movements caused by the condition of the road surface.

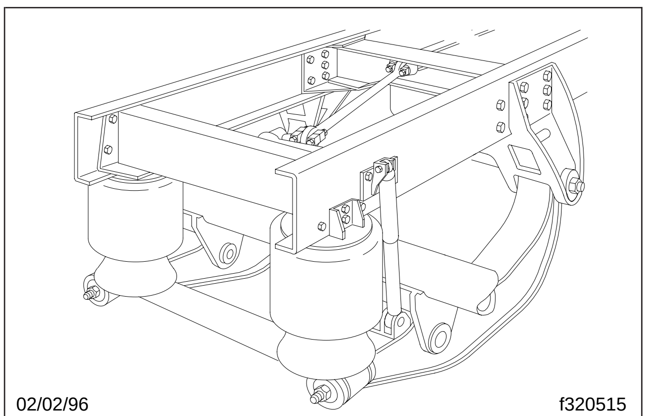
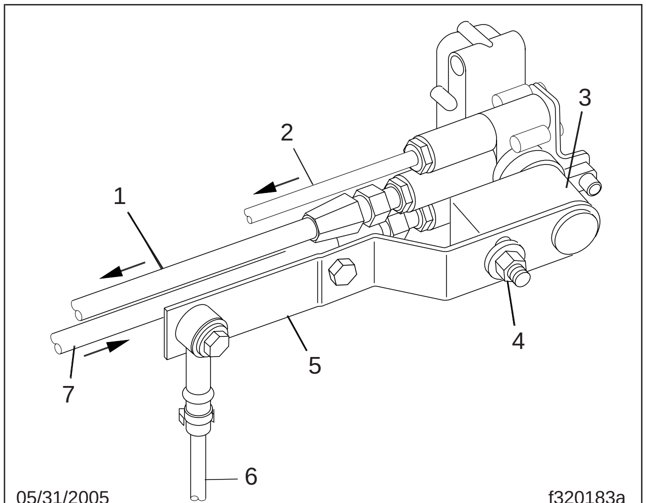


Fig. 1, Neway Suspension



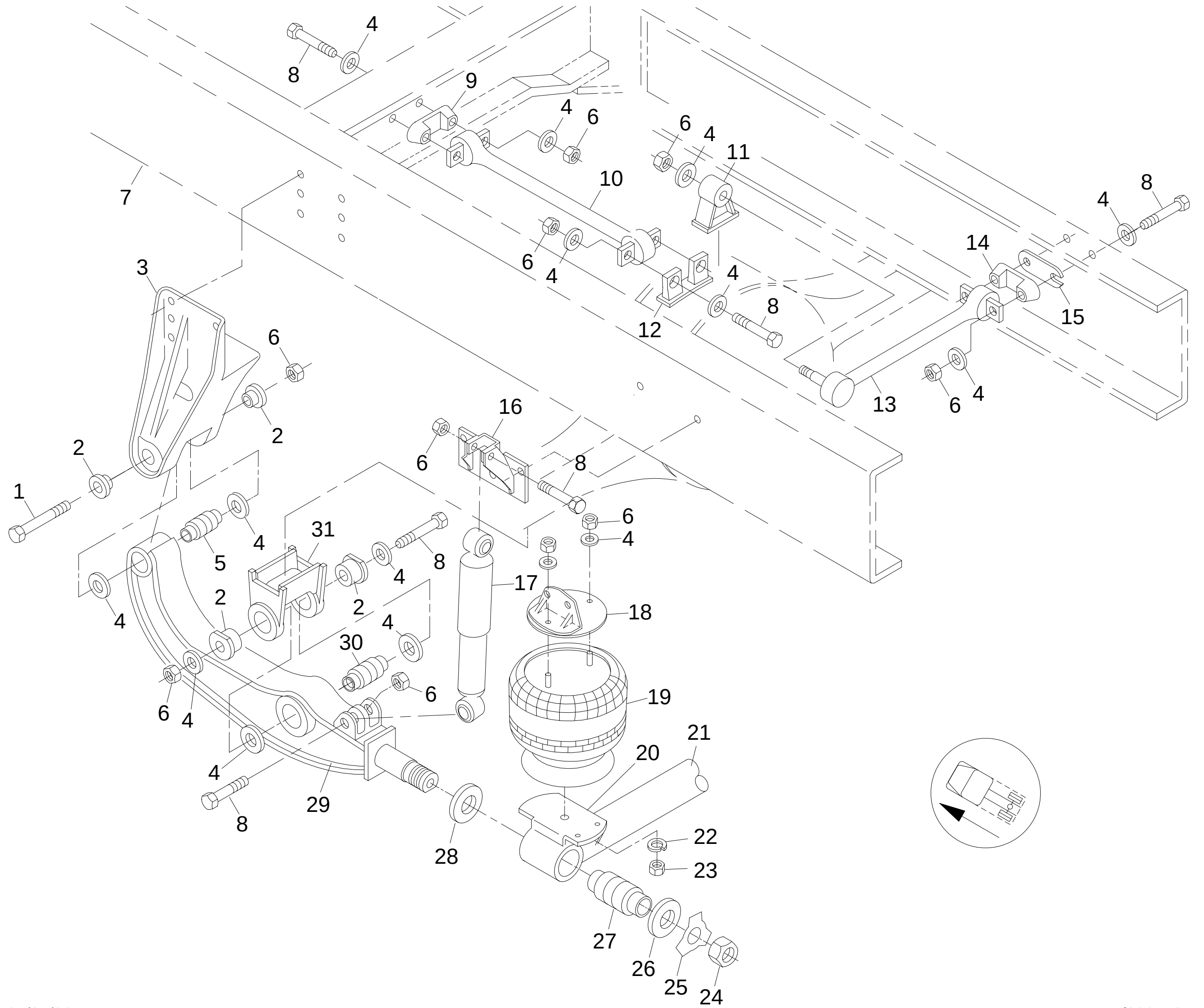
1. Airflow to Spring
2. Exhaust to Atmosphere
3. Nylon Block
4. Adjustment Locknut
5. Control Lever
6. Linkage
7. Airflow from Air Reservoir

Fig. 2, Height Control Valve

A torque rod connects each axle housing to a frame crossmember to prevent torque-induced rotation of the axle. See **Fig. 3**. A similar control rod connects each axle housing to a frame rail to prevent the axle from moving laterally. See **Fig. 3**.

If the air springs lose pressure, a solid rubber bumper inside the spring will support the vehicle until it can be repaired. Do not drive the vehicle over 30 mph (50 km/h) with the air springs deflated, and drive it only as far as the nearest service facility. To deflate the air springs, disconnect the control lever arm from the linkage rod, and press the valve's control lever down to simulate overinflated air springs. The valve will vent the air from the springs.

General Information



1. Bolt, 3/4-16 x 7 inch (Grade 5)
2. Adaptor Bushing
3. Frame Bracket
4. Washer
5. Equalizing Beam Front Bushing
6. Locknut
7. Frame Rail
8. Bolt
9. Torque Rod Crossmember Bracket
10. Torque Rod
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Control Rod
14. Control Rod Frame Bracket
15. Axle Alignment Shim(s)
16. Shock Absorber Frame Bracket
17. Shock Absorber
18. Air Spring Upper Mounting Plate
19. Air Spring
20. Air Spring Seat
21. Transverse Beam
22. Lockwasher
23. Air Spring Hexnut
24. Equalizing Beam Hexnut
25. Tab Washer
26. Spacer Washer
27. Transverse Beam Bushing
28. Equalizing Beam Spacer Washer
29. Equalizing Beam
30. Equalizing Beam Bushing
31. Beam Hanger Bracket

Fig. 3, Neway Suspension Components

Adjustment

1. Park the vehicle on a level surface. Run the engine until the air brake system is fully charged. Chock the tires.
2. Remove the bolt that secures the height control valve linkage to the control lever of each valve. See **Fig. 1** and **Fig. 2**. Disconnect the linkages from the control levers.
3. Exhaust all air from the air springs by pushing the control levers down to the vertical position.
4. Connect one of the control levers to its respective linkage, and allow the air spring(s) controlled by the lever to fill until the valve shuts off.
5. Identify the suspension. An identifying plate is usually found on one of the suspension frame brackets or on a suspension beam.

IMPORTANT: Identification of the suspension model is important because the adjustment of the height control valve is different for each suspension model. See **Table 1** for adjustment information.

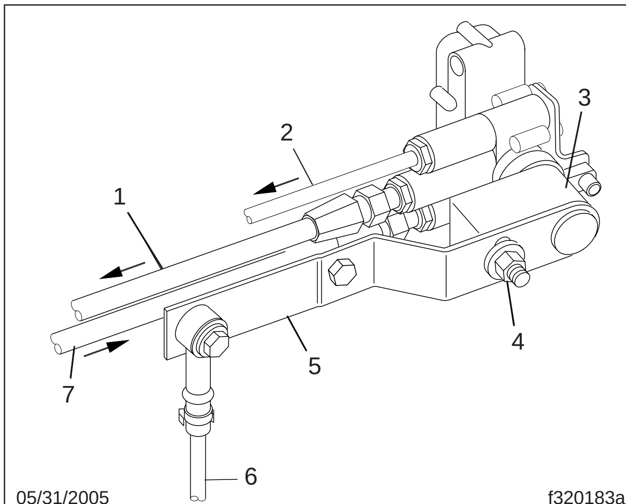
6. Identify the manufacturer of the height control valve; it will be either a Neway height control valve or a Barksdale height control valve.

Height Control Valve Adjustment Measurements		
Suspension	**Vehicle Model**	**Measurement Inches ± 1/4 (mm ± 6)**
AS120 (front)	XC,XB	10 (254)
AD200 (rear)	XC,XB	9-1/2 (241)
ARS112 (front)	VC	13 (330)
ARD200 (rear)	VC	10-3/4 (273)
AS140 (front)	VCL	11 (279)
IFS114 (front)	XC,VCL	17-1/2 (444)
ADTB280 (rear)	VCL	17-1/4 (438)

Table 1, Height Control Valve Adjustment Measurements

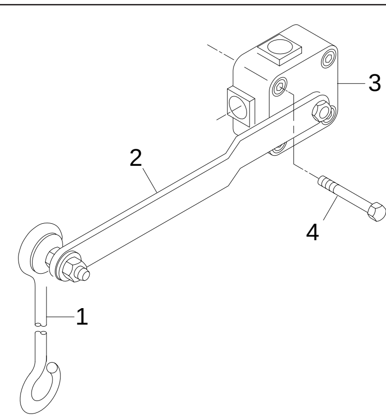
7. On AS120, AS140, ARS112, AD200, and ARD200 suspensions, measure the distance from the underside of the frame rail to the centerline of the lower shock mount bolt nearest to the height control valve. See **Table 1** for model-specific measurement information.

   On IFS114 and ADTB280 suspensions, measure the distance from the lower shock mount bolt centerline to the upper shock mount bolt centerline nearest to the height control valve. See **Table 1** for model-specific measurement information.



1. Airflow to Spring
2. Exhaust to Atmosphere
3. Nylon Block
4. Adjustment Locknut
5. Control Lever
6. Linkage
7. Airflow from Air Reservoir

Fig. 1, Neway Height Control Valve



1. Linkage
2. Control Lever
3. Valve
4. Valve Fastener

Fig. 2, Barksdale Height Control Valve

Height Control Valve Adjustment

8. To adjust the Neway valve, loosen the adjustment locknut on the height control valve lever arm. See **Fig. 1**. Move the control lever arm (slightly relative to the nylon block). Tighten the locknut when the required height measurement is reached.

9. To adjust the Barksdale valve, loosen the locknuts between the height control valve and the height control mounting bracket. See **Fig. 2**. Rotate the valve slightly in the appropriate direction. Tighten the locknuts when the required height measurement is reached.

NOTE: If more adjustment is necessary, loosen the locknuts between the frame rails and the height control mounting bracket.

10. Disconnect the control lever from the linkage, and press it down to deflate the air springs about halfway. Reconnect the linkage to inflate the air springs, then check the height dimension. Repeat the step above and this step until the required measurement is reached.

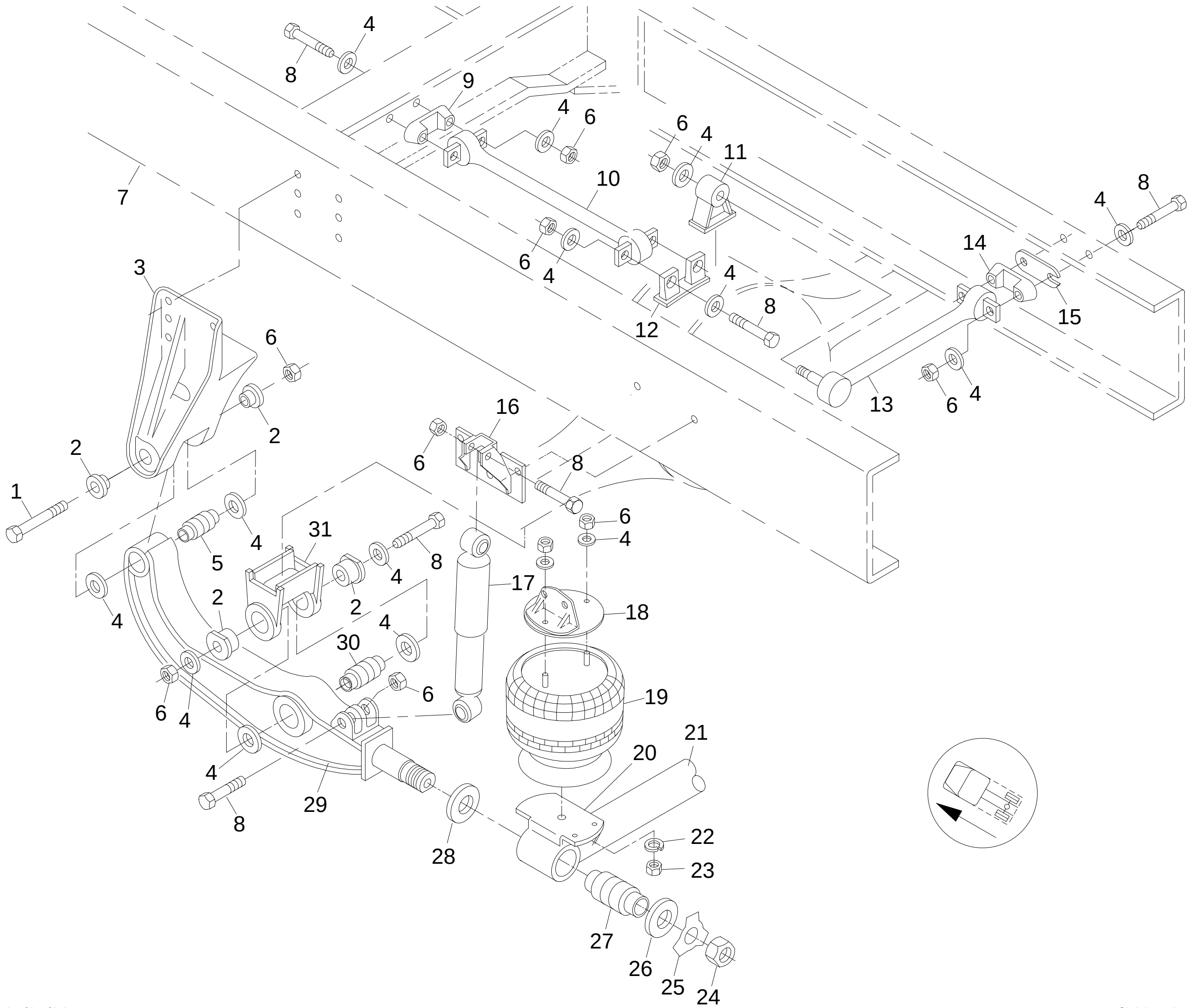
11. Repeat the previous four steps on the other height control valve(s).

12. Connect all linkage assemblies to the control levers. All height dimensions should now be equal. If they aren't, check for loose mounting bolt nuts on the height control valves. Tighten any loose nuts or capscrews. Repeat the adjustment procedures until the required measurement is reached.

Replacement

1. Chock the front tires to prevent vehicle movement. Open the stopcocks on the air tanks to drain the air system.
2. Raise the rear of the vehicle to remove all weight from the rear axles, and place safety stands under the frame rails to secure the vehicle in its raised position. When raised, the height control valves will vent all air from the air springs.
3. Taking care to prevent foreign substances from entering the line or fitting, disconnect the air supply line from the air spring.
4. Remove the locknut, hexnut, and washers that secure the air spring to the air spring upper mounting plate. See **Fig. 1**.
5. Remove the capscrews and lockwashers that connect the air spring to the air spring lower mounting plate on the transverse beam. Remove the air spring.
6. Position the new air spring on the air spring lower mounting plate, then install the capscrews and lockwashers to secure the air spring to the lower mounting plate. Tighten the capscrews to the torque under **Specifications, 400.**
7. Install the locknut, hexnut, and washers previously removed, to connect the air spring to the air spring upper mounting plate. Tighten the nuts to the torque under **Specifications, 400**.
8. Connect the air supply line to the air spring.
9. Remove the safety stands from under the vehicle, then lower the vehicle.
10. There must be a specific distance between the bottom of the frame rail and the centerline of the axle. Adjust the height control valve adjustment; for instructions, refer to **Subject 100**.

Air Spring Replacement



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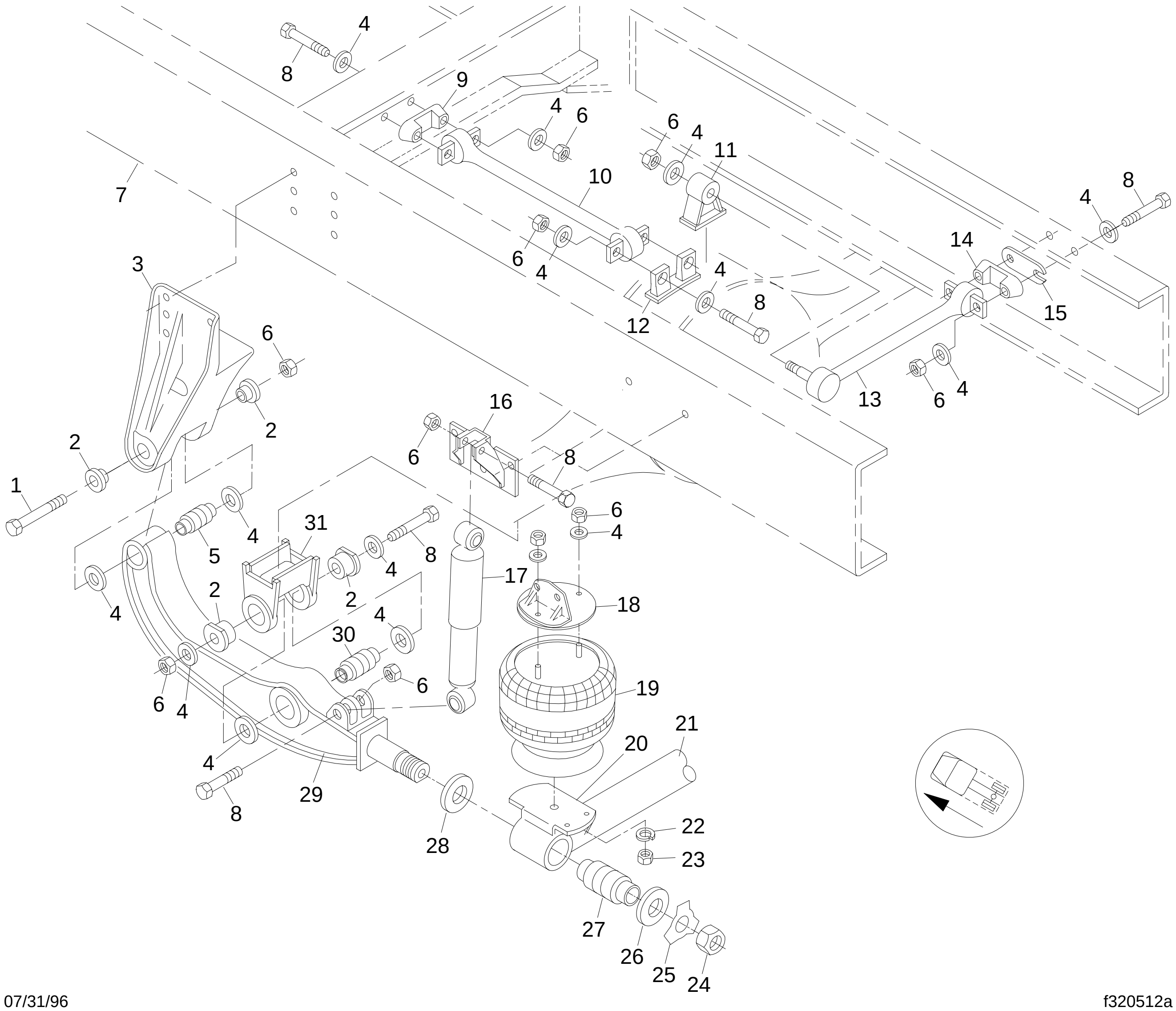
1. Bolt, 3/4-16 x 7 inch (Grade 5)
2. Adaptor Bushing
3. Frame Bracket
4. Washer
5. Equalizing Beam Front Bushing
6. Locknut
7. Frame Rail
8. Bolt
9. Torque Rod Crossmember Bracket
10. Torque Rod
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Control Rod
14. Control Rod Frame Bracket
15. Axle Alignment Shim(s)
16. Shock Absorber Frame Bracket
17. Shock Absorber
18. Air Spring Upper Mounting Plate
19. Air Spring
20. Air Spring Seat
21. Transverse Beam
22. Lockwasher
23. Air Spring Hexnut
24. Equalizing Beam Hexnut
25. Tab Washer
26. Spacer Washer
27. Transverse Beam Bushing
28. Equalizing Beam Spacer Washer
29. Equalizing Beam
30. Equalizing Beam Bushing
31. Beam Hanger Bracket

Fig. 1, Neway Suspension Components

Replacement

1. Remove the locknuts from the shock absorber upper and lower mounting brackets. See **Fig. 1**.
2. If the shock absorber is fully extended, chock the vehicle wheels and jack up the axle to relieve tension from the shock. Remove the shock absorber. If the inner metal sleeve is rusted to the mounting pin, use a small, sharp chisel to force the sleeve from the pin.
3. Install the new shock absorber on the mounting pins and secure it with the locknuts and washers previously removed. Tighten the locknuts to the torque under **Specifications, 400**.

Shock Absorber Replacement



1. Bolt, 3/4-16 x 7 inch (Grade 5)
2. Adaptor Bushing
3. Frame Bracket
4. Washer
5. Equalizing Beam Front Bushing
6. Locknut
7. Frame Rail
8. Bolt
9. Torque Rod Crossmember Bracket
10. Torque Rod
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Control Rod
14. Control Rod Frame Bracket
15. Axle Alignment Shim(s)
16. Shock Absorber Frame Bracket
17. Shock Absorber
18. Air Spring Upper Mounting Plate
19. Air Spring
20. Air Spring Seat
21. Transverse Beam
22. Lockwasher
23. Air Spring Hexnut
24. Equalizing Beam Hexnut
25. Tab Washer
26. Spacer Washer
27. Transverse Beam Bushing
28. Equalizing Beam Spacer Washer
29. Equalizing Beam
30. Equalizing Beam Bushing
31. Beam Hanger Bracket

Fig. 1, Neway Suspension Components

Equalizing Beam Removal and Installation

Removal

1. Chock the front tires.
2. Raise the rear of the vehicle to remove all weight from the rear suspension, and place safety stands to secure the vehicle in its raised position.
3. Remove the rear wheels and tires for access to the suspension. Block the axle securely to prevent it from dropping away from the vehicle as the equalizing beam is removed.
4. With the weight removed from the suspension, the air springs should be fully deflated. If they aren't, disconnect the height control valve linkage from the height control valve control lever. Push the lever down to the vertical position to deflate the air springs.
5. Remove the capscrews and lockwashers that secure the air springs to the air spring lower mounting plates on both ends of the transverse beam. See **Fig. 1**.
6. Remove the cotter pins, locknuts, flatwashers, and retainer washers from the studs in the ends of the equalizing beams. Tap the transverse beam back from the ends of the equalizing beams.

NOTE: In some cases, the transverse beam bushings will stick, making it difficult to remove the transverse beam from the equalizing beams. Use a Porta-Power, or equivalent tool, between the axle housing and the transverse beam at a point as near to the end of the transverse beam as possible to remove the beam.

7. Remove the locknut and washer from the outboard end of the rod bolt. Support the equalizing beam on a floor jack, then extract the equalizing beam center bushing bolt from the beam hanger bracket.
8. Use a drift to tap the adaptor bushings from the beam hanger bracket. Lower the equalizing beam to the floor.
9. Remove the locknut from the inboard end of the bolt. Note the positions of the spacer washers at either side of the equalizing beam so they can be reassembled in their original positions. Use a drift to drive the rod bolt out of the frame bracket. Remove the equalizing beam from the vehicle.

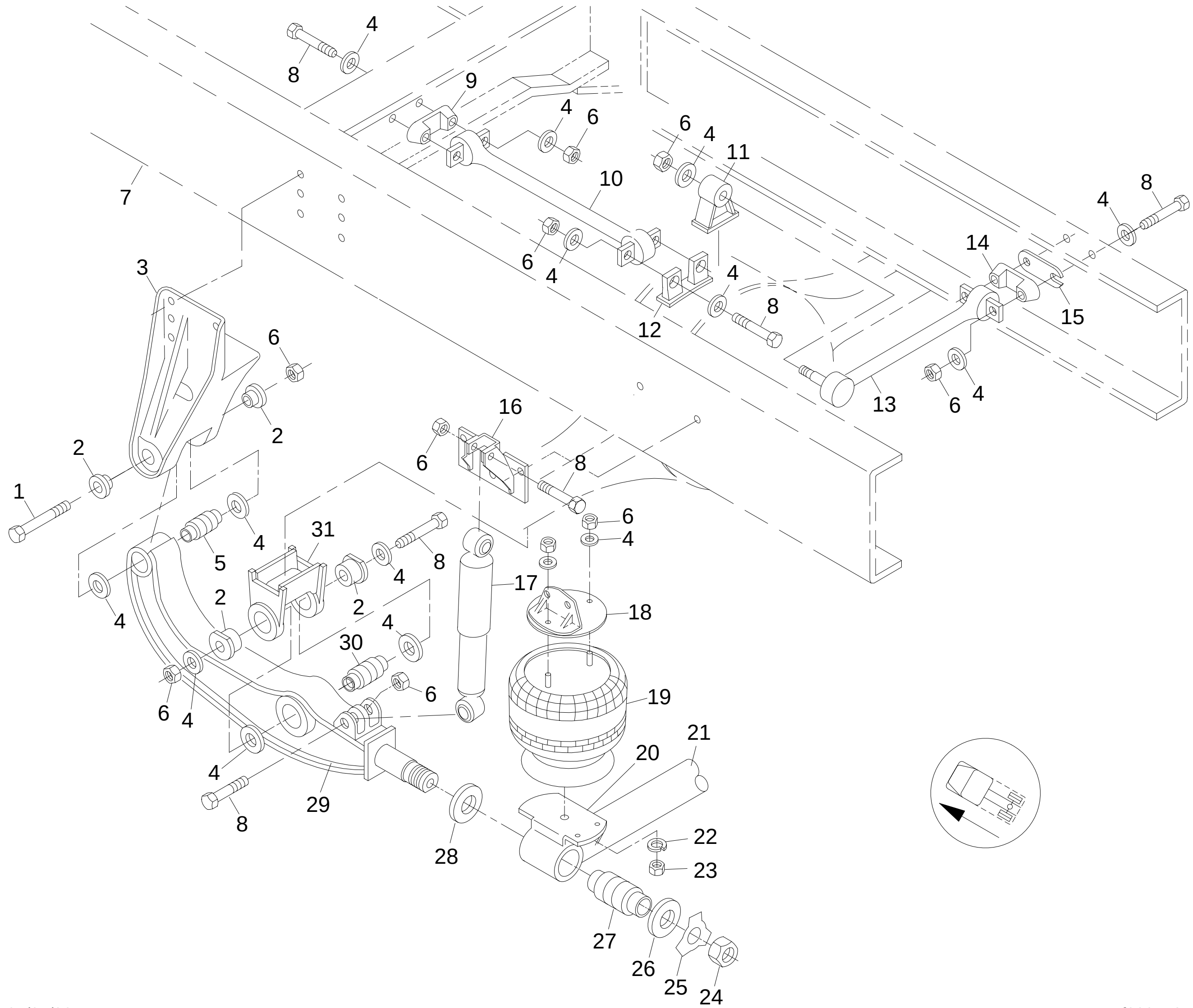
Installation

1. Make sure the adaptor bushings are installed in the frame bracket.
2. Position the equalizing beam with its front bushing centered in the frame bracket. Push the rod bolt into the frame bracket while inserting the spacer washers into their original positions between the equalizing beam and the frame bracket.

NOTE: Refer to **Subject 190** for placement of the spacer washers if their positions were not recorded during removal of the equalizer beam.

3. Lubricate the threads of the rod bolt with SAE-20 oil, then install the locknut. Tighten the locknut to the torque under **Specifications, 400.**
4. Raise the equalizing beam so the center bushing is centered in the beam hanger bracket. Insert the beam hanger adaptor bushings through the beam hanger bracket and into the equalizing beam center bushing.
5. With a flatwasher under the head,insert the rod bolt through the beam hanger adaptor bushings with the threaded end on the outboard side of the suspension.
6. Lubricate the center bushing bolt threads with SAE-20 oil, then install the flatwasher and locknut on the bolt. Tighten the locknut to the torque under **Specifications, 400**.
7. Lubricate the transverse beam bushings with rubber lubricant, soap and water solution, or a waterless hand cleaner. Install the inner halves of the bushings with their thicker ends toward the front of the vehicle.
8. Install the transverse beam on the equalizing beams, with the air spring lower mounting plates tilted toward the rear of the vehicle. Install the outer halves of the transverse beam bushings on the equalizer beam journals.
9. Apply SAE-20 oil to the threads on the studs at the rear of the equalizing beams. Install the retainer washers, flatwashers and locknuts on the studs. Tighten the locknuts to the low end of the torque ranges under **Specifications, 400.** Install the cotter pins and lock them in place. Tighten the locknuts further if it's necessary in order to install the cotter pins.

Equalizing Beam Removal and Installation



1. Bolt, 3/4-16 x 7 inch (Grade 5)
2. Adaptor Bushing
3. Frame Bracket
4. Washer
5. Equalizing Beam Front Bushing
6. Locknut
7. Frame Rail
8. Bolt
9. Torque Rod Crossmember Bracket
10. Torque Rod
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Control Rod
14. Control Rod Frame Bracket
15. Axle Alignment Shim(s)
16. Shock Absorber Frame Bracket
17. Shock Absorber
18. Air Spring Upper Mounting Plate
19. Air Spring
20. Air Spring Seat
21. Transverse Beam
22. Lockwasher
23. Air Spring Hexnut
24. Equalizing Beam Hexnut
25. Tab Washer
26. Spacer Washer
27. Transverse Beam Bushing
28. Equalizing Beam Spacer Washer
29. Equalizing Beam
30. Equalizing Beam Bushing
31. Beam Hanger Bracket

Fig. 1, Neway Suspension Components

10. Apply SAE-20 oil to the threads of the capscrews that secure the air springs to the air spring lower mounting plates. Position the air springs on the plates and install the capscrews and lockwashers. Tighten the capscrews to the torque under **Specifications, 400**.

Replacement

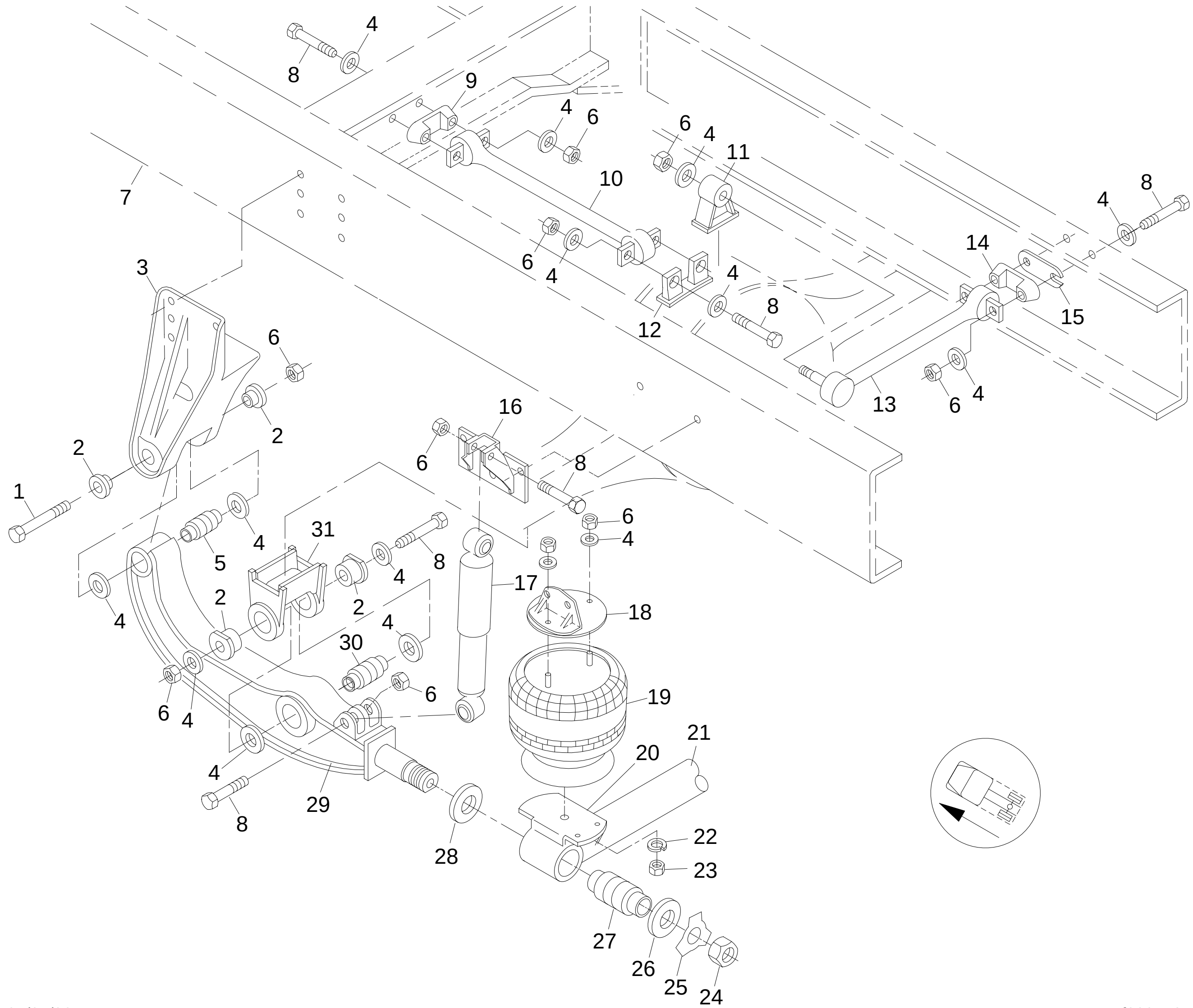
1. Remove the equalizing beam. Refer to **Subject 130**.

WARNING

Do not use a torch to cut the bushing sleeve out of the equalizing beam. To do so could weaken the casting, possibly resulting in loss of vehicle control and personal injury.

2. Using a hydraulic press, apply 2,000 to 3,000 pounds (907 to 1361 kg) pressure to remove the equalizing beam front and center bushings. See **Fig. 1**.
3. Using a wire brush and solvent, clean out the equalizing beam bushing receptacles. Inspect the entire beam for cracks or bends. Replace any damaged equalizing beam with a new one.
4. Lubricate the replacement bushings and the bushing receptacles with a non-mineral lubricant. If standard rubber lubricant is not available, use a soap and water solution or a waterless hand cleaner.
5. Press the replacement bushings into the bushing receptacles with a hydraulic press. Press the bushings slightly past center, then turn the equalizing beam over and press the bushings back to a centered position.
6. Install the equalizing beam. Refer to **Subject 130**.

Equalizing Beam Bushing Replacement



1. Bolt, 3/4-16 x 7 inch (Grade 5)
2. Adaptor Bushing
3. Frame Bracket
4. Washer
5. Equalizing Beam Front Bushing
6. Locknut
7. Frame Rail
8. Bolt
9. Torque Rod Crossmember Bracket
10. Torque Rod
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Control Rod
14. Control Rod Frame Bracket
15. Axle Alignment Shim(s)
16. Shock Absorber Frame Bracket
17. Shock Absorber
18. Air Spring Upper Mounting Plate
19. Air Spring
20. Air Spring Seat
21. Transverse Beam
22. Lockwasher
23. Air Spring Hexnut
24. Equalizing Beam Hexnut
25. Tab Washer
26. Spacer Washer
27. Transverse Beam Bushing
28. Equalizing Beam Spacer Washer
29. Equalizing Beam
30. Equalizing Beam Bushing
31. Beam Hanger Bracket

Fig. 1, Neway Suspension Components

Control Rod Removal, Inspection, and Installation

Removal

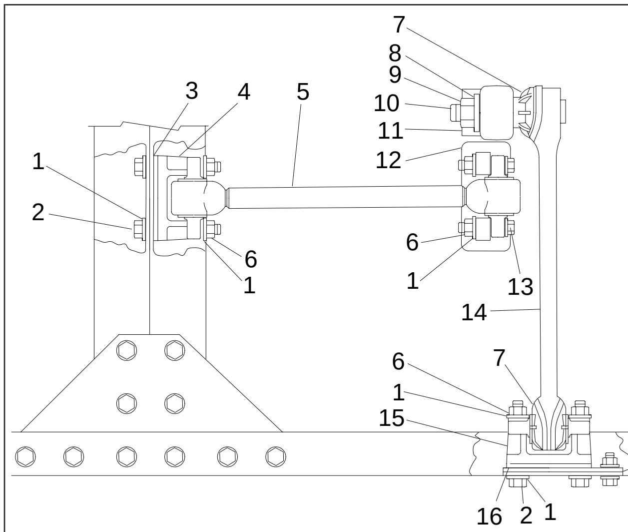
1. Apply the parking brakes.
2. Remove the locknuts and flatwashers from the bolts that secure the control rod frame bracket to the frame rail. See **Fig. 1**. To ease reassembly, note the order of the axle alignment shims between the control rod frame bracket and the backing plate.
3. Remove the control rod frame bracket bolts. Swing the control rod clear, and remove the axle alignment shims and the bracket.
4. Remove the locknut and flatwasher from the ball stud on the inboard end of the control rod. Rap the ball stud eye on the control rod axle bracket with a hammer to loosen the ball stud. If this fails to break it loose, use a tie-rod separator tool to remove the ball stud from the control rod axle bracket. Remove the control rod.
5. Remove the seals from both ends of the control rod. Clean the seals and rod to remove all dirt and grease.

Inspection

Inspect the seals for dryness, cracks, or other signs of deterioration and wear. Replace damaged seals with new ones. Visually inspect the control rod for cracks or bends. Work the ball joint and control rod pin to check for looseness in the bushings. If the control rod is bent, cracked, or otherwise damaged, or if there is any slack in either of the bushings, replace the control rod with a new one.

Installation

1. Lubricate all control rod and fastener threads with SAE-20 oil, and install the seals removed from the rod ends. See **Fig. 1**.
2. Insert the control rod ball stud through the control rod axle bracket, then install the flatwasher and locknut on the stud. Tighten the locknut to the torque under **Specifications, 400**, then rap the control rod axle mount with a hammer. Tighten the locknut again to the torque under **Specifications, 400**.



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1. Flatwasher, 5/8-inch
2. Bolt, 5/8–11 x 5-1/2 Inch
3. Axle Plane Shim(s)
4. Torque Rod Crossmember Bracket
5. Torque Rod
6. Locknut, 5/8–18
7. Seal
8. Flatwasher, 1-1/4 Inch
9. Locknut, 1-1/4–12
10. Ball Stud
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Bolt, 5/8–11 x 4 Inch
14. Control Rod
15. Control Rod Frame Bracket
16. Axle Alignment Shim(s)

Fig. 1, Control Rod Mounting

3. Position the control rod frame bracket and the axle alignment shims against the backing plate on the inside of the frame rail. Move the control rod into position on the control rod frame bracket.
4. Install flatwashers on the control rod frame bracket bolts, then install the bolts through the frame rail, the shims, the control rod frame bracket, and the control rod. Install the flatwashers and locknuts on the bolts, and tighten the locknuts to the torque under **Specifications, 400**.
5. Check the alignment of the axle. Refer to **Subject 180** for instructions.

Torque Rod Removal, Inspection, and Installation

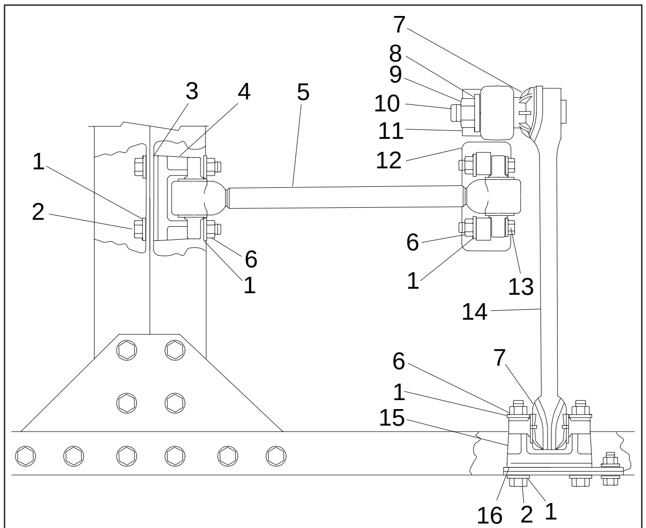
Removal

1. Apply the parking brakes.

WARNING

When the torque rods are disconnected from the axle brackets, the axles become free to pivot on the equalizer beam end bushings. Keep clear of the beam hangers and beam ends to avoid possible injury.

2. Remove the locknuts and the flatwashers from the bolts that secure the torque rod crossmember bracket to the vehicle frame crossmember. For ease of installation, note the order of the axle plane shims between the torque rod crossmember bracket and the frame crossmember. See Fig. 1.



1. Flatwasher, 5/8-inch
2. Bolt, 5/8–11 x 5-1/2 Inch
3. Axle Plane Shim(s)
4. Torque Rod Crossmember Bracket
5. Torque Rod
6. Locknut, 5/8–18
7. Seal
8. Flatwasher, 1-1/4 Inch
9. Locknut, 1-1/4–12
10. Ball Stud
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Bolt, 5/8–11 x 4 Inch
14. Control Rod
15. Control Rod Frame Bracket
16. Axle Alignment Shim(s)

Fig. 1, Torque Rod Mounting

3. Remove the torque rod crossmember bracket bolts. Swing the torque rod clear of the torque rod crossmember bracket, and remove the axle plane shims together with the torque rod crossmember bracket.
4. Remove the locknuts and flatwashers from the bolts that secure the torque rod to the torque rod axle bracket. Remove the bolts. Remove the torque rod from the vehicle.

Inspection

Inspect the torque rod for bends or cracks. Work the torque rod pins to check for looseness in the polyurethane bushings. If the torque rod is bent, cracked, or otherwise damaged, replace it with a new one. If either of the polyurethane bushings is loose, replace the bushing with a new one. For instructions, refer to **Subject 170**.

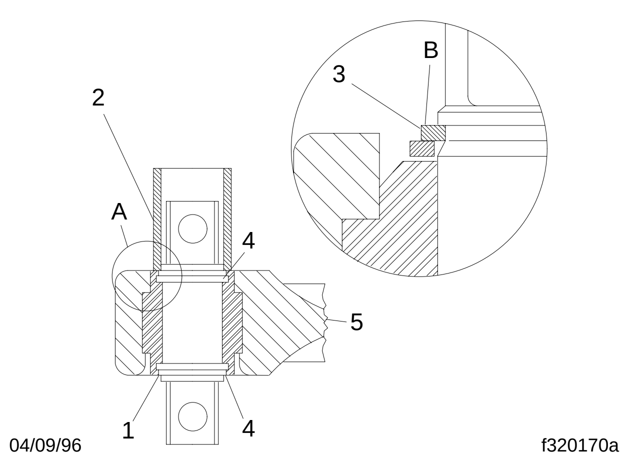
Installation

1. Lubricate all torque rod and fastener threads with SAE-20 oil.
2. Position the torque rod against the torque rod axle bracket. Slip a flatwasher over each of the two bolts, then insert the bolts through the torque rod axle bracket and the torque rod. See **Fig. 1**.
3. Install the flatwashers and locknuts on the torque rod axle bracket bolts. Tighten the locknuts to the torque under **Specifications, 400**.
4. Position the torque rod crossmember bracket and the axle plane shims against the frame crossmember, and move the torque rod into place on the torque rod crossmember bracket.
5. Install flatwashers on the bolts, and install the bolts through the frame crossmember, the shims, the torque rod crossmember bracket, and the torque rod. Install flatwashers and locknuts on the bolts, and tighten the locknuts to the torque under **Specifications, 400**.

Replacement

NOTE: In order to replace the torque rod polyurethane bushings, you need special installation tool kit P-097-009. This tool kit can be purchased from Freightliner, or it can be machined, using the dimensions given in **Specifications, 400.**

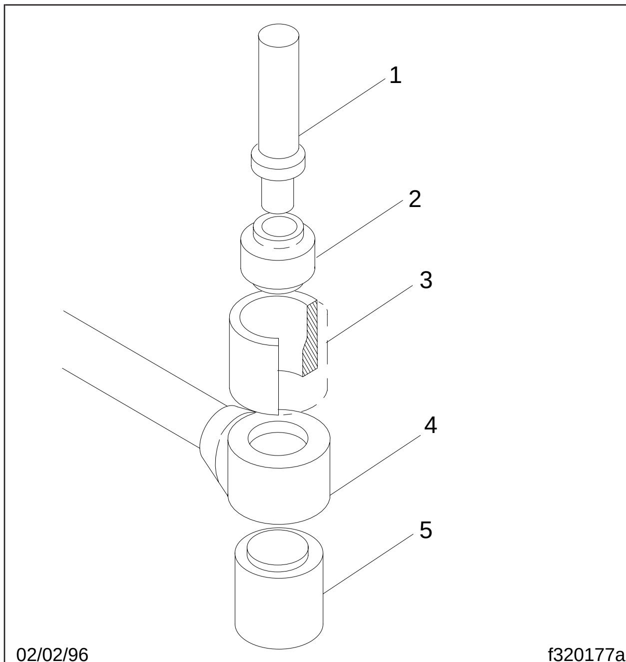
1. Remove the snap ring and washer from each side of the bushing to be removed. See **Fig. 1**. Note that the torque rod eye has a smaller shoulder on one side than on the other, and the larger shoulder has a rounded edge around the inside of the eye. The polyurethane bushing must be pressed in and out through the larger side.



A. Detail
B. Install washer and snap ring with sharp edges to outside.
1. Snap Ring
2. Pressing Sleeve
3. Snap Ring
4. Washer
5. Torque Rod

Fig. 1, Bushing Snap Ring Installation

2. Using the plunger from the special tool kit on a hydraulic press, press the old bushing out of the torque rod eye. Clean all dirt, grease, or foreign matter from the torque rod.
3. Coat the replacement bushing with a non-mineral lubricant, such as rubber lubricant or waterless hand cleaner. Position the bushing in the larger end of the insertion sleeve from the tool kit, then fit the beveled (smaller) end of the sleeve into the larger side of the torque rod eye.
4. Center the torque rod eye on the tool base, and insert the plunger tool into the polyurethane bushing. See **Fig. 2**. Press the bushing into the torque rod eye.



1. Plunger
2. Polyurethane Bushing
3. Insertion Sleeve
4. Torque Rod
5. Base

Fig. 2, Torque Rod Bushing Installation

5. Install the snap ring and flatwasher on one end of the torque rod pin, with the sharp edges of the washer and the snap ring facing the outward end of the pin. See **Fig. 1**.
6. Press the torque rod pin into the torque rod bushing from the same side as the bushing was pressed into the torque rod eye. Make sure the snap ring seats. Do not lubricate the torque rod pin.
7. Turn the torque rod over and install a flatwasher, with the sharp edge facing away from the bushing; then install the other snap ring onto the outer shoulder of the pin, with the sharp edge facing outward.

Torque Rod Bushing Replacement

8. Place a pressing sleeve over the end of the torque rod pin, then seat the snap ring. See **Fig. 1**.
9. After assembly, press the torque rod pin slightly to center it in the torque rod eye.

   There should be no slack on either side of the polyurethane bushing, and the bushing should be compressed by about half the thickness of the snap ring. If necessary, install a second washer under one of the snap rings to compress the bushing.

Lateral Alignment

1. Park the vehicle on a level surface; then position the front tires straight ahead and chock them. Release the parking brakes, and place the transmission in neutral.
2. Raise the rear of the vehicle until the tires clear the ground, then place safety stands under the rear of the vehicle to hold it in this position.
3. Check the wheel bearing adjustment. Refer to **Group 35** for instructions. Adjust or replace the wheel bearings as needed.
4. Measure the lateral runout of the rear wheels. If the runout on any wheel exceeds 0.18 inch (4.6 mm), replace the wheel before proceeding with the axle alignment check.
5. Remove the safety stands and lower the rear of the vehicle. Relieve any internal stresses in the suspension by jacking the axles up and letting them down; or, remove the tire chocks, then move the vehicle back and forth (with the inter-axle differential disengaged).
6. Measure the distance (Dimension A) between the left frame rail and the nearest point on the inside wheel rim. See **Fig. 1**.
7. Measure the distance (Dimension B) between the right frame rail and the nearest point on the inside wheel rim.
8. Compare Dimension A with Dimension B. If they're within 1/8 inch (3.25 mm) of being equal, alignment is not necessary. However, if they're different by more than 1/8 inch (3.25 mm), adjust the lateral alignment.

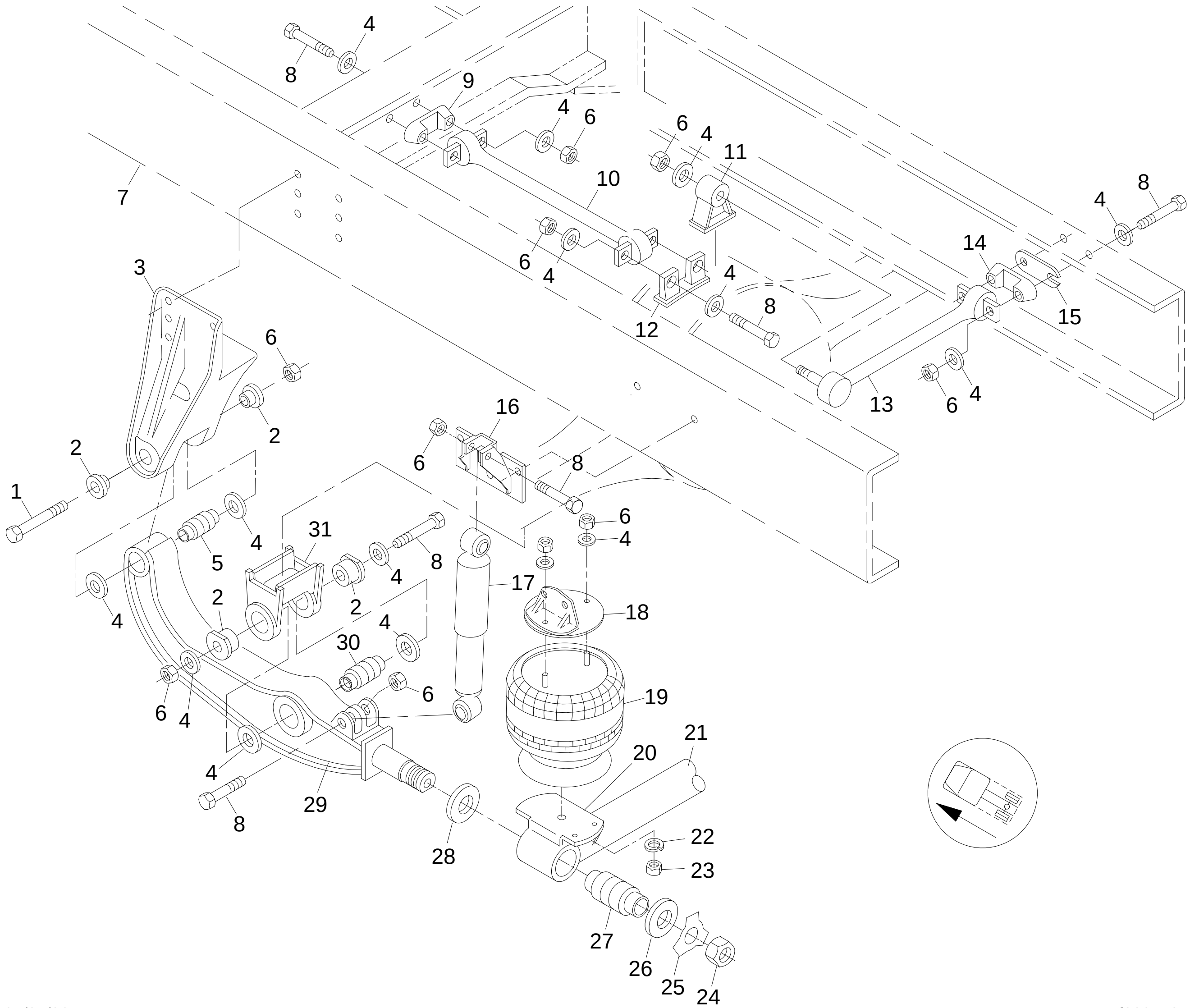
   8.1 Loosen the locknuts on the bolts that secure the lateral rod mount to the frame rail.

   8.2 Add or remove one axle alignment shim for each 1/8 inch (3.25 mm) difference between Dimensions A and B. Adding shims will decrease the measurement on the side of the vehicle to which the lateral rod is attached, and removing shims will increase the measurement.

   8.3 After installing the shims, lubricate the threads on the lateral rod mount bolts with engine oil; tighten the locknuts to the torque under **Specifications 400**.
9. Perform the previous three steps on the other axle.
10. On suspensions equipped with an axle alignment feature (alignment bushings welded to slotted frame brackets), proceed to **Subject 190**.

    On suspensions not equipped with an axle alignment feature, no further checking is required. Apply the parking brakes; then remove the chocks from the tires.

Rear Axle Lateral Alignment



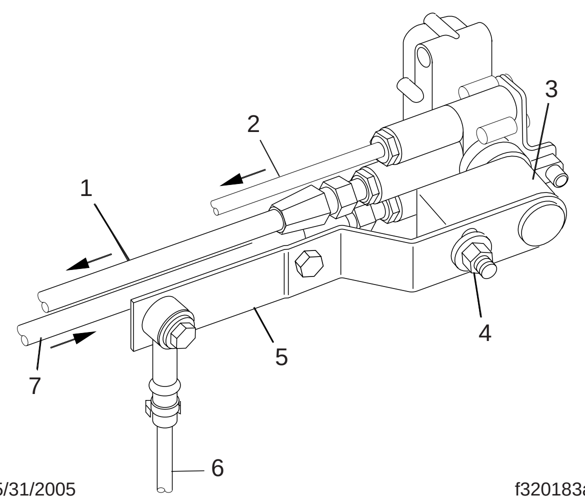
1. Bolt, 3/4-16 x 7 inch (Grade 5)
2. Adaptor Bushing
3. Frame Bracket
4. Washer
5. Equalizing Beam Front Bushing
6. Locknut
7. Frame Rail
8. Bolt
9. Torque Rod Crossmember Bracket
10. Torque Rod
11. Control Rod Axle Bracket
12. Torque Rod Axle Bracket
13. Control Rod
14. Control Rod Frame Bracket
15. Axle Alignment Shim(s)
16. Shock Absorber Frame Bracket
17. Shock Absorber
18. Air Spring Upper Mounting Plate
19. Air Spring
20. Air Spring Seat
21. Transverse Beam
22. Lockwasher
23. Air Spring Hexnut
24. Equalizing Beam Hexnut
25. Tab Washer
26. Spacer Washer
27. Transverse Beam Bushing
28. Equalizing Beam Spacer Washer
29. Equalizing Beam
30. Equalizing Beam Bushing
31. Beam Hanger Bracket

Fig. 1, Neway Suspension Components

Rear Axle Parallel Alignment

Parallel Alignment

1. Check and, if needed, adjust the lateral alignment of the rear axle(s) before checking parallel alignment. See **Subject 180** for instructions.
2. Check the axles for parallel alignment. Refer to the rear axle section in this manual for instructions.
3. Adjust the rear axle, if necessary.
   3.1 Using jack stands, support the vehicle frame at normal ride height. Disconnect both height control valve linkages from their respective control levers. See **Fig. 1**. Then exhaust all air from all air springs by pushing the valve control levers down.
   3.2 Remove the equalizing beam pivot connection locknut and bolt, and both spacer washers. See **Fig. 2**. Lower the equalizing beam from the frame bracket.
   3.3 Cut the welds off of the alignment bushings on both sides of the frame bracket. Remove the alignment bushings; then grind any remaining weld material off of the frame bracket and alignment bushings.



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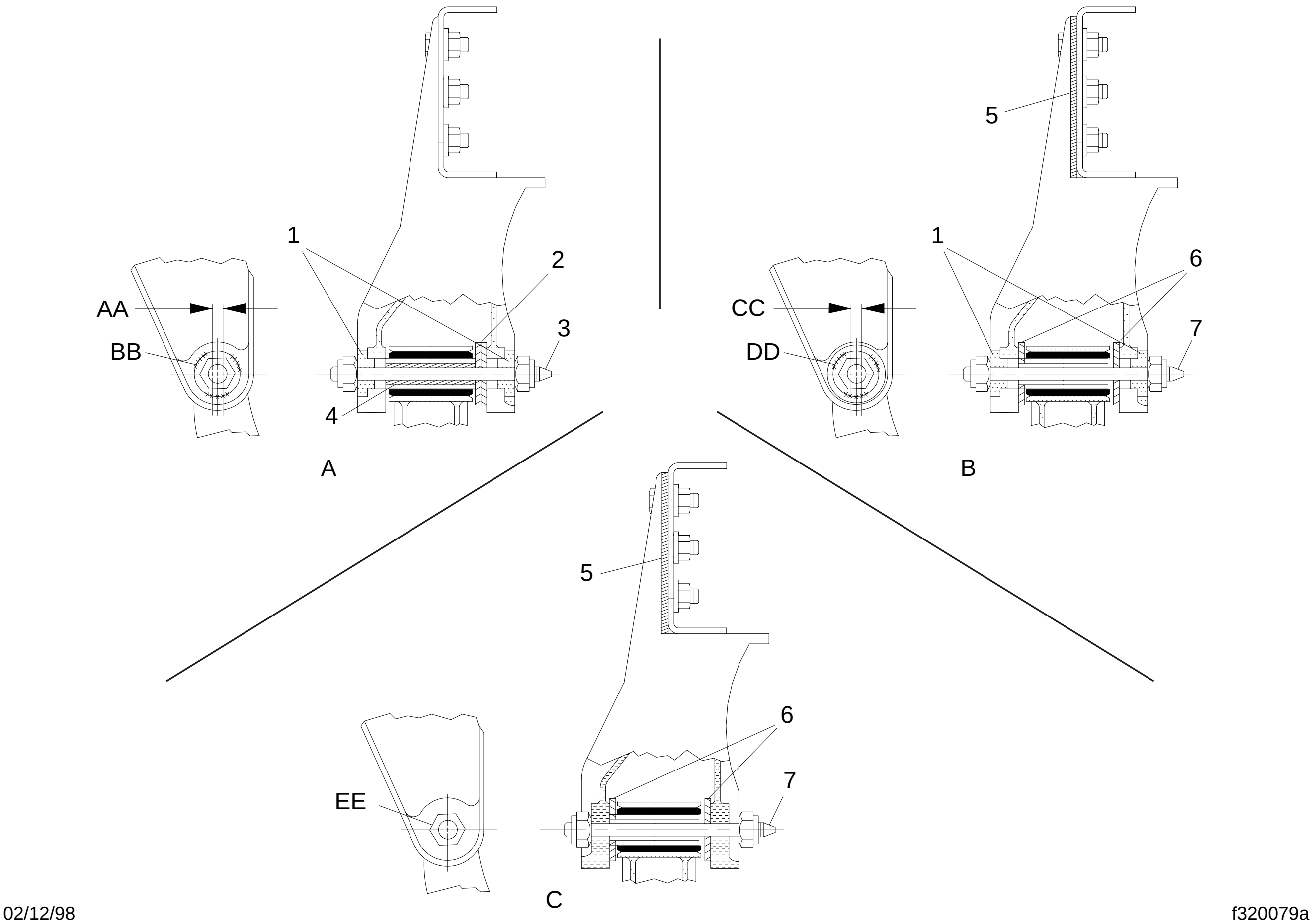
1. Airflow to Spring
2. Exhaust to Atmosphere
3. Nylon Block
4. Adjustment Locknut
5. Control Lever
6. Linkage
7. Airflow from Air Reservoir

Fig. 1, Height Control Valve

   3.4 Position the alignment bushings in the frame bracket; then raise the equalizing beam until the front eye is aligned with the frame bracket. Install the spacer washers and pivot connection bolt and locknut. Position the spacer washers. See **Fig. 2**. Suspension installations which have a 1/4-inch (6-mm) frame-rail spacer between the forward frame-rail bracket and the frame rail will require one spacer washer on each side of the equalizing beam. Installations without a frame-rail spacer require two spacer washers on the inboard side of the equalizing beam.
   3.5 Move the axle forward or backward by rolling the wheels on that side of the vehicle (only that side), until the correct axle alignment is obtained.
   3.6 With the axle aligned and the vehicle frame supported at normal ride height, torque the equalizing beam front bushing locknut to the torque under **Specifications, 400**.
   3.7 Weld both of the alignment bushings to the frame bracket, using AWS spec E7018 welding rod or Linde 3/32 FC 72 wire weld, or an equivalent. Weld (1/4-inch fillet) each bushing with three, 3/4-inch (19-mm) long welds. See **Fig. 2**.
4. Connect the linkages to their respective control levers.
5. Apply the parking brakes; then remove the jack stands from the frame and the chocks from the tires.

Rear Axle Parallel Alignment



A. Without Frame Rail Spacer, With Alignment Bushings
B. With Frame Rail Spacer, With Alignment Bushings
C. With Frame Rail Spacer, Without Alignment Bushings

1. Alignment Bushings
2. Two Spacer Washers on the Inboard Side of the Beam
3. Rod Bolt, 1-1/8–12
4. Delrin Spacer
5. 1/4-inch Frame Rail Spacer
6. One Spacer Washer on Each Side of the Beam
7. Rod Bolt, 1-1/4–12

AA. Measurement: 0.50" (12.7 mm) Axle Alignment Adjustment
BB. Weld: Three places approximately 3/4" (19 mm) long
CC. Measurement: 0.25" (6.4 mm) Axle Alignment Adjustment
DD. Weld: Three places approximately 3/4" (19 mm) long
EE. No Axle Alignment Adjustment

Fig. 2, Spacer Washer Installation and Alignment Bushing Welding

Troubleshooting Tables

Problem—Air Springs Are Flat

Problem—Air Springs Are Flat	
Possible Cause	**Remedy**
Low air pressure in the vehicle brake system.	Check the air pressure gauge on the instrument panel. If the air pressure is low, run the engine until a minimum pressure of 70 psi (483 kPa) is shown on the gauge.
Air leaking from the suspension air system or the air brake system.	Listen for leakage due to loose fittings or damaged air lines, air springs, brake actuators or control valves. Tighten loose fittings or replace work or damaged air lines with new ones.

Problem—Air Spring(s) Flat on One Side of the Vehicle

Problem—Air Spring(s) Flat on One Side of the Vehicle	
Possible Cause	**Remedy**
Air leakage between the pressure holding valve and the air spring(s).	Listen for leakage due to loose fittings or damaged air lines. Tighten loose fittings or replace damaged lines with new ones.
Air spring leaking.	Inspect the air spring for leaks caused by damage, wear, or deterioration. If any air spring is leaking, install a new one.
Bent, broken, or disconnected height control valve linkage.	Inspect the linkage for damaged or loose parts. Reconnect loose linkage parts or replace damaged parts with new ones.
Height control valve out of adjustment.	Disconnect the height control valve linkage from the height control valve control lever. Move the lever upward. If the air spring then inflates, adjust the height control valve.
Inoperative height control valve.	If movement of the control lever in the previous step fails to inflate the air spring, the height control valve is damaged. Replace the valve.

Problem—Vehicle Leans Due to Unequal Inflation of the Air Springs

Problem—Vehicle Leans Due to Unequal Inflation of the Air Springs	
Possible Cause	**Remedy**
Damaged height control valve linkage.	Inspect the height control valves and linkages for damage. Repair or replace damaged parts.
Loose or missing height control valve bolts or adjustment locknut.	Inspect for damage to the height control valve mounting bolts or adjustment locknut. Replace any missing bolts or nuts, then adjust the height control valve.
Height control valve out of adjustment.	Adjust the height control valve.

Troubleshooting

Problem—Air Springs Deflate Rapidly When the Vehicle Is Parked

Problem—Air Springs Deflate Rapidly When the Vehicle Is Parked	
Possible Cause	**Remedy**
Air leakage from the suspension air system.	Listen for leakage due to loose fittings or damaged air lines, air springs, or height control valves. Tighten loose fittings and replace worn or damaged parts with new ones.

Problem—Vehicle Rides Too High or Too Low

Problem—Vehicle Rides Too High or Too Low	
Possible Cause	**Remedy**
Height control valve out of adjustment.	Disconnect the height control valve linkage from the height control valve control lever. Move the lever upward. If the air spring then inflates, adjust the height control valve.

Problem—Air Spring Blown Out

Problem—Air Spring Blown Out	
Possible Cause	**Remedy**
Air spring cut or punctured.	Locate large leaks by listening for escaping air, and locate small leaks by applying a soap and water solution to the suspected air spring and watching for bubbles. Temporarily repair punctures or cuts less than 1/8-inch (3-mm) long by applying hot patches on both sides of the hole. If the cut is more than 1/8-inch (3-mm) long, install a new air spring.
Tires, rims, or chains rubbing the air spring.	Check the clearance between the air spring and the tire. If the tire, rim, or chains contact the inflated air spring, change to narrower tires and rims to provide clearance for tires with chains.
Air brake actuator rubbing against the air spring.	Relocate the brake actuator with factory approved parts to provide adequate clearance.

Problem—Air Spring Deflated Due to Fatigue

Problem—Air Spring Deflated Due to Fatigue	
Possible Cause	**Remedy**
Driving the vehicle too long or too fast with the air springs deflated.	If the vehicle must be driven with the air springs deflated, maintain a speed of less than 30 mph (48 km/h), and drive only as far as the nearest repair facility.
Continual or repeated overextension of the air springs.	Inspect for broken or loose shock absorbers or shock absorber mounting brackets. Reconnect loose parts and replace any damaged parts. Check the adjustment on the height control valve.

Troubleshooting

Problem—Air Spring Doesn’t Fully Deflate When All Weight Is Removed from the Suspension

Problem—Air Spring Doesn’t Fully Deflate When All Weight Is Removed from the Suspension	
Possible Cause	**Remedy**
Restricted air line between the height control valve and the air spring.	Disconnect the height control valve linkage, and push the control lever down. If the air spring remains inflated, check for a pinched or blocked line. Clean out any plugged line and replace any damaged line.

Specifications

Suspension Torque Specifications (lubricated threads)	
Description	**Torque: lbf·ft (N·m)**
Axle U-Bolts	150 (203)
Axle Front U-Bolts	150 (203)
Rear Spring Eye Bolts	200 (271)
Spring Shackle Eye Bolts	240 (325)
Rear Shock Upper Bracket	120 (163)
Rear Shock Mounting Bolts	55 (75)
Axle Stop Bumper Pad Bolts	5 (7)
Rear Sway Bar Bushing Hardware	100 (136)
Axle Input Yoke Mounting Nut	470 (637)
Rear Spring Hanger Frame (3/8-inch) Bolts	50 (68)
Rear Spring Hanger Frame (7/16-inch) Bolts	80 (108)
Air Bag to Air Bracket	35 (47)
Axle Brackets to Beams	600 (813)
Transverse Beam to Air Beam	550 (746)
Air Beams to Rear Hangers	320 (434)
Pivot Bolts	480 (651)
Axle Bolts	280 (298)
Rear Shocks	100 (136)

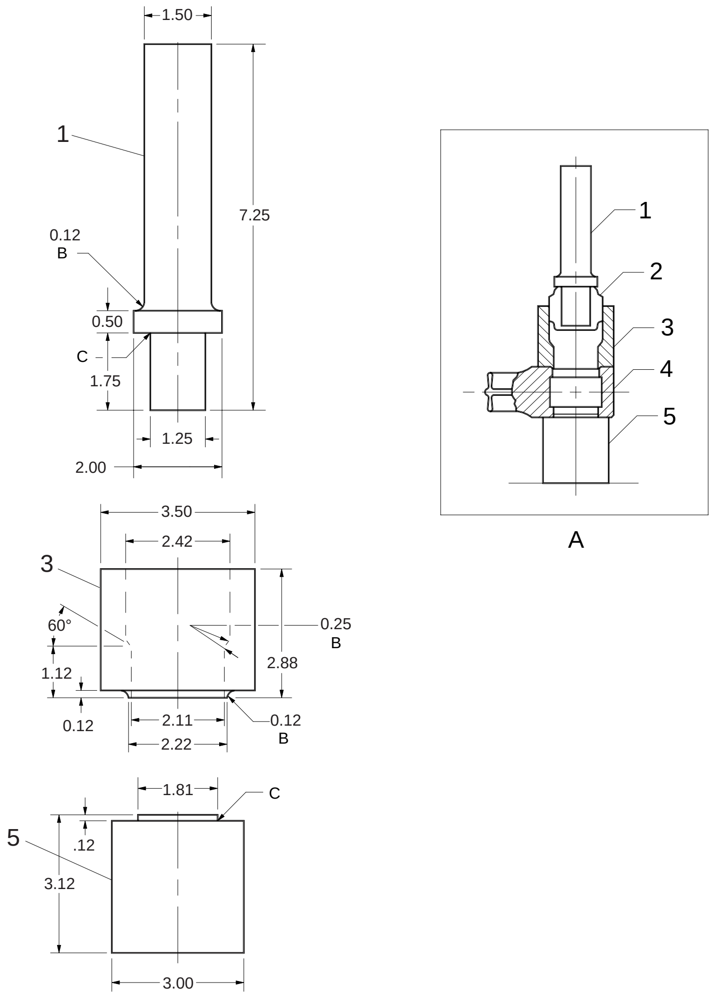
Table 1, Suspension Torque Specifications (lubricated threads)

See **Fig. 1** and **Table 2** for the bushing installation tool specifications.

Bushing Installation Tool Materials		
Tool	**Dimensions**	**Material**
A	Bar, 2" Diameter (51 mm)	Mild Steel
B	Tube, 3.50" (89 mm) o.d. x 0.75" (19 mm) wall	Mild Steel
C	Bar, 3" Diameter (76 mm)	Mild Steel

Table 2, Bushing Installation Tool Materials

Specifications



A. Detail
B. Radius
C. Minimum Radius
1. Plunger
2. Bushing
3. Insertion Sleeve
4. Torque Rod
5. Base

Fig. 1, Bushing Installation Tool

General Information

IMPORTANT: Do not tow the vehicle by the independent front suspension assembly, if so equipped. Components of the suspension can be damaged.

General Description

The Neway IFS–114 is an independent, front-steer air suspension system designed for RV use. The system consists of long and short double wishbone control arms, wide-mount air springs, ABS-ready wheel ends, shock absorbers set outside the frame rails, and an integral subframe. The lower control arms mount to the subframe with maintenance-free rubber bushings. Both upper and lower control arms mount to the post using tapered roller bearings.

The independent suspension isolates road input and eliminates bump steer. Dual height control air valves are used.

The hydraulic shock absorbers are of the direct double-acting type. They provide a continuous dampening effect both on compression and rebound. These shock absorbers are of telescopic design with rubber grommets at the mounting points for quiet operation. The shock absorbers are sealed, non-adjustable units, and must be replaced as complete assemblies. If an air spring is damaged or is leaking, it should be replaced.

Suspension Assembly Removal and Installation

Removal

WARNING

Before beginning work on the vehicle, ensure that the rear tires are securely chocked and that the vehicle is secure on the jackstands. If the vehicle is not properly supported, with the wheels removed and as the suspension is being removed, it could fall, which could cause severe injury, death, and substantial property damage.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake, and chock the rear tires.
2. Exhaust the air in the brake system.

WARNING

Before jacking on the vehicle, ensure that the rear tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

3. Raise the vehicle frame by jacking underneath the front suspension subframe until the weight is off of the front suspension.
4. Place jackstands under the frame rails, close to the front of the vehicle. Remove the jack.

IMPORTANT: Work on only one side of the vehicle at a time. When all the steps have been completed on one side, proceed to the other side and repeat the procedure on that side.

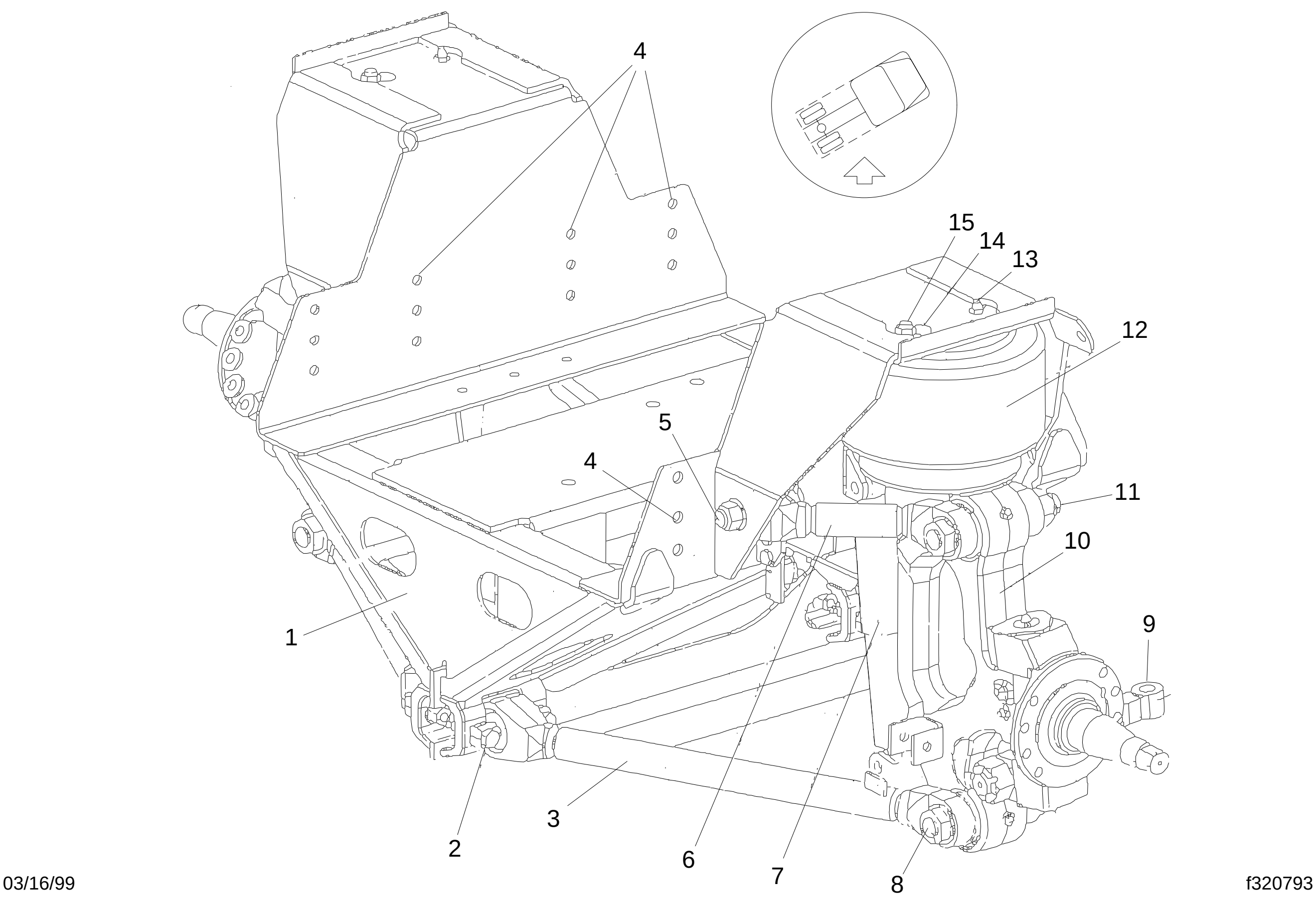
5. Remove the wheel nuts, wheel, and the brake drum.
6. Remove the brake shoes. See **Group 42** for instructions.
7. Remove the cotter pin from the steering rod tie rod end at the steering arm.
8. Remove the nut and disconnect the tie rod end from the steering arm. Position the tie rod out of the way. See **Fig. 1**.
9. Disconnect the air suspension height control valve control rod from its mounting tab (not shown) on the rear of the lower control arm. See **Fig. 2**.
10. Remove the lower and upper shock absorber mounting bolts and remove the shock absorber. See **Fig. 3**.
11. Disconnect the air suspension height control valve mounting bracket from the rear upper control arm mounting bracket on the suspension subframe. See **Fig. 2**. Position the height control valve assembly out of the way.
12. Cut the tie straps securing the ABS sensor line to the service brake chamber air line.
13. Remove the ABS sensor from the brake spider assembly. See **Group 42** for instructions.
14. Disconnect the service brake chamber air line.
15. Disconnect the air spring air line at the fitting in the large fastener on top of the air spring. See **Fig. 1**.
16. On top of the air spring retaining plate, remove the nut from the small fastener and loosen the nut on the large fastener with the air line fitting. See **Fig. 1**. Tilt the air spring so that the small fastener comes out of its hole. Then move the air spring sideways and slide the large fastener from its slot into the larger cut-out opening. See **Fig. 4**. Pull down on the air spring so that both fasteners are freed from the retaining plate.
17. Remove the cotter pins from the ends of the bolts which secure the upper and lower control arms to the post. See **Fig. 2**.
18. Remove the nuts and thrust washers from the bolts.

WARNING

Carefully support the post and hub assembly with an engine hoist or floor jack. See Fig.3. Ensure that the post/hub assembly does not fall as severe injury and property damage could result.

IMPORTANT: As you remove the upper and lower outboard control arm bolts, carefully remove the O-ring at each end of the bolt between the control arm and the tapered roller bearings in the post. See **Fig. 2**.

Suspension Assembly Removal and Installation



1. Subframe
2. Lower Control Arm/Subframe Bolt
3. Lower Control Arm
4. Subframe/Frame Rail Mounting Bolt Holes
5. Upper Control Arm/Subframe Bolt
6. Upper Control Arm
7. Shock Absorber
8. Lower Control Arm/Post Bolt
9. Steering Arm
10. Post
11. Upper Control Arm/Post Bolt
12. Air Spring
13. Small Fastener
14. Cut-Out
15. Large Fastener (with fitting)

Fig. 1, Front Suspension Assembly (three-quarter view from rear)

19. Remove the upper and lower bolts from the control arms and the post.

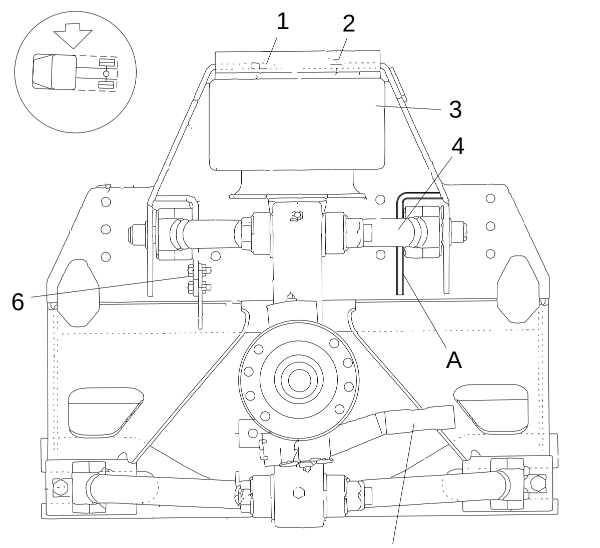
20. Set the post and hub assembly, with the air spring attached, aside.

21. Remove the nuts, bolts, washers, and the two upper control arm halves from their brackets on the suspension subframe. See **Fig. 2**.

IMPORTANT: Take note of the positions of the camber washers installed between the lower control arm and the subframe. See **Fig. 3**. Upon assembly, ensure that the washers are installed in their original positions.

22. Remove the four in-facing bolts attaching the lower control arm to the subframe. See **Fig. 2**. Then remove the control arm and camber washers.

23. Remove the cotter pin and nut from the tie rod end at the pitman arm and disconnect the tie rod from the pitman arm.



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1. Subframe/Frame Rail Mounting Bolt Holes
2. Subframe
3. Lower Control Arm/Subframe Bolt
4. Lower Control Arm
5. Lower Control Arm/Post Bolt
6. O-Ring Locations
7. Steering Arm
8. Upper Control Arm/Subframe Bolt
9. Upper Control Arm
10. Air Spring
11. Small Fastener
12. Large Fastener (with fitting)
13. Upper Control Arm/Post Bolt
14. Post
15. Air Suspension Height Control Valve Mounting Bracket

Fig. 2, Front Suspension Assembly (side view)

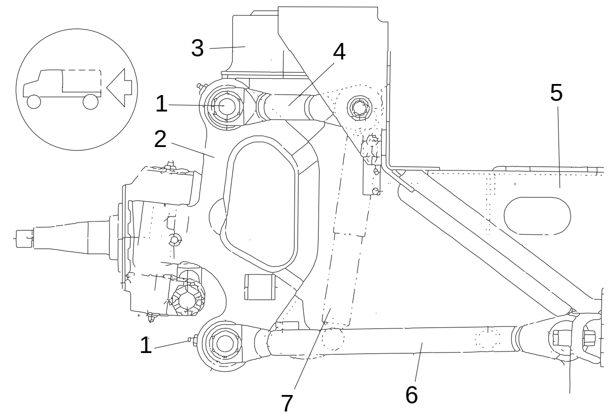
24. Remove the nut from the stud securing the air brake line bracket at the front of the subframe and disconnect the bracket from the stud.

NOTE: It is necessary to disconnect the two hydraulic power steering lines at the steering gear and also to remove the steering driveline.

25. Repeat the steps for the opposite side.

WARNING

Ensure that the subframe is securely supported from below before removing the 24 subframe mounting bolts and nuts . See Fig.1. If the subframe were to fall, severe injury and property damage could result.



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1. Air Spring
2. Upper Control Arm/Post Bolt
3. Post
4. Lower Control Arm/Post Bolt
5. Shock Absorber
6. Upper Control Arm
7. Upper Control Arm/Subframe Bolt
8. Lower Control Arm
9. Lower Control Arm/Subframe Bolt
10. Camber Washer Locations
11. Subframe

Fig. 3, Front Suspension Assembly (rear view)

26. Support the subframe from below and remove the 24 nuts and bolts securing the suspension subframe to the frame rails. See Fig. 1.
27. Jack up the subframe, remove the support, and carefully lower the subframe to the floor.

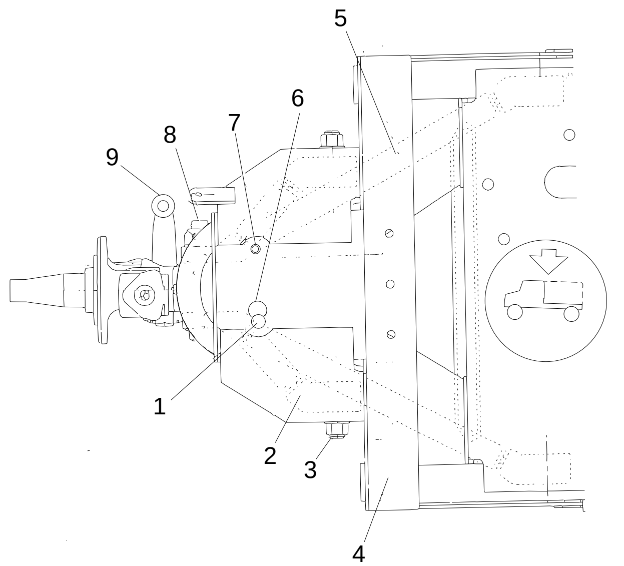
Installation

WARNING

Ensure that the subframe is securely supported when you raise it into position. If the subframe were to fall, severe injury and property damage could result.

IMPORTANT: Two adjustable suspension crossmembers are located between the frame rails, at the front and at the rear of the suspension subframe. Each crossmember attaches to two

Suspension Assembly Removal and Installation



1. Large Fastener (with airline fitting)
2. Upper Control Arm
3. Upper Control Arm/Subframe Bolt
4. Subframe
5. Lower Control Arm
6. Cut-Out
7. Small Fastener
8. Upper Control Arm/Post Bolt
9. Steering Arm

Fig. 4, Front Suspension Assembly (overhead view)

angle brackets at the left-side frame rail. Three adjustment bolts secure each angle bracket to a crossmember.

Before installing the subframe, loosen the 12 (total) crossmember adjustment bolts. Then, secure the subframe to the frame rails and tighten the fasteners to specification. Ensure that no gap exists between the subframe and the frame rails. Tighten the 12 (total) crossmember adjustment bolts 49 to 63 lbf·ft (66 to 85 N·m).

Work on only one side of the vehicle at a time. When all the steps have been completed on one side, proceed to the other side and repeat the procedure on that side.

1. Raise the subframe into position against the frame rails and align the bolt holes. See **Fig. 1**.

NOTE: The height control valve line brackets mount to the lower rear subframe bolts on each side. Install the brackets later in the procedure.

2. Install the 12 bolts (facing out) on each side of the subframe and the 12 nuts. Tighten the nuts 98 to 125 lbf·ft (133 to 170 N·m).
3. Install the tie rod end in the pitman arm and install the nut.
4. Tighten the nut 100 to 125 lbf·ft (135 to 170 N·m) and install a new cotter pin.
5. Place the upper control arm halves, with a thrust washer on either side, in position inside their mounting brackets on the subframe. See **Fig. 2**.

NOTE: The forward upper control arm bolt faces forward and the rear upper control arm bolt faces the rear. See **Fig. 2**.

6. Install the upper control arm mounting bolts and nuts. Do not tighten them at this time.
7. Place the lower control arm in position with the camber washers in their original positions against the lower edge of the subframe. See **Fig. 1** and **Fig. 3**.
8. Install two in-facing bolts, with thrust washers under the bolt heads and nuts, at each of the two control arm mounting points. See **Fig. 2**.
9. Tighten the bolts 130 to 170 lbf·ft (176 to 230 N·m).
10. Clean and inspect the O-rings and the tapered roller bearings in the post. See **Fig. 2**. Apply fresh grease to the bearings and O-rings.

WARNING

Carefully support the post and hub assembly with an engine hoist or floor jack. See Fig.3. Ensure that the post/hub assembly does not fall as severe injury and property damage could result.

11. Carefully move the post/hub/air spring assembly into position between the outboard tabs of the lower control arm. See **Fig. 1**. At the same time, ensure that the bearings are in position in the races of the post and that the O-rings are in position against the bearings, and not pinched.

NOTE: Spread the open end of the lower control arm slightly, using a bottle jack placed between the two arms, to facilitate the positioning of the post in the control arm tabs. See **Fig. 1**.

12. Install the mounting bolt, facing the rear, and nut, with a thrust washer under the bolt head and the nut. See **Fig. 1**.

NOTE: Ensure that the O-rings are in position and not pinched.

13. Raise the post/hub/air spring assembly.
14. With the forward bearing and O-ring in place, carefully position the post against the inside of the tab of the upper control arm's forward arm. Insert the mounting bolt and thrust washer, facing the rear, through the forward arm and post. See **Fig. 1**.
15. Place the rear arm, with bearing and O-ring in position, against the post. See **Fig. 1**.
16. Install the bolt fully through the rear of the rear arm.

NOTE: Ensure that the O-rings are in position and not pinched.

17. Install the thrust washer and nut. Tighten both upper and lower control arm/post bolts 630 to 770 lbf·ft (855 to 1045 N·m). Tighten the upper control arm/subframe bolts 450 to 550 lbf·ft (610 to 745 N·m).
18. Tilt the air spring and insert the large fastener into the cut-out opening in the mounting plate. Then slide the large fastener back into its slot and position the small fastener into its mounting hole. See **Fig. 4**. Install both nuts and tighten them 31 to 42 lbf·ft (42 to 57 N·m).
19. Insert the top of the shock absorber into its mounting bracket on the subframe. Install the bolt and nut. See **Fig. 1**.
20. Insert the bottom of the shock absorber into its mounting bracket on the rear of the post, align the bolt holes, and install the bolt and nut. See **Fig. 1**. Tighten both upper and lower bolts 35 lbf·ft (47 N·m).
21. Install the air suspension height control valve mounting bracket at the two holes inside the forward tab of the rear pair of tabs, where the rear upper control arm half mounts to the subframe. See **Fig. 2**. Install the two bolts and nuts and tighten them securely.
22. Position the bottom of the height control valve control rod against the tab (not shown) on the rear of the lower control arm. Install the bolt and nut and tighten them securely. See **Fig. 2**.
23. Secure the height control valve air line guide bracket with the lower rear subframe mounting bolt and tighten 98 to 125 lbf·ft (133 to 170 N·m). See **Fig. 2**.
24. Connect the height control valve air line to the 90-degree fitting in the large fastener at the top of the air spring and tighten the fitting. See **Fig. 4**.
25. Connect and tighten the service brake chamber air line.
26. Insert the ABS sensor fully into its mounting hole in the brake spider and tie strap the sensor line to the brake chamber air line. See **Group 42** for instructions.
27. Install the tie rod end in the steering arm and install the nut. See **Fig. 4**.
28. Tighten the nut 100 to 125 lbf·ft (135 to 170 N·m) and install a new cotter pin.
29. Attach the brake chamber air line guide bracket to the stud at the front of the subframe and tighten the nut securely.
30. Install the brake shoes. See **Group 42** for instructions. Install the brake drum.
31. Install the wheel and lug nuts. See **Group 40** for instructions.
32. Repeat the steps for the opposite side.

WARNING

Before jacking on the vehicle, ensure that the rear tires are securely chocked. Exercise caution when jacking. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

33. Raise the vehicle by jacking under the subframe. Remove the jackstands and lower the vehicle.
34. Remove the chocks.

IMPORTANT: After performing this procedure or removing and replacing individual components, adjust the front brakes. See **Group 42**. Check the front end alignment. See **Group 33**.

Specifications

Fastener Torques	
Description	**Torque lbf·ft (N·m)**
Crossmember Adjustment Bolts	49-63 (66-85
Subframe to Frame Rail Bolts	98-125 (133-170)
Tie Rod End Nut (pitman arm)	100-125 (135-170)
Lower Control Arm to Subframe Bolts	130-170 (176-230)
Control Arm to Post Bolts (upper and lower)	630-770 (855-1045)
Upper Control Arm to Subframe Bolts	450-550 (610-745)
Air Spring Fastener Nuts (large and small)	31-42 (42-57)
Shock Absorber Bolts	35 (47)
Tie Rod End Nut (steering arm)	100-125 (135-170)

Table 1, Fastener Torques

General Description

The Neway ADTB–280 is a drive axle air suspension system designed for RV use. This is a single-axle suspension that uses air springs. The top of each air spring is bolted to an outrigger, and the bottom of each air spring is attached to a suspension beam assembly crossmember. The suspension allows for vertical travel.

The Neway suspension maintains a stable, level ride by adjusting the air spring height according to vehicle load and road conditions. Two height control valves, one mounted on each frame rail, are linked to the suspension beam assembly and monitor ride height in relation to the beam assembly. If the load is riding too high, the beam assembly pulls the valve's control lever down, and the valve lowers the load by venting air from the springs. If the load rides too low, the beam assembly pushes the valve's control lever up, and the valve raises the load by delivering air to the springs. The air springs and the shocks mounted between the beam assembly and the frame rail extensions absorb road shock.

The design of the height control valves allow a several second delay between delivering air to and venting air from the air springs. This prevents the valve from reacting to abrupt axle movements caused by the condition of the road surface.

Two lower torque rods connect the suspension beam assembly to brackets attached to the frame rails. An upper torque rod connects the differential to the frame crossmember just ahead of the differential. The torque rods prevent torque-induced rotation of the axle. A similar control rod connects the differential to the left-hand frame rail to prevent the axle from moving laterally.

If the air springs lose pressure, a solid rubber bumper inside the spring will support the vehicle until it can be repaired. Do not drive the vehicle over 30 mph (50 km/h) with the air springs deflated, and drive it only as far as the nearest service facility. To deflate the air springs, disconnect the control lever arm from the linkage rod, and press the valve's control lever down to simulate overinflated air springs. The valve will vent the air from the springs.

Suspension Assembly Removal and Installation

Removal

WARNING

Before beginning work on the vehicle, ensure that the front tires are securely chocked and that the vehicle is secure on jackstands. If the vehicle is not properly supported, with the wheels removed and as the suspension is being removed, it could fall, which could cause severe injury, death, and substantial property damage.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake, and chock the front tires.
2. Exhaust the air in the suspension and brake systems.

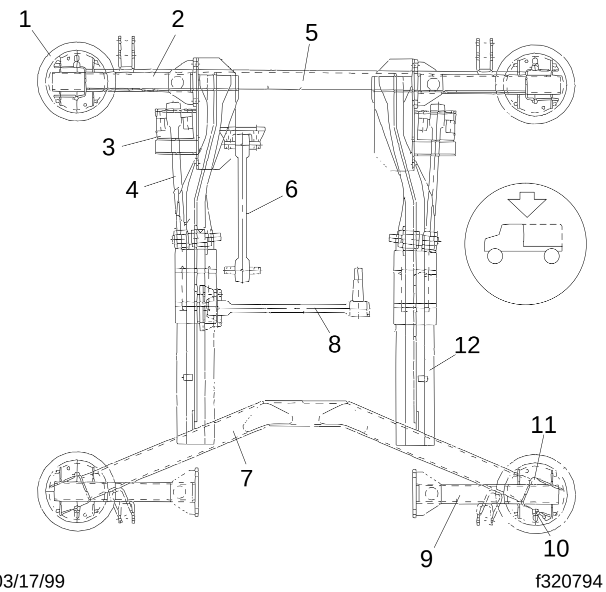
WARNING

Before jacking on the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

3. Lift the vehicle and place jackstands under the frame rails and also under all four corners of the beam assembly. See **Fig. 1**.
4. Remove the lug nuts and wheels on both sides of the vehicle.

NOTE: If only the rear beam assembly needs to be removed, the rear axle may be left in place, supported by jackstands under the brake hubs. If this is done, it is not necessary to disconnect or remove the driveshaft, torque rods, air lines, or ABS lines. It is necessary to remove the axle clamps which secure the axle to the beam assembly.

5. On one side of the vehicle, disconnect the air lines from the fittings in the large fasteners securing the forward and rear air springs to the upper mounting platforms. See **Fig. 2**.
6. Remove the air line fittings from the fasteners. See **Fig. 1**.

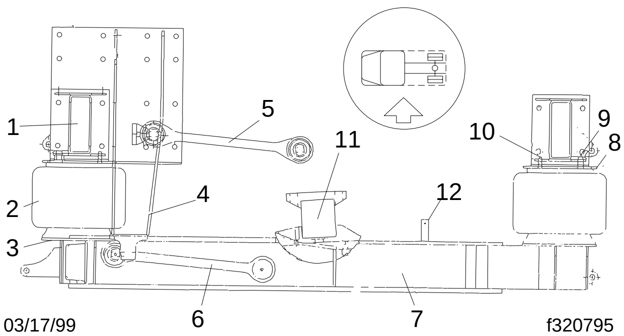


1. Air Spring Upper Mounting Platform
2. Left-Side Outrigger
3. Lower Torque Rod Bracket
4. Left-Hand Lower Torque Rod
5. Forward Beam Assembly Crossmember
6. Upper Longitudinal Torque Rod
7. Rear Beam Assembly Crossmember
8. Upper Transverse Torque Rod
9. Right-Side Outrigger
10. Large Fastener (with fitting)
11. Small Fastener
12. Beam Assembly

Fig. 1, Rear Suspension Assembly (overhead view)

7. Remove the two nuts and washers from the fasteners securing the forward and rear air springs to the upper mounting platforms. See **Fig. 2**.
8. Remove the nut and washer from the fasteners (not shown) securing the forward and rear air springs to the lower mounting platforms and remove the air springs. See **Fig. 2**.
9. Repeat the above steps on the opposite side and remove the air springs on that side.
10. Remove the upper and lower shock absorber (not shown) mounting bolts and nuts from all four shock absorbers. Remove all four shock absorbers.
11. Disconnect the suspension height control valve control rods (not shown) from their mounting tabs

Suspension Assembly Removal and Installation



1. Outrigger
2. Air Spring
3. Air Spring Lower Mounting Platform
4. Lower Torque Rod Bracket
5. Upper Longitudinal Torque Rod
6. Left-Hand Lower Torque Rod
7. Beam Assembly Rail
8. Air Spring Upper Mounting Platform
9. Large Fastener (with fitting)
10. Small Fastener
11. Rear Axle
12. Height Control Valve Control Rod Mounting Tab

Fig. 2, Rear Suspension Assembly (side view)

at the rear of the beam assembly, on both sides of the vehicle. See **Fig. 2**.

WARNING

Before jacking on the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

12. On one side of the vehicle, reposition the forward floor jack underneath the center of the forward beam assembly crossmember. See **Fig. 1**.

IMPORTANT: Take note of the position of any alignment shims or washers when disconnecting the torque rods. Place them back in their original positions on assembly.

13. On that same side, remove the two bolts and nuts from the forward end of the lower torque rod at the torque rod bracket. See **Fig. 2**.
14. Inside the beam assembly side rail, remove the nut and washer (not shown) securing the lower torque rod to the outside of the beam assembly side rail. Remove the torque rod. See **Fig. 2**.
15. Repeat the above three steps on the opposite side and remove the torque rod on that side.
16. On both sides of the vehicle, mark and then disconnect the brake chamber air lines from the brake chambers (not shown).
17. Remove the bolts, nuts, and washers securing the upper longitudinal torque rod at the frame crossmember, just ahead of the differential, and at the mounting bracket at the left side of the differential. See **Fig. 1**. Remove the torque rod.
18. Remove the bolts, nuts, and washers securing the upper transverse torque rod at the left-hand inside of the frame rail and at the mounting bracket on the right side of the differential. See **Fig. 1**. Remove the torque rod.
19. Remove the four U-joint bolts and disconnect the driveshaft (not shown) at the rear of the differential and secure it out of the way with tie straps.

WARNING

Before jacking on the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

20. Ensure that a floor jack is supporting each of the four corners of the beam assembly, under each air spring mounting location. See **Fig. 1**.
21. Remove the jackstand supporting the suspension beam assembly rear crossmember. See **Fig. 1**.
22. Remove the jackstands supporting the brake hubs (only if removing the axle with the beam assembly).
23. Place a wooden pallet or dolly on the floor underneath the rear suspension beam assembly.
24. Carefully and in increments, lower the four floor jacks equally which are supporting the rear beam assembly beneath the four air spring lower mounting locations. Lower the floor jacks until the beam assembly is resting on the pallet or dolly.
25. Disconnect the ABS sensor wires (not shown) at the vehicle floor, above the differential.

NOTE: If necessary for clearance to withdraw the beam assembly/axle on the pallet or dolly

Suspension Assembly Removal and Installation

out from underneath the vehicle, raise the rear of the vehicle at the rear crossmember and re-position the jackstands higher.

26. Using a fork lift truck, withdraw the pallet or dolly out from underneath the vehicle on whichever side offers better access.

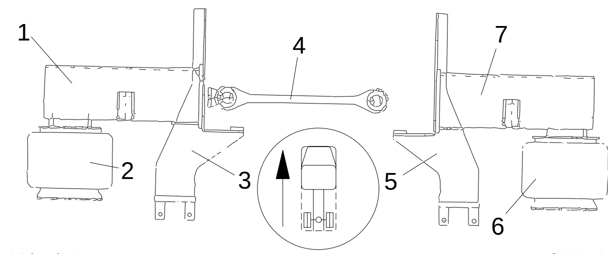
WARNING

Before attempting to separate the axle from the beam assembly, ensure that the pallet or dolly is securely supported at each corner. If the pallet or dolly with the axle/beam assembly should fall, severe injury, death, and substantial property damage could result.

27. On each side of the rear axle, remove the four nuts and washers at the bottoms of the axle clamp (not shown) retaining bolts. Remove the axle retaining clamps.
28. Lift the rear axle assembly off the beam assembly with a crane and set it aside.

NOTE: Before the lower torque rod brackets can be removed, it is necessary to remove the forward outriggers, which contain the forward, upper air spring mounting platforms. See **Fig. 3**.

Installation



1. Left-Side Outrigger
2. Left-Side Air Spring
3. Left-Hand Lower Torque Rod Bracket
4. Upper Transverse Torque Rod
5. Right-Hand Lower Torque Rod Bracket
6. Right-Side Air Spring
7. Right-Side Outrigger

Fig. 3, Rear Suspension Assembly (rear view)

NOTE: Before installing the axle/beam assembly, install the lower torque rods loosely at the their rear mounting points. Then, tie strap the torque rods to the beam assembly side rails to keep them parallel when installing the axle/beam assembly. See **Fig. 2**.

1. With the axle/beam assembly on a wooden pallet or dolly, maneuver it into position beneath the vehicle with a fork lift truck.

WARNING

Exercise caution when performing the following steps with the axle/beam assembly and pallet or dolly supported by the fork lift truck. Keep hands, feet, and limbs clear of the underside of the pallet or dolly. If the pallet or dolly with the axle/beam assembly should fall, severe injury, death, and substantial property damage could result.

2. Raise the pallet or dolly and bring the rear of the differential (not shown) into position with the driveshaft.

NOTE: Tie strap the differential yoke to the driveshaft to keep it in position.

3. Install the U-joint yoke caps and bolts but do not fully tighten them yet.

Suspension Assembly Removal and Installation

IMPORTANT: Place any alignment shims or washers back in their original positions when installing the torque rods.

4. Maneuver the pallet or dolly with the fork lift truck. Remove the tie straps and position the forward ends of the lower torque rods in place, ahead of the left and right lower torque rod brackets. See **Fig. 2**.
5. Install the bolts, washers, and nuts and secure the two lower torque rods to their forward mounting brackets. Tighten each mounting bolt 170 lbf·ft (230 N·m).
6. Tighten the nut on the tapered shaft at the rear of the torque rods 400 lbf·ft (542 N·m). See **Fig. 1**.

WARNING

Before jacking on the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

7. Place jackstands under the right and left brake hubs (only if the axle was removed with the beam assembly) and under the four beam assembly corners. See **Fig. 1**.
8. Back out the forklift with the pallet or dolly.
9. Place the upper longitudinal torque rod in position and attach it at the rear to the differential with the two bolts, washers, and nuts. See **Fig. 1**. Tighten each mounting bolt 170 lbf·ft (230 N·m).
10. Attach the front of the torque rod to the forward frame crossmember. See **Fig. 2**. Place the rectangular plate ahead of the crossmember and the shims and bracket between the crossmember and the torque rod. Install the mounting bolts, nuts, and washers. Tighten each mounting bolt 170 lbf·ft (230 N·m).
11. Attach the upper transverse torque rod to the mounting ear on the right side of the differential and install the washer and nut. See **Fig. 3**. Tighten the nut on the tapered shaft 400 lbf·ft (542 N·m).

WARNING

Before jacking on the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

12. Maneuver the left side of the beam assembly with a floor jack. Align the left-side frame rail bolt holes, the plate, shims, bracket, and the upper transverse torque rod mounting holes. See **Fig. 1**. Install the two bolts, washers, and nuts at the left-side frame rail. Tighten each mounting bolt 170 lbf·ft (230 N·m).
13. Connect the two ABS sensor wires (not shown) at the bottom of the vehicle floor. Tie strap the wires securely out of the way.
14. Connect the previously marked two brake chamber air hoses to each brake chamber (not shown). Tighten the fittings securely.
15. Remove the tie straps and tighten the driveshaft U-joint bolts 135 lbf·ft (183 N·m).
16. Place each shock absorber (not shown) in position and install the bolts, washers, and nuts, with the nuts facing in. Tighten each mounting bolt 110 lbf·ft (150 N·m).
17. Install each air spring by inserting the lower mounting fastener (not shown) into its hole in the lower platform. Install the washer and nut. Tighten each mounting nut 35 lbf·ft (47 N·m).
18. Guide the two upper fasteners into their mounting holes in the upper platform. See **Fig. 2**. Install the washers and nuts on the two fasteners. Tighten each mounting nut 35 lbf·ft (47 N·m).
19. Attach the left- and right-side height control valve control rods (not shown) to their mounting tabs on the beam assembly. See **Fig. 2**. Install the bolts, washers, and nuts and tighten them securely.
20. Install the air spring air line fittings in the large upper fasteners at the top of the air springs and tighten them securely. See **Fig. 1**.
21. Connect the air spring air lines (not shown) to the fittings and tighten them securely.

22. Install the inner wheels and then install the outer wheel fasteners over the inner fasteners. See **Group 40** for instructions.
23. Install the outer wheels and the lug nuts.

WARNING

Before jacking on the vehicle, ensure that the front tires are securely chocked. Exercise caution when jacking. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

24. Jack up the beam assembly at both rear corners equally and remove the jackstands. See **Fig. 1**.
25. Lower the vehicle.
26. Remove the chocks from the front tires.

IMPORTANT: Check to make sure the suspension is level by measuring the lengths of the four shock absorbers. All four shocks should measure an equal length.

Specifications

Fastener Torques	
Description	Torque lbf·ft (N·m)
Lower Torque Rod to Forward Mounting Bracket Bolts	170 (230)
Lower Torque Rod Nuts (rear)	400 (542)
Upper Longitudinal Torque Rod to Differential Bolts	170 (230)
Upper Longitudinal Torque Rod to Crossmember Bolts	170 (230)
Upper Transverse Torque Rod to Differential Nut	400 (542)
Upper Transverse Torque Rod to Left-Side Frame Rail Bolts	170 (230)
Driveshaft U-Joint Bolts	135 (183)
Shock Absorber Bolts	110 (150)
Air Spring Lower Fastener Nut	35 (47)
Air Spring Upper Fastener Nuts	35 (47)

Table 1, Fastener Torques

General Information

The Holland® Neway® suspension uses air drawn from the vehicle air system to pressurize the air springs. The height control valve regulates the air pressure required for varying loads and maintains the design ride height. This suspension can provide a cushioned ride throughout the load range, from empty to fully loaded. See **Fig. 1**.

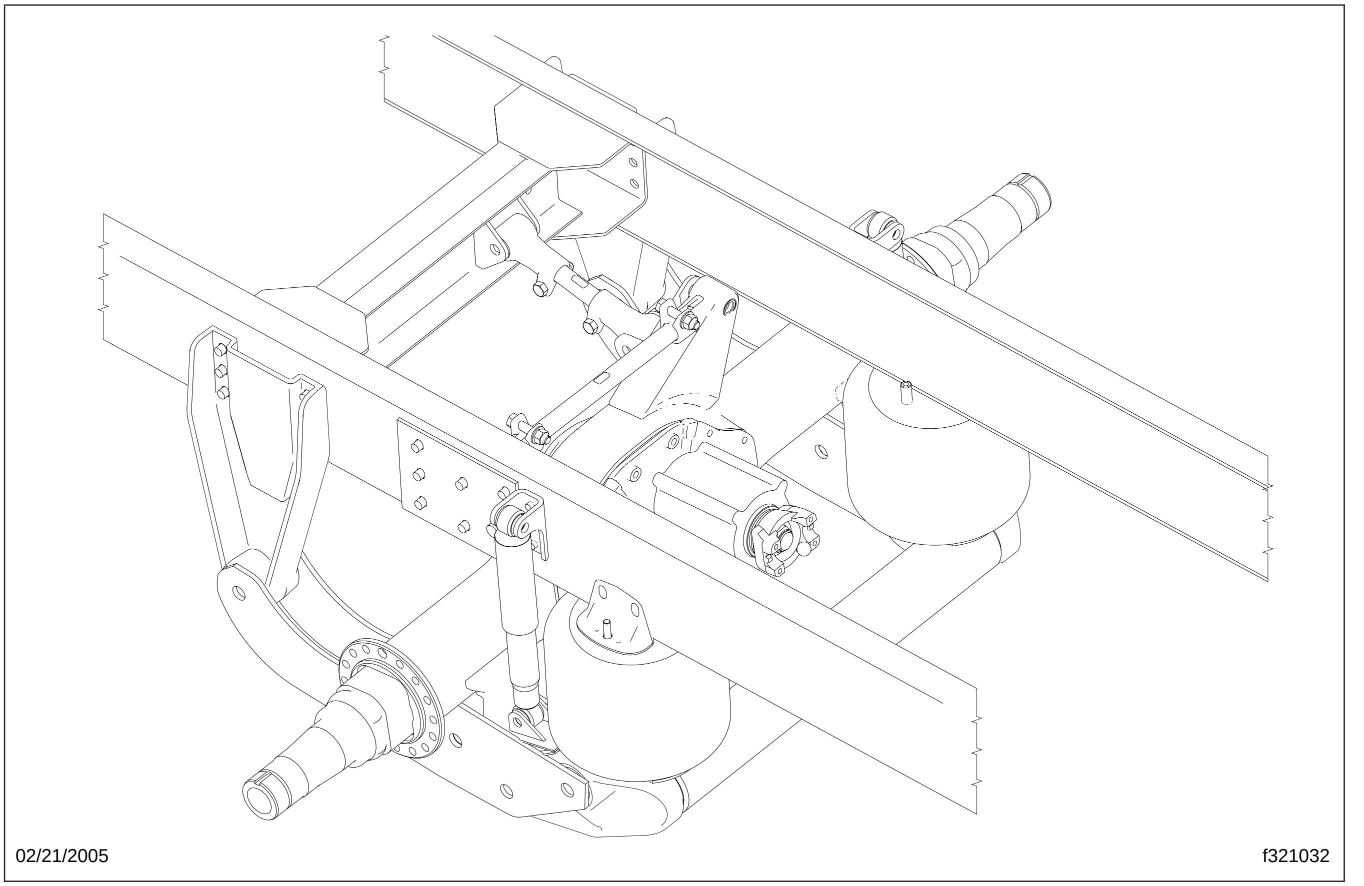


Fig. 1, Holland Neway ADL (120/123) Suspension

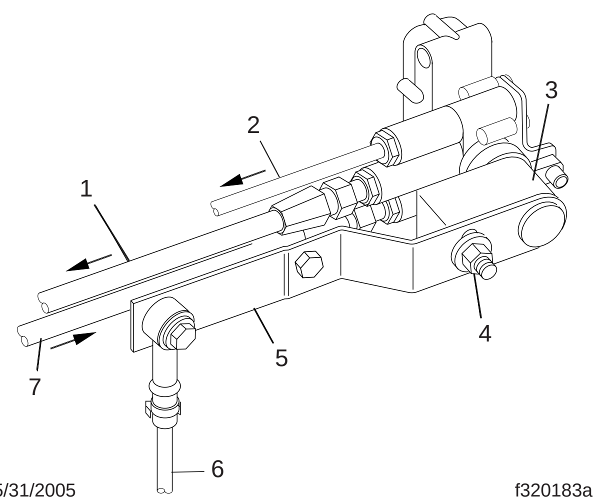
The Recreational Vehicle chassis can be equipped with the the Holland® Neway® ADL-120 or the ADL-123 Suspension. Information included in this section applies to both suspensions.

Ride Height Checking

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Pressurize the air system with a constant supply of air to 100 psig (690 kPa). Both air springs should inflate and locate the suspension at the proper ride height.
3. The distance from the bottom flange of the frame rail to the center of the lower shock mounting bolt should measure a ride height of 10-1/4 ±1/4 inches (256 ±6 mm). If the ride height is not within a 1/4 inch (6 mm) of the correct ride height of 10-1/4 inches (256 mm), adjust the height control valve using the following steps.

Ride Height Adjustment

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Remove the bolt that secures the height control valve linkage to the control lever of the valve. See **Fig. 1**.



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1. Airflow to Spring
2. Exhaust to Atmosphere
3. Nylon Block
4. Adjustment Locknut
5. Control Lever
6. Linkage
7. Airflow from Air Reservoir

Fig. 1, Height Control Valve

3. Exhaust all air from the air springs by pushing the control lever down to the vertical position.
4. Connect the control lever to its respective linkage, and allow the air springs controlled by the lever to fill until the valve shuts off.
5. To adjust the valve, loosen the adjustment locknut on the height control valve lever arm. See **Fig. 1**. Move the control arm (slightly relative to the nylon block). Tighten the locknut when the required height measurement is reached.
6. Disconnect the control lever from the linkage, and press it down to deflate the air springs about halfway. Reconnect the linkage to inflate the air springs, then check the height dimension.
7. When the height control valve is adjusted, disconnect the control lever from the height control valve linkage, and push it down to the vertical position to fully deflate the air spring.
8. Connect the linkage assembly to the control lever.
9. Remove the chocks from the tires.

Follow the instructions in the rear axle alignment checking section of **Group 35** to see if rear axle alignment adjustment is needed. If it is needed, proceed as follows:

Axle Alignment Adjustment

IMPORTANT: Holland® Neway® recommends that the chassis be set at the specified ride height of 7 inches ±1/4 inch (178 ±6 mm) prior to axle alignment.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Support the frame with jack stands, then completely exhaust air from the springs by disconnecting the air supply line from the air spring.

WARNING

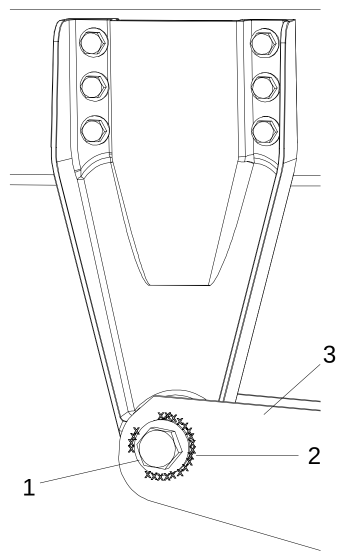
Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Remove the pivot bolt from that axle end that has an alignment block welded to each of the equalizing beam plates. See **Fig. 1**.
4. Grind off the welds that attach the alignment blocks to the equalizing beam plates. Be careful not to grind off equalizing beam plate material. See **Fig. 1**.

WARNING

Never remove parent material from an equalizing beam plate when grinding to remove the alignment block. If parent material is removed, weakening the plate, always replace the equalizing beam plate with a new plate.

5. Replace the pivot bolt, alignment blocks, hardened washer, and nut with new hardware. Tighten all the hardware so that all components are secure, but do not tighten to torque specifications.
6. Move the equalizing beam plate forward or backward to align the axle. See **Fig. 2**.
7. Tighten the pivot connection nut 800 to 850 lbf·ft (1085 to 1153 N·m).



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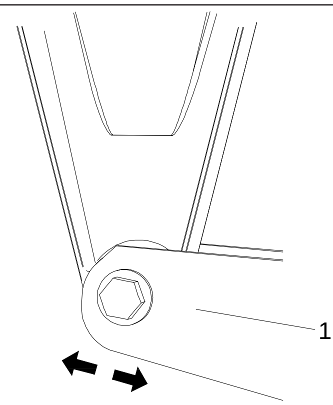
1. Alignment Block and Pivot Bolt
2. Alignment Block Welding Pattern
3. Equalizing Beam Plate

Fig. 1, Alignment Block Welded to the Equalizing Beam



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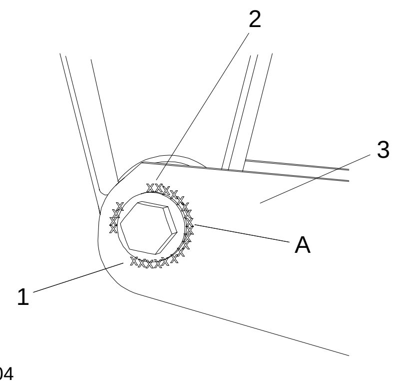
1. Equalizing Beam Plate

Fig. 2, Adjusting the Alignment Block Prior to Welding

8. Check the alignment, then weld the alignment blocks to the equalizing beam plates. See **Fig. 3**.

IMPORTANT: A minimum three minute cool down period is required after welding the pivot connection before applying torque to the pivot nut.

Axle Alignment Adjustment



A. Weld Both Sides as Shown (One Continuous Weld; Start forward of the centerline. End forward of the bolt center line).
1. Weld Start
2. Weld End
3. Equalizing Beam Plate

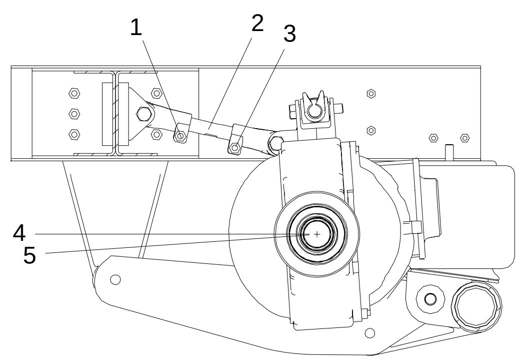
Fig. 3, Alignment Block Welded in Place

9. After the alignment blocks have cooled, tighten the pivot connection nut 800 to 850 lbf·ft (1085 to 1153 N·m).

Follow the instructions in the rear axle alignment checking section of **Group 41** to see if rear axle pinion angle adjustment is needed. If it is needed, proceed as follows:

Pinion Angle Adjustment

1. To get the pinion angle, measure the frame angle relative to the ground. Next, measure the top of the axle arm flat relative to the ground. Subtract the axle arm flat angle from the frame angle. The result will be the pinion angle.
2. The pinion angle is adjusted by changing the length of the torque rod. See **Fig. 1**.



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1. Adjustment Nut
2. Torque Rod Center Link
3. Adjustment Nut
4. Line Parallel to the Ground
5. Pinion Angle

Fig. 1, Pinion Angle Adjustment

3. Loosen both adjustment nuts on the torque rod. See **Fig. 1**.
4. Use a pipe wrench to turn the torque rod center link, or if the center link has wrench flats, use a 1-9/16 inch (40 mm) open-end wrench to turn the link.
5. Tighten the two adjustment nuts.
6. Check and adjust the ride heighe, using the procedures in **Subject 100** .

Suspension Air Spring Replacement

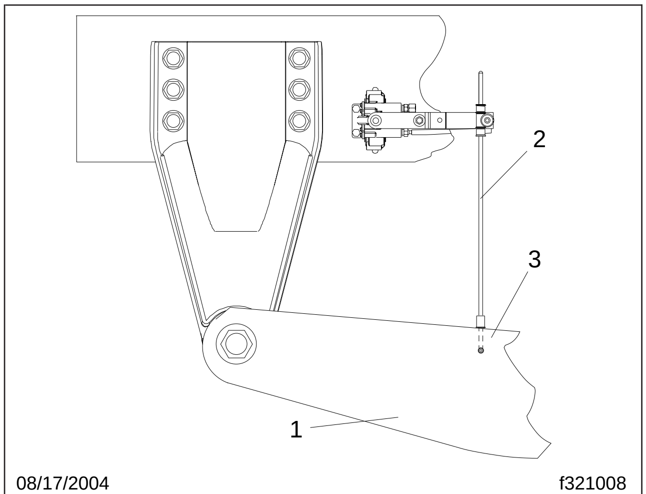
Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Support the frame with jack stands.

WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link. See **Fig. 1**.

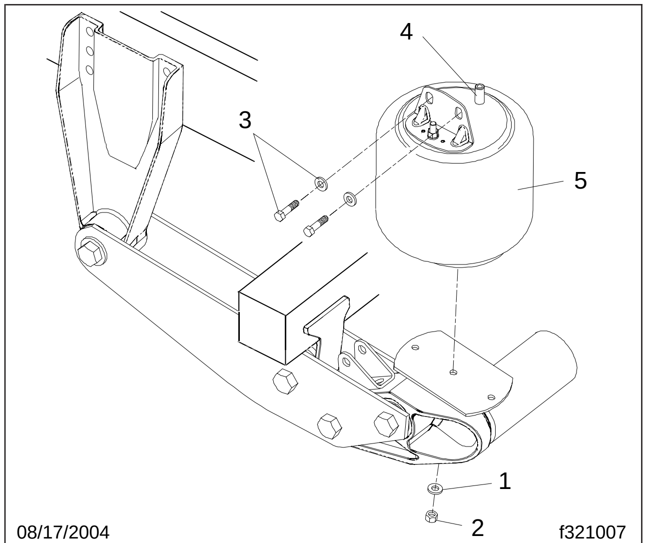


1. Equalizing Beam Plate
2. Height Control Valve Link
3. Lower Link Connection

Fig. 1, Height Control Valve Linkage

4. Remove the frame fasteners.
5. Disconnect then remove the air spring assembly. See **Fig. 2**.

IMPORTANT: Air springs must be replaced with the proper air spring for the vehicle installation. Check the flexible member and piston for the part number. If the part number is not identifiable, contact the air spring manufacturer for assistance.



1. Washer
2. Air Spring Piston Fastener
3. Frame Fasteners
4. Air Supply Fitting
5. Air Spring

Fig. 2, Air Spring Assembly

6. Install the new air spring assembly. Install then tighten the air spring piston fastener 30 to 35 lbf·ft (41 to 48 N·m).
7. Install then tighten the frame fasteners 30 to 35 lbf·t (41 to 48 N·m).
8. Connect the air supply line and height control valve lower-link connection. See **Fig. 1**.
9. Remove the jack stands.

CAUTION

While the vehicle air system pressure capabilities may be in excess of 120 psi (827 kPa), the air spring pressure must not be set above 100 psi (690 kPa) or the rubber air spring can tear or fracture.

10. Start and run the engine until air system pressure reaches 100 psig (690 kPa). Check for leaks.

Suspension Air Spring Replacement

11. Both air springs should inflate the suspension to the proper ride height. Check the ride height using the instructions in **Subject 100**, and follow the instructions there, if an adjustment is needed.
12. Remove the chocks from the tires.

Replacement

NOTE: Because the axle adapter is welded to the axle, a Holland® Neway® bushing service tool (p/n 505 44 012) is available to ease removal and replacement of bushings. The bushing service tool can be used on all ADL bushings, including pivot connections and equalizing beam connections. See **Fig. 1**.

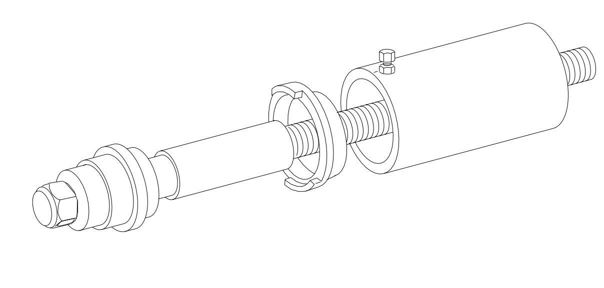

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Fig. 1, Bushing Service Tool

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Raise the rear of the vehicle and support the frame with jack stands.

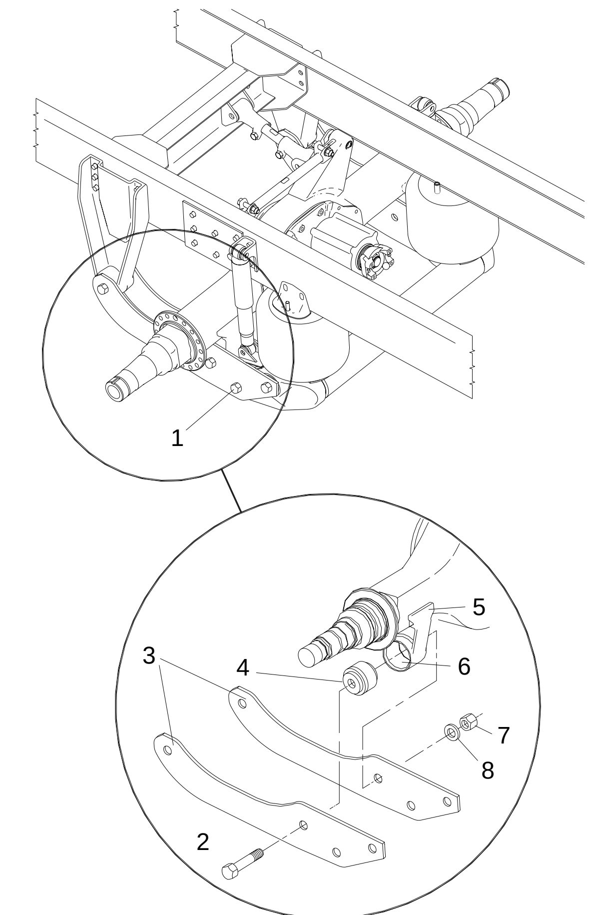
WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Remove the tires.
4. Using a floor jack, support the axle at the axle bowl.
5. Using another floor jack, support the equalizing beam.
6. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link.

NOTE: If the air spring has a leak and is deflated, this step must still be completed.

7. Disconnect the shock absorbers and the air springs at the lower connections.
8. Remove the axle adapter connection hardware on both sides of the equalizing beam. See **Fig. 2**.



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1. Axle Connection Bolt
2. Axle Connection Bolt
3. Equalizing Beam Plates
4. Bushing
5. Axle Adapter
6. Receptacle
7. Nut
8. Washer
9. Equalizing Beam

Fig. 2, Axle Adapter Bushing Replacement

Axle Adapter Bushing Replacement

9. Using a floor jack, support the equalizing beam and slowly lower the assembly to provide access to the axle adapter bushings.

NOTE: If the equalizing beam plates are too snug on the axle adapter, it may be necessary to loosen the equalizing beam connection hardware on both sides.

10. Using the bushing service tool, press out the axle adapter bushings.

IMPORTANT: Do not use an open flame or other heat source to remove the bushings.

11. Remove and clean all foreign material from the axle adapter bushing receptacles.
12. Inspect the axle adapters, the axle adapter welds, and other parts for cracks or failed welds. If cracks are detected anywhere on an axle adapter, replace the adapter.

WARNING

Never repair a cracked axle adapter. Do not weld cracks. Secondary weld failures during use may cause loss of vehicle control, component damage, serious injury, or death.

13. Lubricate the new replacement bushings and bushing receptacles with an approved rubber lubricant or a soap and water solution.

IMPORTANT: Do not use oil-based lubricants or brake fluid as they can cause damage to the rubber.

14. Using the bushing service tool, press the new bushings into the axle adapter receptacles. See **Fig. 2**.

NOTE: The bushing must be centered in the axle adapter receptacle.

15. Using a floor jack, raise the equalizing beam assembly to its original position. Assemble the equalizing beam using new hardware. Tighten all axle adapter nuts and equalizing beam nuts 800 to 850 lbf·ft (1085 to 1153 N·m).

IMPORTANT: The suspension should be close to the ride height when tightening the axle adapter connection to avoid bushing windup. The axle bowl can be supported with a floor jack. Do not raise the rear of the vehicle.

16. Connect the air springs, shock absorbers, and height control valve link.
    - 16.1 Tighten the air spring nuts 30 to 35 lbf·ft (41 to 48 N·m).
    - 16.2 Tighten the shock absorber fasteners 250 to 280 lbf·ft (340 to 380 N·m).
    - 16.3 Tighten the height control valve and fasteners.
17. Remove the floor jack supporting the axle bowl.
18. Install the tires. Remove the jack stands and lower the vehicle.
19. Increase the vehicle air system reservoir pressure to 100 psig (690 kPa). Check for leaks.

CAUTION

While the vehicle air system pressure capabilities may be in excess of 120 psi (827 kPa), the air spring pressure must not be set above 100 psi (690 kPa) or the rubber air spring can tear or fracture.

20. Both air springs should inflate the suspension to the proper ride height. Check the ride height, using the instructions in **Subject 100**, and follow the instructions there if an adjustment of the ride height is needed.
21. Remove the chocks from the tires.

Frame Bracket Pivot Bushing Replacement

Replacement

NOTE: A Holland® Neway® bushing service tool (p/n 505 44 012) is available to ease removal and replacement of bushings. The bushing service tool can be used on all ADL bushings, including pivot connections and equalizing beam connections. See **Fig. 1**.

IMPORTANT: At the time of service, replace both bushings.

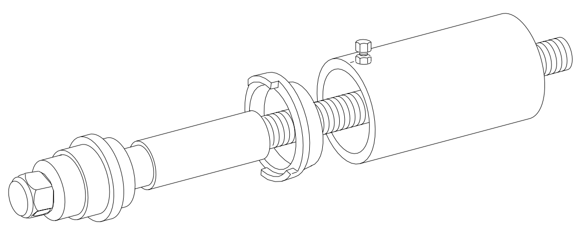

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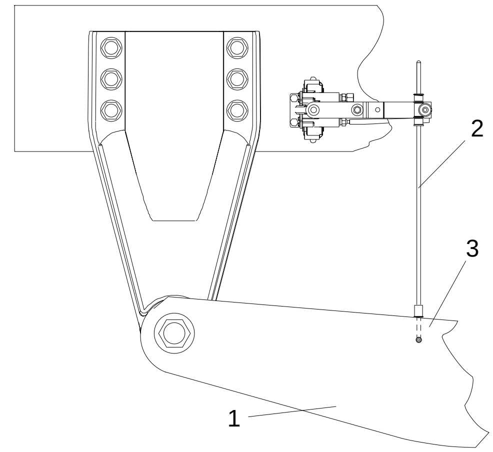
Fig. 1, Bushing Service Tool

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Raise the rear of the vehicle and support the frame with jack stands.

WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Remove the tires.
4. Using a floor jack, support the axle at the axle bowl.
5. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link. See **Fig. 2**.



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1. Equalizing Beam Plate
2. Height Control Valve Link
3. Lower Link Connection

Fig. 2, Height Control Valve Linkage

NOTE: If the air spring has a leak and is deflated, this step must still be completed.

6. Disconnect the shock absorbers and air springs at the lower connections.
7. Remove the pivot connection hardware. See **Fig. 3**.
8. Using the floor jack that supports the axle bowl, lower the axle and suspension to gain access to the frame bracket pivot bushings.
9. Using the bushing service tool, press out the frame bracket pivot bushings.

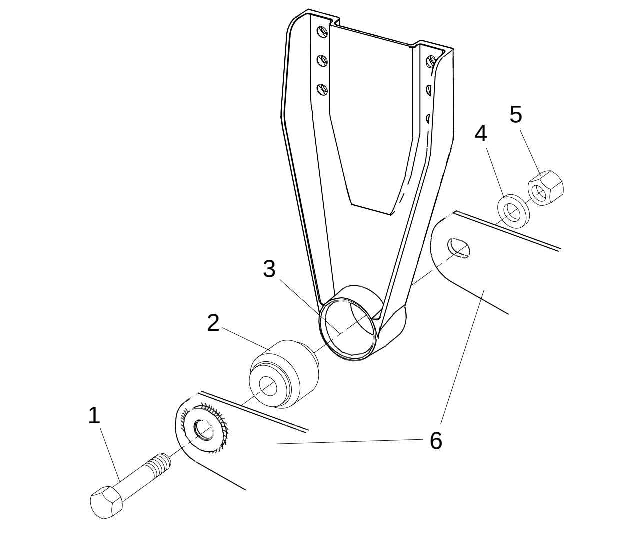
IMPORTANT: Do not use an open flame or other heat source to remove the bushings.

10. Clean out all foreign material from the frame bracket pivot bushing receptacle(s).
11. Inspect the frame brackets for cracks. If cracks are detected anywhere on a frame bracket, replace the bracket.

WARNING

Never repair a cracked frame bracket. Do not weld cracks. Secondary weld failures during use may cause loss of vehicle control, serious injury, or death.

Frame Bracket Pivot Bushing Replacement



1. Bolt
2. Bushing
3. Pivot Bushing Receptacle
4. Washer
5. Nut
6. Equalizing Beam Plates

Fig. 3, Frame Bracket Pivot Bushing Replacement

12. Lubricate the new replacement bushings and bushing receptacles with an approved rubber lubricant or a soap and water solution.

IMPORTANT: Do not use oil-based lubricants or brake fluid, as they can cause damage to the rubber.

13. Center the bushings in the frame bracket receptacles. Using the bushing service tool, press the new bushings into the proper receptacles.
14. Assemble the pivot connection, and raise the axle and suspension to its original position.

IMPORTANT: Do not lift the vehicle off of the jack stands.

15. Align the holes from the equalizing beams with the holes from the pivot bushings, and install the pivot hardware.
16. Tighten the pivot connection nuts 800 to 850 lbf·ft (1085 to 1153 N·m).

IMPORTANT: The suspension should be close to the ride height when tightening the front pivot connection to avoid bushing windup. The axle bowl can be supported with a floor jack. Do not raise the rear of the vehicle.

17. Connect the air springs, shock absorbers, and height control valve link.
    - 17.1 Tighten the air spring nuts 30 to 35 lbf·ft (41 to 48 N·m).
    - 17.2 Tighten the shock absorbers and fasteners 250 to 280 lbf·ft (340 to 380 N·m).
    - 17.3 Tighten the height control valve and fasteners.
18. Install the tires. Remove the jack stands, lower the vehicle, and remove the floor jack supporting the equalizing beam.
19. Increase the suspension air system reservoir pressure to 100 psig (690 kPa). Check for leaks.

CAUTION

While the vehicle air system pressure capabilities may be in excess of 120 psi (827 kPa), the air spring pressure must not be set above 100 psi (690 kPa) or the rubber air spring can tear or fracture.

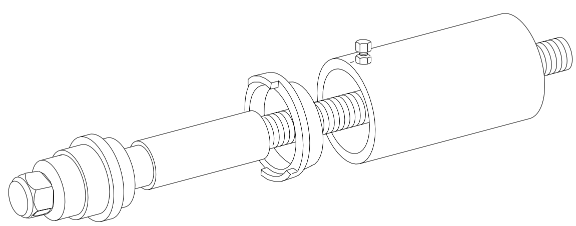
20. Both air springs should inflate the suspension to the proper ride height. Check the ride height, using the instructions in **Subject 100**, and follow the instructions there if an adjustment of the ride height is needed.
21. Remove the chocks from the tires.

Equalizing Beam Bushing Replacement

Replacement

NOTE: A Holland® Neway® bushing service tool (p/n 505 44 012) is available to ease removal and replacement of bushings. The bushing service tool can be used on all ADL bushings, including pivot connections and equalizing beam connections. See **Fig. 1**.

IMPORTANT: At the time of service, replace both bushings.



08/17/2004 f580383

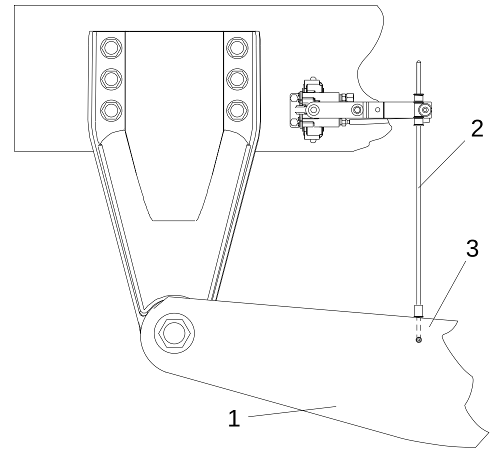
Fig. 1, Bushing Service Tool

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Raise the rear of the vehicle and support the frame with jack stands.

WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Remove the tires.
4. Using a floor jack, support the axle at the axle bowl.
5. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link. See **Fig. 2**.



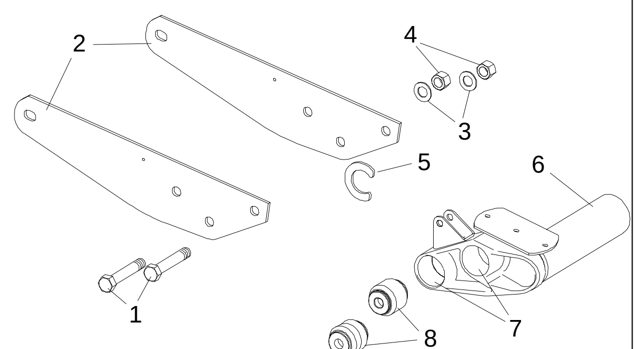
08/17/2004 f321008

1. Equalizing Beam Plate
2. Height Control Valve Link
3. Lower Link Connection

Fig. 2, Height Control Valve Linkage

NOTE: If the air spring has a leak and is deflated, this step must still be completed.

6. Disconnect the shock absorbers and air springs at the lower connections.
7. Remove the equalizing beam connection hardware on both sides. See **Fig. 3**.



08/17/2004 f321011

1. Bolts
2. Equalizing Beam Plates
3. Washers
4. Nuts
5. Washer
6. Equalizing Beam
7. Receptacles
8. Bushings

Fig. 3, Equalizing Beam Bushing Replacement

Equalizing Beam Bushing Replacement

8. Using the floor jack, support and lower the equalizing beam, to provide access to the equalizing beam bushings.

NOTE: The axle adapter hardware connecting the equalizing beam plates to the axle adapter may need to be loosened on both sides.

9. Using the bushing service tool, press out the equalizing beam bushings.

IMPORTANT: Do not use an open flame or other heat source to remove the bushings.

10. Clean out all foreign material from the equalizing beam bushing receptacles.
11. Inspect the equalizing beam for any cracks or failed welds. If cracks are detected anywhere on the beam, replace the beam.

WARNING

Never repair a cracked transverse beam. Do not weld cracks. Secondary weld failures during use may cause loss of vehicle control, serious injury or death.

12. Lubricate the new bushings and bushing receptacles with an approved rubber lubricant or a soap and water solution.

IMPORTANT: Do not use oil-based lubricants or brake fluid. Damage to the rubber can occur.

13. Center the bushings in the equalizing beam receptacles. Using the bushing service tool, press the bushings into the equalizing beam receptacles.
14. Raise the equalizing beam assembly to its original position. Assemble the equalizing beam with new hardware, and tighten all the equalizing beam nuts 800 to 850 lbf·ft (1085 to 1153 N·m).
15. Connect the air springs, shock absorbers, and height control valve link.
    - 15.1 Tighten the airspring nuts 30 to 35 lbf·ft (41 to 48 N·m).
    - 15.2 Tighten the shock absorbers and fasteners 250 to 280 lbf·ft (340 to 380 N·m).
    - 15.3 Tighten the height control valve and fasteners.
16. Remove the floor jack supporting the axle bowl.
17. Install the tires. Remove the jack stands, lower the vehicle, and remove the floor jack supporting the equalizing beam.
18. Increase the suspension air system reservoir pressure to 100 psig (690 kPa). Check for leaks. Both air springs should inflate the suspension to the proper ride height.

CAUTION

While the vehicle air system pressure capabilities may be in excess of 120 psi (827 kPa), the air spring pressure must not be set above 100 psi (690 kPa) or the rubber air spring can tear or fracture.

19. Check the ride height. If ride height adjustment is necessary, see **Subject 100** .
20. Remove the chocks from the tires.

Shock Absorber Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Support the frame with jack stands.

WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

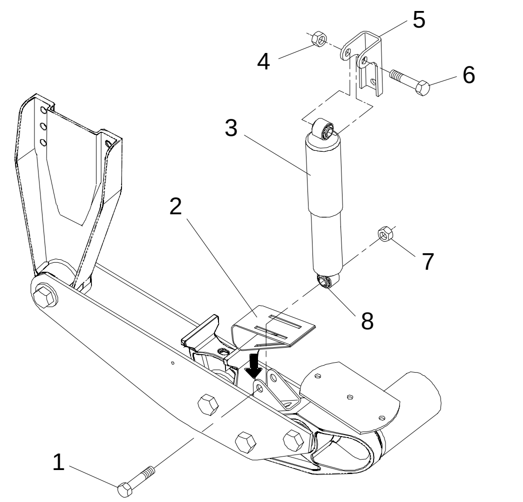
3. Remove the tires.
4. Using a floor jack, support the axle at the axle bowl.
5. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link.

NOTE: If the air spring has a leak and is deflated, this step must still be completed.

6. Remove the upper and lower mounting hardware and the shock absorber. See **Fig. 1**.

NOTE: Inspect the space within and above the debris shield (below the lower loop of the shock) and remove any debris that may be lodged in this space.

7. Install the new shock absorber. Shock orientation is with the dust cover near the top mounting bolt. See **Fig. 1**.
8. Install the upper and lower mounting hardware. Tighten the fasteners 250 to 280 lbf·ft (340 to 380 N·m).
9. As needed, attach the height control valve linkage or attach the air supply line.
10. Remove the floor jack and install the tires.
11. Remove the jack stands.
12. Remove the chocks from the tires.



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1. Bolt
2. Debris Shield
3. Shock Absorber
4. Nut
5. Mounting Bracket
6. Bolt
7. Nut
8. Shock Lower Loop

Fig. 1, Shock Replacement

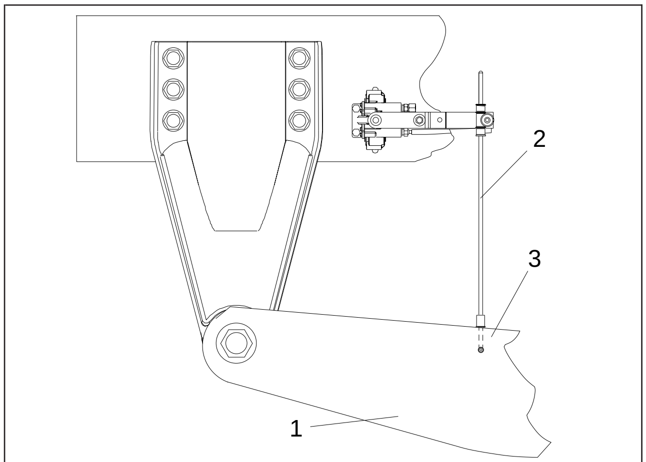
Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Raise the rear of the vehicle and support the frame with jack stands.

WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Remove the tires.
4. Using a floor jack, support the axle at the axle bowl.
5. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link. See **Fig. 1**.



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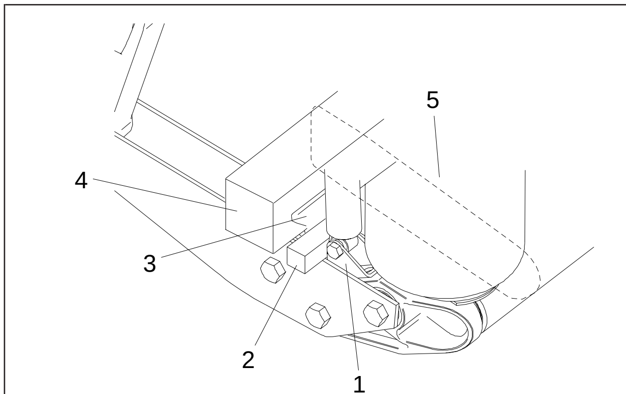
1. Equalizing Beam Plate
2. Height Control Valve Link
3. Lower Link Connection

Fig. 1, Height Control Valve Linkage

NOTE: If the air spring has a leak and is deflated, this step must still be completed.

6. Disconnect the shock absorbers and air springs at the lower connections.
7. With the floor jack supporting the axle bowl, lower the suspension and axle to gain access to the torque rod.
8. Secure the axle to ensure the axle will not move when the torque rod is removed.
   - 8.1 Place a solid 1-3/4 inch (44 mm) square spacer block between the axle adapter and the lower shock bracket to prevent the axle from moving backwards.
   - 8.2 Loop and tie a chain around the axle and equalizing beam to prevent the axle from moving forward. See **Fig. 2** for an outline of the chain placement location.



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1. Lower Shock Bracket
2. 1-3/4 x 1-3/4 Inch Spacer Block
3. Axle Adapter
4. Axle
5. Chain Placement

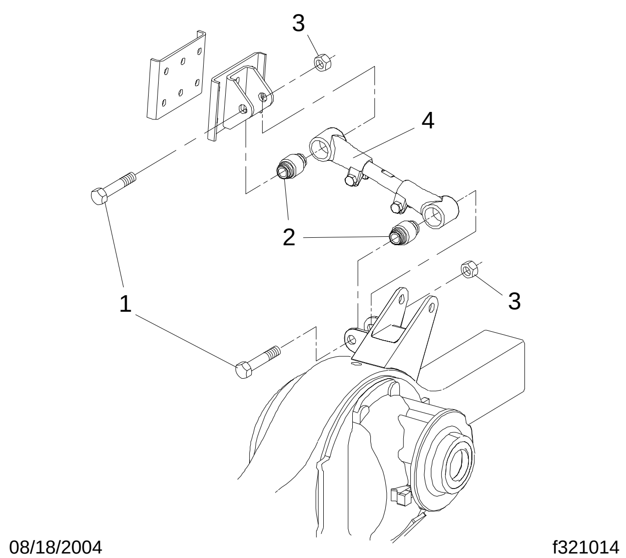
Fig. 2, Chain Placement

WARNING

Always secure the axle. Failure to secure the axle could cause the axle to move in either direction, which may result in serious personal injury.

9. Remove the torque rod connection hardware. See **Fig. 3**.
10. Using a hydraulic press capable of 10,000 lb (4540 kg) of force, press the bushings out from the torque rod ends.

Torque Rod Bushing Replacement



1. Bolts
2. Bushings
3. Nuts
4. Torque Rod

Fig. 3, Torque Rod Removal/Installation

WARNING

The torque rod support fixture must be securely mounted to the hydraulic press. Otherwise, the torque rod may abruptly shift and cause personal injury.

IMPORTANT: Do not use an open flame or other heat source to remove the bushings.

11. Clean out all foreign material from the torque rod bushing receptacles.

NOTE: Because the axle adapter is welded to the axle, a Holland® Neway® bushing service tool (p/n 505 44 012) is available to ease replacement of bushings. The bushing service tool can be used on all ADL bushings, including pivot connections and equalizing beam connections. See Fig. 4.

12. Lubricate the replacement bushings and bushing receptacles with an approved rubber lubricant or a soap and water solution.

IMPORTANT: Do not use oil-based lubricants or brake fluid as they can cause damage to the rubber.

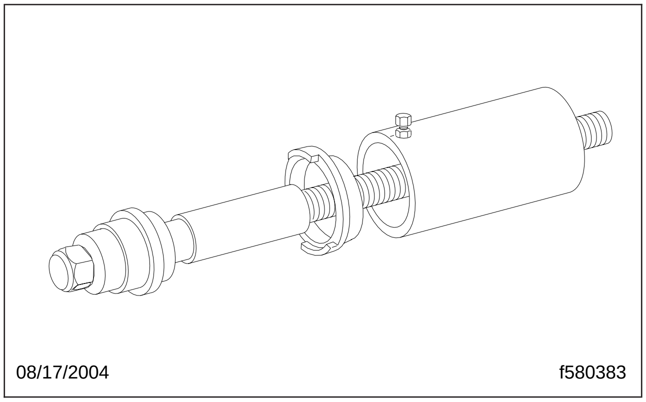


Fig. 4, Bushing Service Tool

13. Center the bushings in the frame bracket receptacle. Using the bushing service tool, press in the torque rod bushings.
14. Attach the torque rod using new hardware, and tighten the fasteners 800 to 850 lbf·ft (1085 to 1153 N·m).
15. With the floor jack supporting the axle bowl, raise the axle/suspension to its original position. Connect the air springs, shock absorbers, and height control valve link.

    15.1 Tighten the air spring nuts 30 to 35 lbf·ft (41 to 48 N·m).

    15.2 Tighten the shock absorber fasteners 250 to 280 lbf·ft (340 to 380 N·m).

    15.3 Tighten the height control valve fasteners.

    IMPORTANT: The suspension should be close to the ride height when tightening the axle adapter connection to avoid bushing windup. The axle bowl can be supported with a floor jack. Do not raise the rear of the vehicle.

16. Install the tires. Remove the jack stands and lower the vehicle.
17. Increase the suspension air system reservoir pressure to 100 psig (690 kPa). Check for leaks. Both air springs should inflate the suspension to the proper ride height.

CAUTION

While the vehicle air system pressure capabilities may be in excess of 120 psi (827 kPa), the air

Torque Rod Bushing Replacement

spring pressure must not be set above 100 psi (690 kPa) or the rubber air spring can tear or fracture.

18. Remove the chocks from the tires.

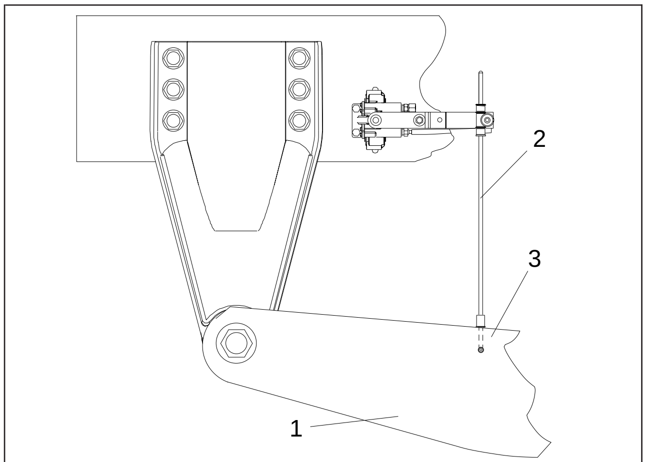
Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Raise the rear of the vehicle and support the frame with jack stands.

WARNING

Always use jack stands of sufficient strength. Failure to do so may cause the vehicle to fall, resulting in personal injury and/or vehicle damage.

3. Remove the tires.
4. Using a floor jack, support the axle at the axle bowl.
5. Exhaust the air from the suspension either by disconnecting the air supply line from the air spring or using the height control valve. If the height control valve is used, disconnect the link from the lower connection and pull down on the link. See **Fig. 1**.

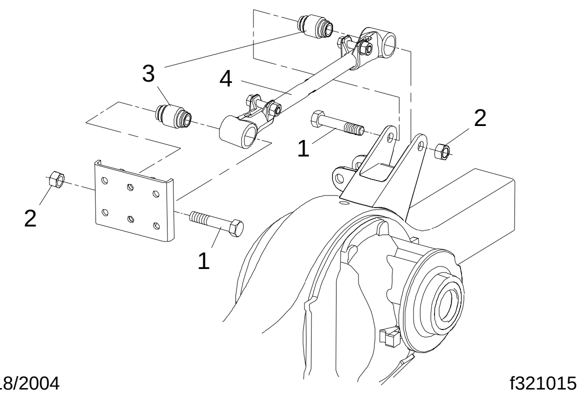


1. Equalizing Beam Plate
2. Height Control Valve Link
3. Lower Link Connection

Fig. 1, Height Control Valve Linkage

NOTE: If the air spring has a leak and is deflated, this step must still be completed.

6. Disconnect the shock absorbers and air springs at the lower connections.
7. Using the floor jack that supports the axle bowl, lower the axle and suspension to gain access to the frame bracket pivot bushings.
8. Remove the track bar connection hardware. See **Fig. 2**.



1. Bolts
2. Nuts
3. Bushings
4. Track Bar

Fig. 2, Track Bar Replacement

9. Using a hydraulic press capable of 10,000 lb (4540 kg) of force, press the bushings out from the torque rod ends.

WARNING

The track bar support fixture must be securely mounted to the hydraulic press. Otherwise, the track bar may abruptly shift and cause personal injury.

IMPORTANT: Do not use an open flame or other heat source to remove the bushings.

NOTE: Because the axle adapter is welded to the axle, a Holland® Neway® bushing service tool (p/n 505 44 012) is available to ease replacement of bushings. The bushing service tool can be used on all ADL bushings, including pivot connections and equalizing beam connections. See **Fig. 3**.

10. Clean out all foreign material from the track bar bushing receptacles.
11. Lubricate the new bushings and bushing receptacles with an approved rubber lubricant or a soap and water solution.

Track Bar Replacement

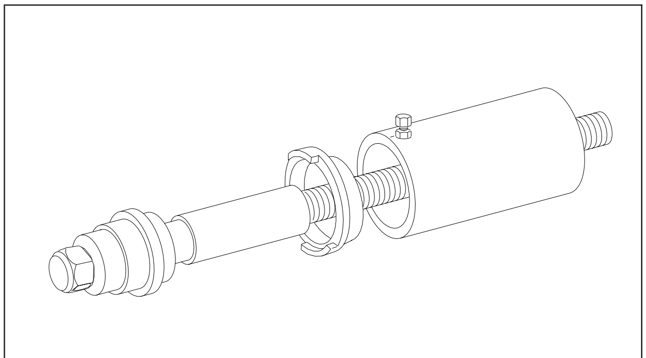


Fig. 3, Bushing Service Tool

IMPORTANT: Do not use an oil-based lubricant or brake fluid. Damage to the rubber can occur.

12. Center the bushings in the track bar receptacles. Using the bushing service tool, press in the bushings.
13. Attach the track bar using new hardware and tighten the fasteners 400 to 450 lbf·ft (542 to 610 N·m).
14. With the floor jack supporting the axle bowl, raise the axle/suspension to its original position.
15. Connect the air springs, shock absorbers, and height control valve link.
    - 15.1 Tighten the air spring nuts 30 to 35 lbf·ft (41 to 48 N·m).
    - 15.2 Tighten the shock absorber fasteners 250 to 280 lbf·ft (340 to 380 N·m).
    - 15.3 Tighten the height control valve.

IMPORTANT: The suspension should be close to the ride height when tightening the front pivot connection to avoid bushing windup. The axle bowl can be supported with a floor jack. Do not raise the rear of the vehicle.

16. Install the tires. Remove the jack stands, lower the vehicle, and remove the floor jack.
17. Increase the suspension air system reservoir pressure to 100 psig (690 kPa). Check for leaks. All air springs should inflate the suspension to the proper ride height.

CAUTION

While the vehicle air system pressure capabilities may be in excess of 120 psi (827 kPa), the air spring pressure must not be set above 100 psi (690 kPa) or the rubber air spring can tear or fracture.

18. Remove the chocks from the tires.

Troubleshooting

Problem—All Air Springs Are Flat

Problem—All Air Springs Are Flat	
Possible Cause	**Remedy**
There is insufficient air pressure in the vehicle air system.	Check the air pressure gauge on the instrument panel. If air pressure is low, run the engine until a minimum pressure of 100 psig (690 kPa) is indicated on the gauge.
Air is leaking from the suspension air system or the air brake system.	Test for air leakage due to loose fittings or damaged air lines, air springs, brake actuators, or control valve. Tighten loose fittings to stop the leakage and/or replace worn or damaged parts.

Problem—Air Springs Deflate Rapidly When the Vehicle Is Parked

Problem—Air Springs Deflate Rapidly When the Vehicle Is Parked	
Possible Cause	**Remedy**
Air is leaking from the suspension air system.	Test for air leakage due to loose fittings between the air tank and air suspension or damaged air lines, air springs, or height control valve. Apply a soapy solution to connections and air springs, if necessary, to check for bubbles (leaks). Tighten loose fittings to stop the leakage and/or replace worn or damaged parts.

Problem—The Ride Height Is Too Low or Too High

Problem—The Ride Height Is Too Low or Too High	
Possible Cause	**Remedy**
The height control valve is out of adjustment.	Adjust the height control valve.

Problem—The Air Spring Is Ruptured

Problem—The Air Spring Is Ruptured	
Possible Cause	**Remedy**
The air spring is cut or punctured.	Replace the air spring. See **Subject 130**.

Problem—The Air Spring Failed

Problem—The Air Spring Failed	
Possible Cause	**Remedy**
Continual or repeated over-extension of the air spring.	Inspect for a broken or loose shock absorber or shock absorber mounting bracket. Connect loose parts and replace any damaged parts. Check the adjustment of the height control valve.
The air spring is worn out.	Replace the air spring. See **Subject 130**.

Troubleshooting

Problem—The Air Spring(s) Fail to Fully Deflate When All Weight Is Removed from the Suspension

Problem—The Air Spring(s) Fail to Fully Deflate When All Weight Is Removed from the Suspension	
Possible Cause	**Remedy**
There are restricted air line(s) between the height control valve and the air spring(s).	Disconnect the height control valve linkage and rotate the actuating lever to the 45 degree down position. If the air spring(s) remain inflated, check for pinched or blocked line(s).

Problem—Shock Absorber Failures

Problem—Shock Absorber Failures	
Possible Cause	**Remedy**
Overextension/mislocated shock brackets.	Incorrect shocks are installed. Check for oil leaking from the shock. If the shock is worn out from length of service, replace the shock.

Problem—Excessive Tire Wear

Problem—Excessive Tire Wear	
Possible Cause	**Remedy**
The axles are not aligned.	Align the axles. See **Group 35**.

Problem—The Vehicle Is Unstable or Handles Poorly

Problem—The Vehicle Is Unstable or Handles Poorly	
Possible Cause	**Remedy**
There are loose frame bolts or attachments.	Tighten the frame bolts. See **Group 31**.
There is a cracked or loose frame crossmember.	Repair or replace damaged frame members and tighten all nuts and bolts to the correct specifications.
Check the ride height.	Adjust the ride height if necessary.
There is a loose equalizing beam connection.	Replace worn bushings. See **Subject 160**.
There is a loose or worn pivot connection.	Tighten the pivot connections to and/or replace the bushings if necessary. See **Subject 150**.
There is a cracked or loose equalizing beam plate(s).	Replace the failed part.

Problem—Constant Noise from the Suspension

Problem—Constant Noise from the Suspension	
Possible Cause	**Remedy**
There is a loose shock, track bar, or torque rod.	Tighten to specification. See **Group 32**.
There is a loose equalizing beam plate connection at the frame bracket, axle adapter, and/or transverse beam.	Tighten the appropriate hardware to specification.

Troubleshooting

Problem—Constant Noise from the Suspension	
Possible Cause	**Remedy**
There is debris wedged between the axle adapter and the transverse beam.	Remove the debris shield and remove all debris. Install the the debris shield.

Problem—Driveline Vibration

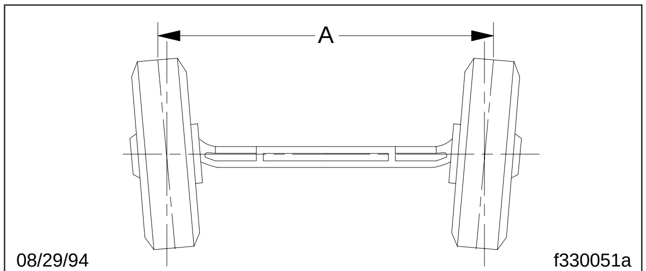
Problem—Driveline Vibration	
Possible Cause	**Remedy**
The pinion angle is out of adjustment.	Adjust the pinion angle. See **Subject 120**.
The ride height is incorrect.	Adjust the ride height. See **Subject 100**.

General Description

Correct front axle wheel alignment is needed to ensure long tire life, ease of handling, and steering stability.

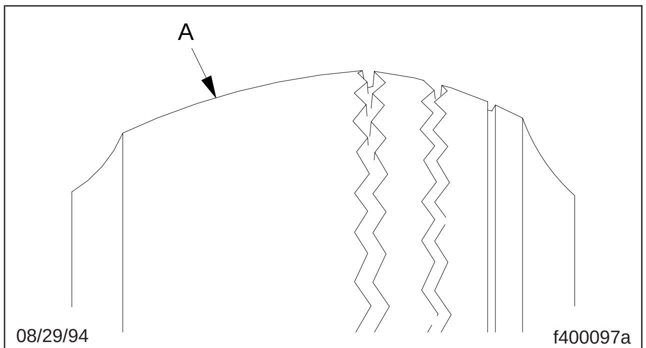
Three factors are involved in wheel alignment: camber angle, caster angle, and wheel toe-in.

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**.

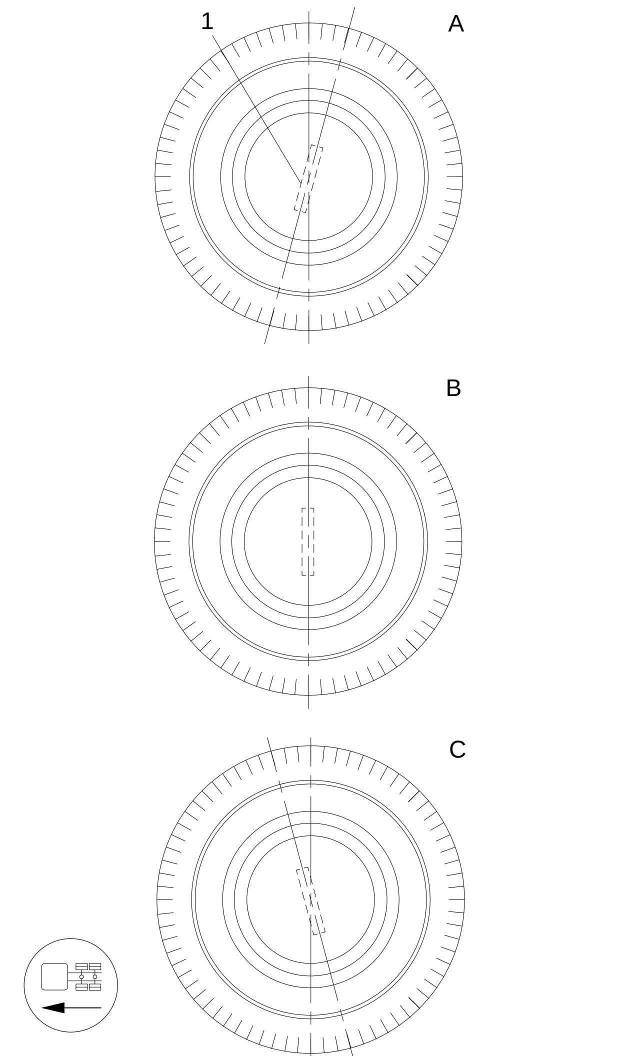
Advanced wear patterns can be seen, but less severe wear patterns are detected only by rubbing the palm of your hand flat across the tire tread.

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; see **Section 33.01** for other possible causes.

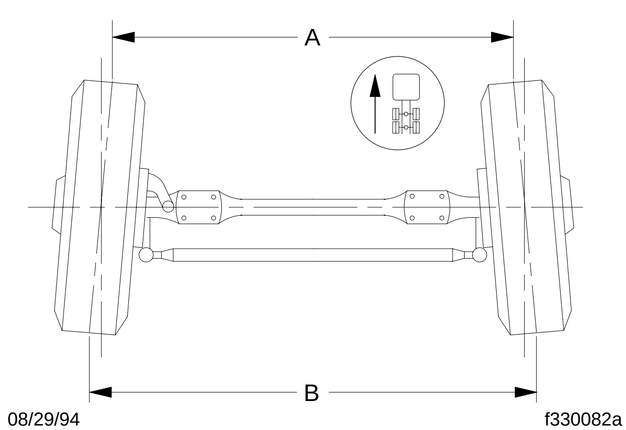
If excessive tire tread wear has resulted from incorrect wheel alignment, replace the damaged tires. For minimum tread wear specifications, see Group 40 of the chassis maintenance manual.

General Information



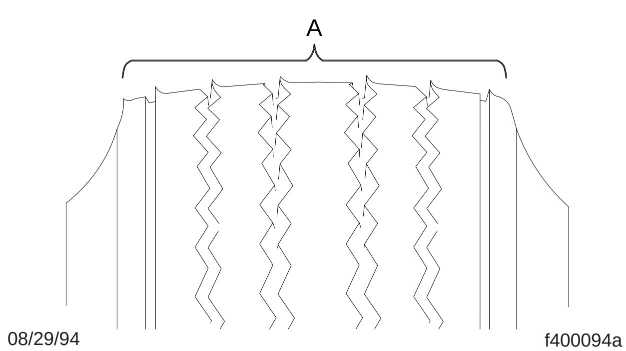
1. Knuckle Pin (King Pin)
A. Positive Caster
B. Zero Caster
C. Negative Caster

Fig. 3, Caster Angle



NOTE: B minus A equals toe-in.

Fig. 4, Wheel Toe-In (overhead view)

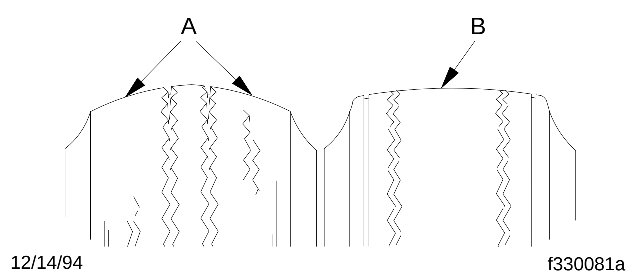


A. Feathered Edges

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** in this manual and the 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**.



A. Underinflation Wear B. Overinflation Wear

Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels, rims, or wheel stud holes. Replace the wheel if any of these conditions exist.
5. On each side of the vehicle, check the height of the chassis above the ground. Sagging, fatigued, or broken suspension springs create a lopsided vehicle appearance. This causes an unbalanced weight distribution. Anything that changes the ratio of weight on the springs affects the alignment angles and also the tire tread contact area. Replace damaged springs as instructed in **Group 32** 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 **Group 46** 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**.

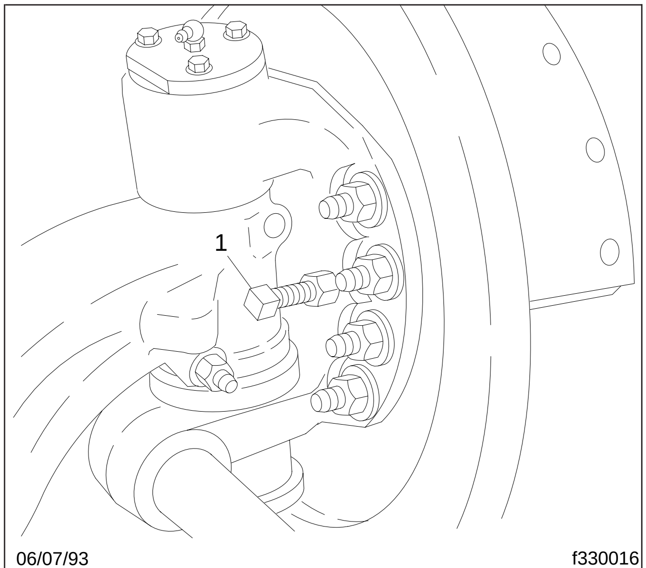


Fig. 1, Axle Stop

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 **Group 46** of 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.

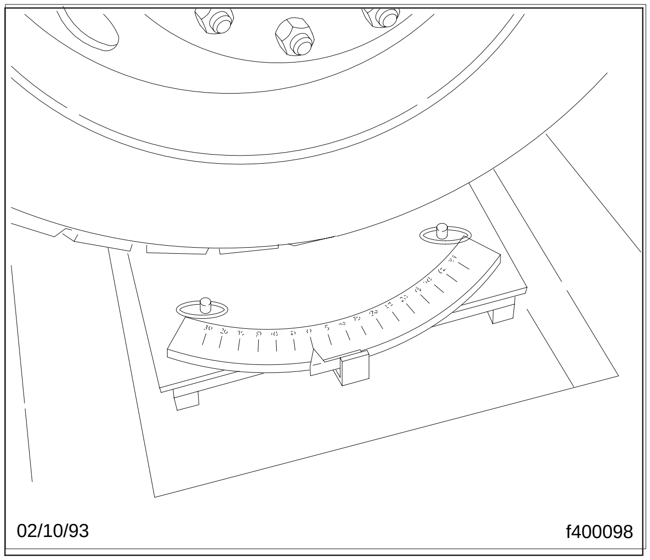


Fig. 2, Turn-Plate (Turntable), Stationary Type

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.

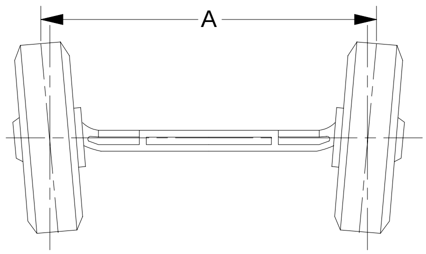
   Tighten the locknut to the value in the torque table under **Specifications, 400**.

Steering Angle Checking and Adjusting

5. Repeat the step above with the steering wheel turned counterclockwise. Adjust the axle stop, as needed.
6. Adjust the power 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, see **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

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



A. Camber (positive)

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. 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.

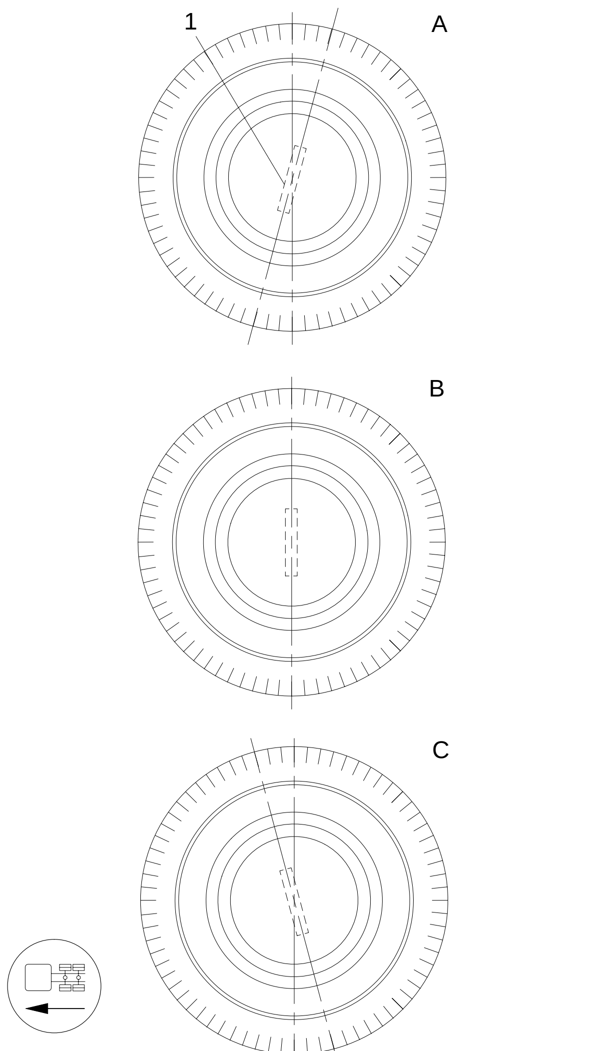
WARNING

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

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



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.

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:

IMPORTANT: Extreme angle shims cannot be used to correct caster angles that vary by more than 2 degrees from the values in the table. Weak or broken leaf springs, or worn shackle bushings, can cause extreme deviations to caster angles. Replace damaged parts before doing caster adjustments.

1. Apply the parking brakes, and chock the front and rear tires.
2. Back off the U-bolt nuts from the U-bolts on one side of the front axle.
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.

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 applicable table in **Specifications, 400**.

   U-bolt nuts need periodic retightening. Refer to the suspension section in the chassis maintenance maintenance manual for recommended intervals.

Caster Angle Checking and Adjusting

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.

Wheel Toe-In Checking and Adjusting

Checking and Adjusting

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

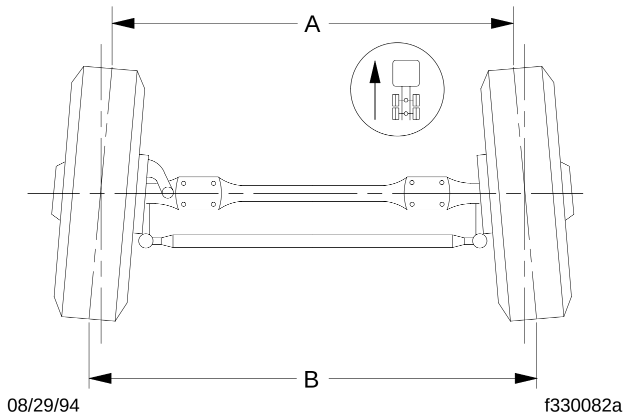
Using the alignment equipment manufacturer's operating instructions, measure the wheel toe-in. Compare the measurement with that shown in the appropriate table in **Specifications, 400**. If corrections are needed, go to the applicable (tie rod adjustment) step below.

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.



NOTE: B minus A equals toe-in.

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

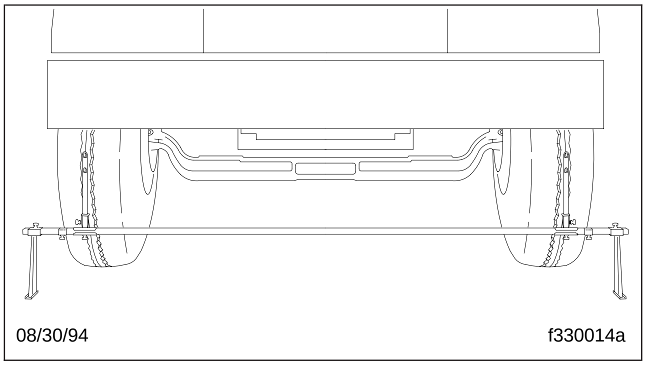


Fig. 2, Trammel Bar Positioning

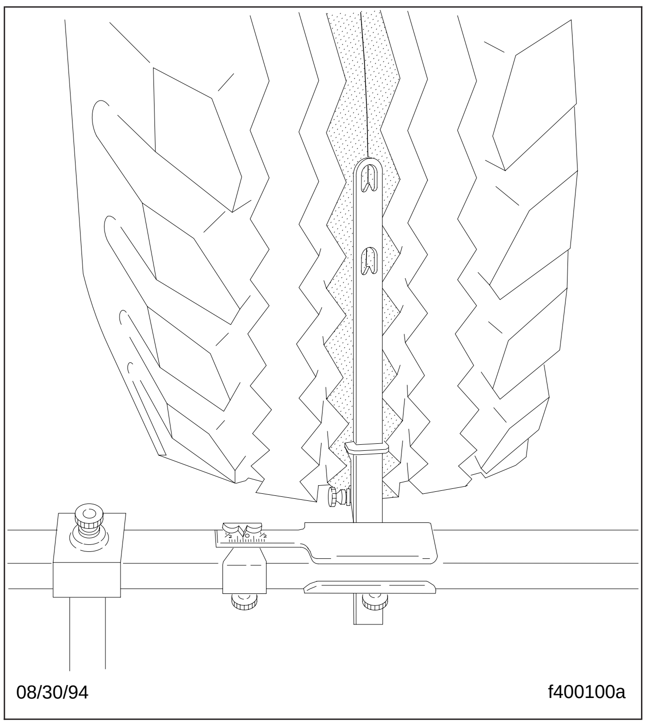


Fig. 3, Calculating Wheel Toe-In

Specifications

NOTE: The specifications in **Table 1** are for unloaded vehicles. The specifications will vary as weight is added to the vehicle and transferred to the front axle.

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 the table.

Camber, Caster, and Toe-In			
Suspension	**Camber: degrees**	**Caster: degrees**	**Toe-In: inches**
AS-120	0 ± 1/2	4.5 to 6.0	0 to 1/16
IFS	0 ± 1/2	4.0 to 5.0	0 to 1/16
Softek (front-engine diesel chassis)	0 ± 1	2.9 to 4.9	+1/32 to +3/32

Table 1, Camber, Caster, and Toe-In

<table>
<tr><th colspan="3">Tie Rod Clamp Locknut Torque Values</th></tr>
<tr><th>Axle Model</th><th>Clamp Nut Size</th><th>Torque: lbf·ft (N·m)</th></tr>
<tr><td>FC–941
FD–961
FF–961
FG–941
FL–941</td><td>5/8–11
5/8–18</td><td>40 to 60 (54 to 81)
40 to 55 (54 to 75)</td></tr>
<tr><td>SteerTek (front-engine diesel chassis)</td><td>5/8–11</td><td>50 to 60 (68 to 81)</td></tr>
</table>

Table 2, Tie Rod Clamp Locknut Torque Values

Miscellaneous Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
U-Bolt High Nut	5/8–11	195 (264)
	3/4–16	335 (454)
Stopscrew Locknut	—	58 (78)

Table 3, Miscellaneous Torque Values

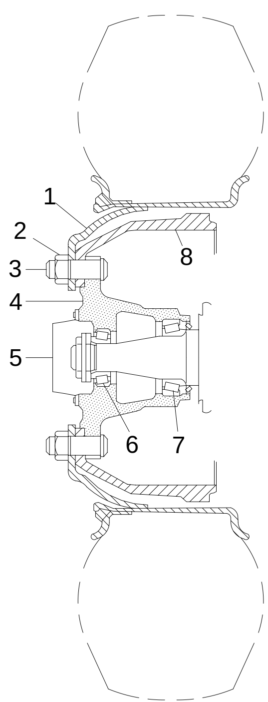
General Information

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**.



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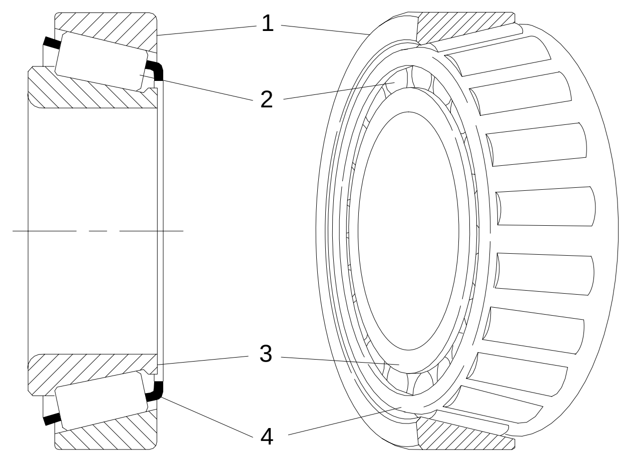
1. Disc Wheel
2. Wheel Nut
3. Wheel Stud
4. Hub
5. Hub Cap
6. Outer Wheel Bearing
7. Inner Wheel Bearing
8. Brake Drum

Fig. 1, Hub and Wheel Assembly



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1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Wheel Bearing

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.

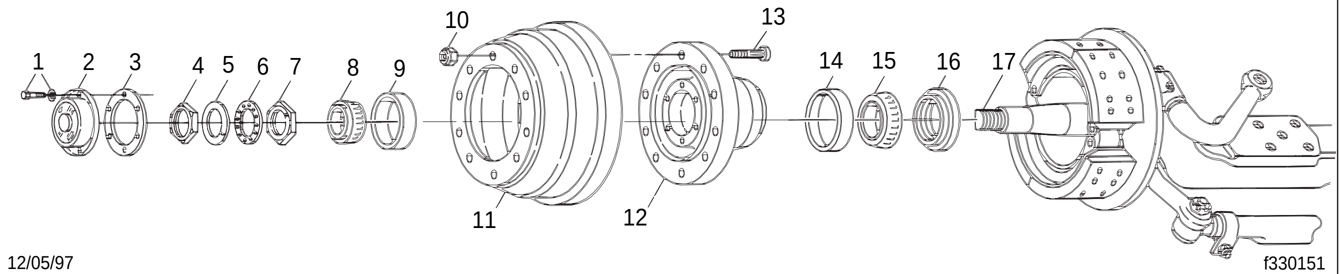
WHEEL STUDS

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



1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Hub Cap Gasket
4. Jam Nut
5. Lockwasher
6. Lockring
7. Wheel Bearing Adjusting Nut
8. Outer Wheel Bearing
9. Outer Wheel Bearing Cup
10. Wheel Nut
11. Brake Drum, Outboard-Mounted
12. Wheel Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Axle Spindle (Steering Knuckle)

Fig. 3, Typical Front Axle Assembly

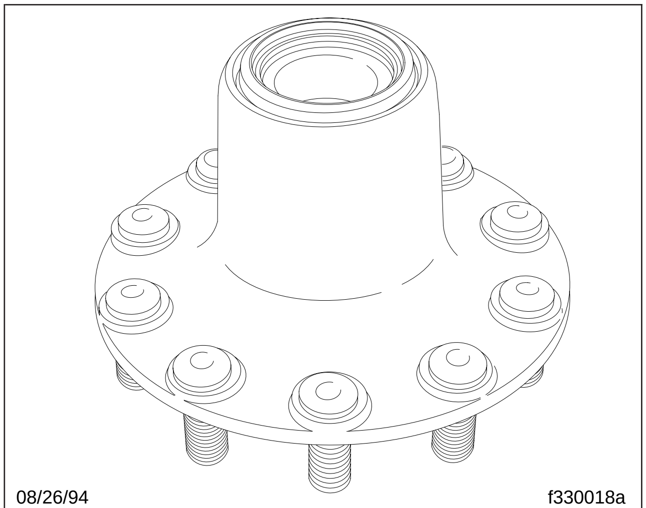
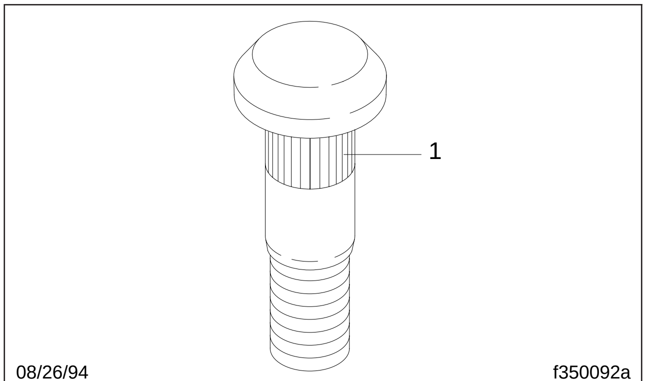


Fig. 4, Typical Front Axle Wheel Hub

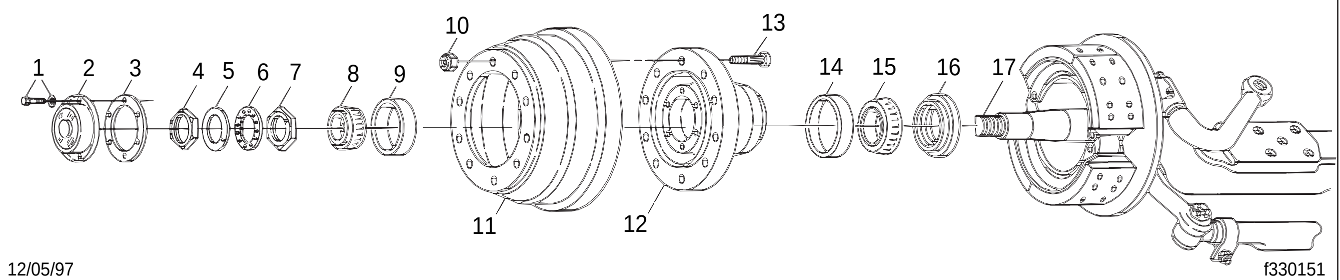


1. Serrations

Fig. 5, Wheel Stud

Hub Assembly Removal and Installation, Disc Wheels

Removal



1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Hub Cap Gasket
4. Jam Nut
5. Lockwasher
6. Lockring
7. Wheel Bearing Adjusting Nut
8. Outer Wheel Bearing
9. Outer Wheel Bearing Cup
10. Wheel Nut
11. Brake Drum, Outboard-Mounted
12. Wheel Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Axle Spindle (Steering Knuckle)

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. 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. 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). See **Fig. 1**. 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.

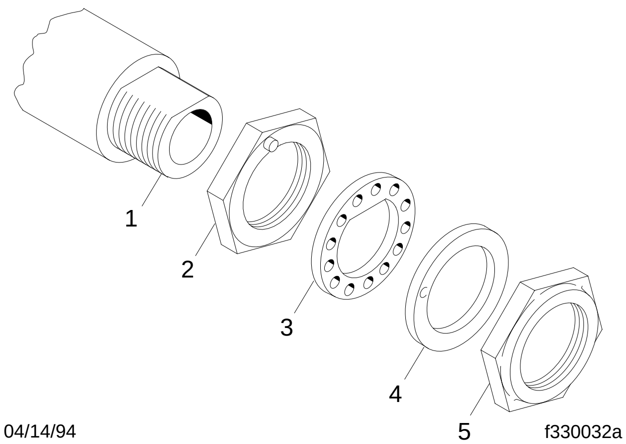
7. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket.
8. Remove the axle spindle (steering knuckle) jam nut, lockwasher, and lockring. See **Fig. 2**.
9. Back off the wheel bearing adjusting nut about two turns, or enough to allow the weight of the hub to be lifted from 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

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

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.

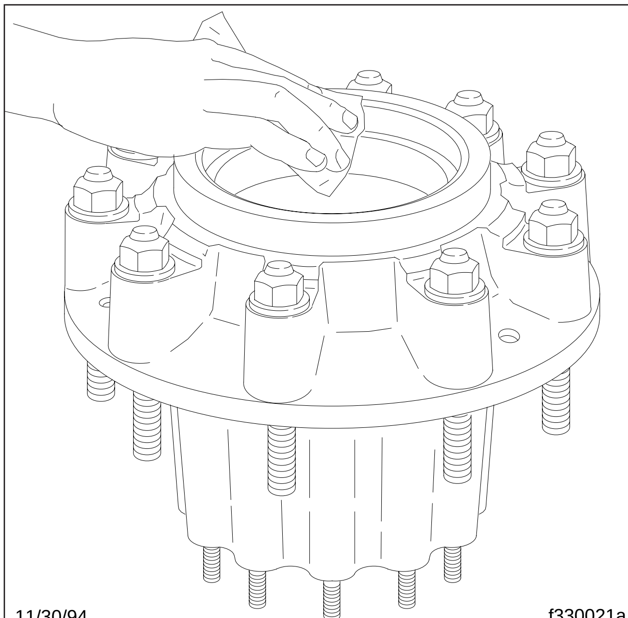
13. Remove the hub from the axle spindle. Be careful not to damage the axle spindle threads as the assembly is removed.
14. Remove the oil or grease seal from the hub with a seal removal tool.
15. Remove the inner wheel bearing from the hub. Handle the bearing assembly with clean, dry hands.

    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.

16. Using an emery cloth or file, remove all burrs from the hub shoulder. See Fig. 3 or Fig. 4.

    Clean any metal filings from the parts. For instructions, see Subject 110.



NOTE: Typical application.

Fig. 3, Clean the Hub Shoulder

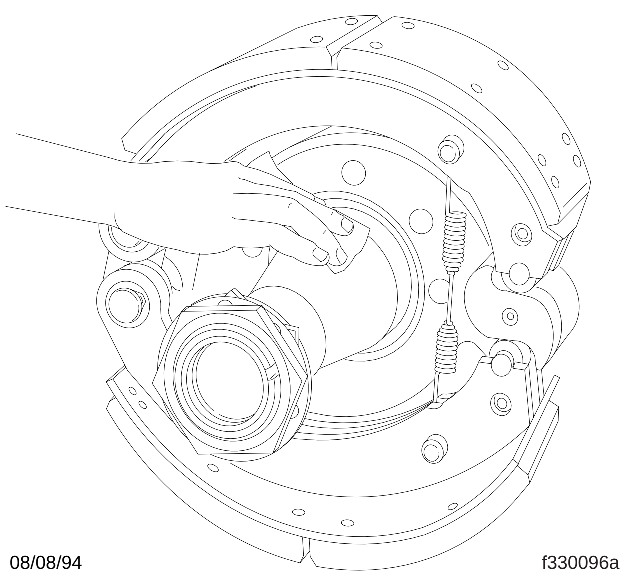
Installation

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, continuing through installation of the wheels.

1. Using clean solvent, remove the old oil or grease from the axle spindle (steering knuckle) and the

Hub Assembly Removal and Installation, Disc Wheels



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NOTE: Typical application.

Fig. 4, Clean the Spindle

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.

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.

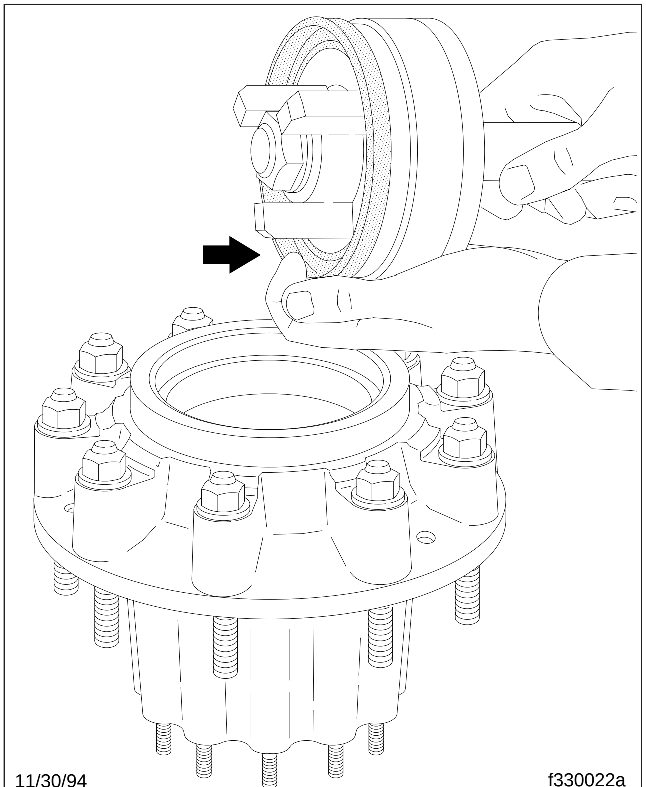
3. If the axle is equipped with oil-lubricated bearings, coat them with fresh oil; if equipped with greased bearings, pack them using a pressure packer, if possible. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease 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. 5**. The correct adaptor is identified on the box.



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NOTE: Typical application.

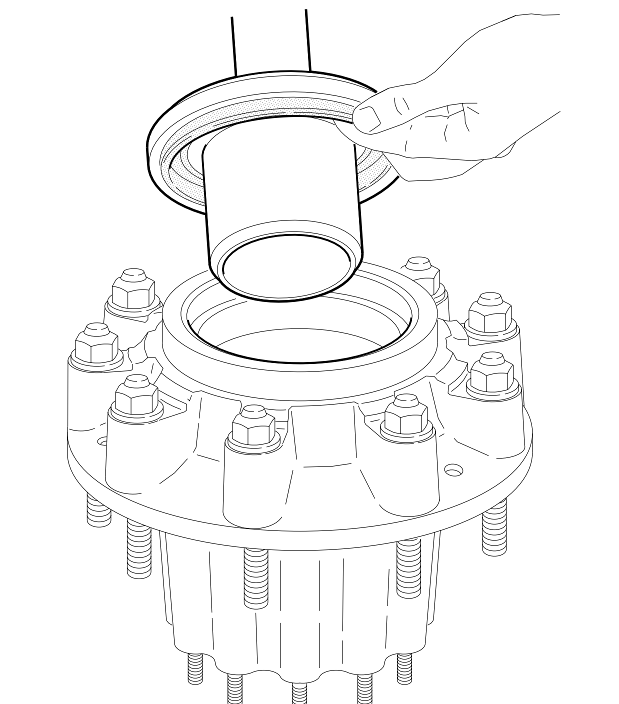
Fig. 5, Seat the Seal in the Tool

   5.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 6**. 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. 7**. 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

Hub Assembly Removal and Installation, Disc Wheels



NOTE: Typical application.

Fig. 6, Insert the Tool

seal back and forth. A slight movement indicates a damage-free installation.

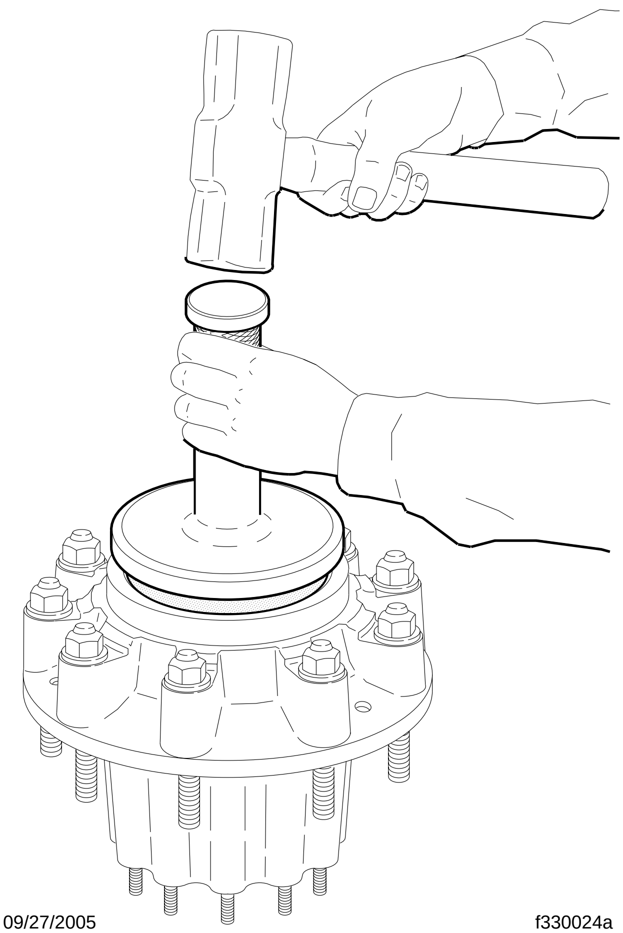
6. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.

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. 8**.

   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.

8. Install the wheel bearing adjusting nut. Tighten the nut finger-tight. Adjust the bearings. See **Fig. 2**.

   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.



NOTE: Typical application.

Fig. 7, Strike the Tool

   8.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner (adjusting) nut 100 lbf·ft (136 N·m) while rotating the wheel hub assembly in both directions.

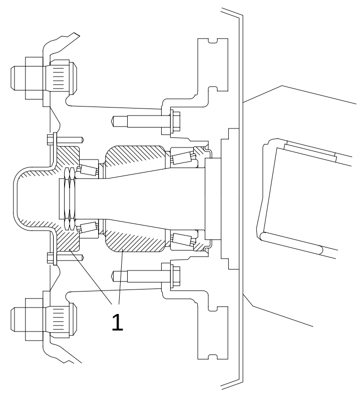
   8.2 Loosen the inner nut completely.

   8.3 Tighten the inner nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.

   8.4 Back off the inner nut one-third turn.

   8.5 Install the jam nut and locking device as follows.

Hub Assembly Removal and Installation, Disc Wheels



1. Lubricate here.

Fig. 8, Lubricate the Bearings

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**.

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.

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.

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.

Hub Assembly Removal and Installation, Disc Wheels

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. 8**.
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.

<table>
<tr><th colspan="3">Jam Nut Torques</th></tr>
<tr><th rowspan="2">Locking Device</th><th colspan="2">Torque: lbf·ft (N·m)</th></tr>
<tr><th>1-1/8 to 2-5/8 Inch Jam Nuts</th><th>2-5/8 Inch or Larger Jam Nuts</th></tr>
<tr><td>Tanged Nut-Lock</td><td colspan="2" rowspan="2">100 (136)</td></tr>
<tr><td>Lockring</td></tr>
<tr><td>Tanged Nut-Lock and Lockring</td><td rowspan="2">200–300 (271–407)</td><td rowspan="2">250–400 (339–542)</td></tr>
<tr><td>Lockwasher and Lockring</td></tr>
</table>

Table 1, Jam Nut Torques

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. 9. 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.

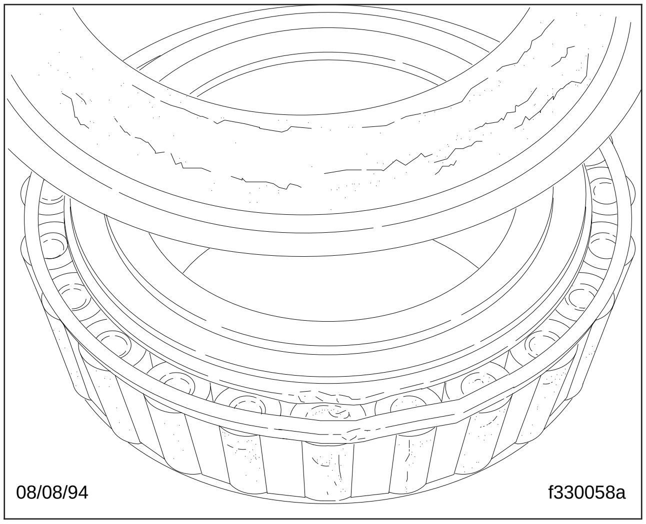


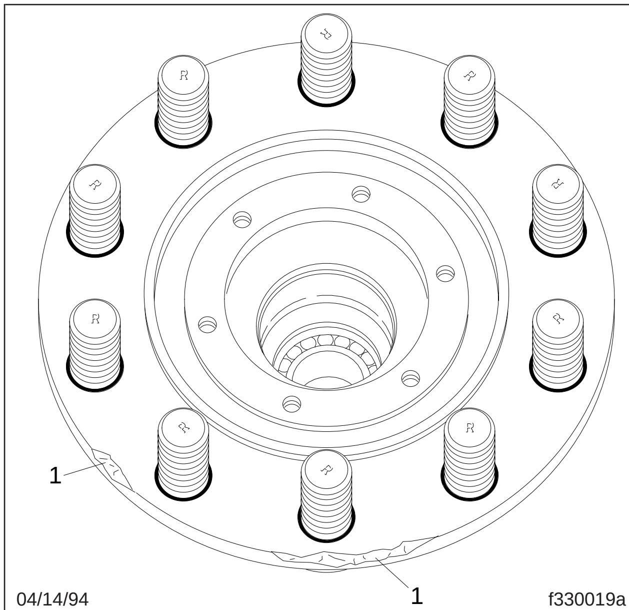
Fig. 9, Bearing Damage Resulting from Inadequate Lubrication

16. Adjust the front axle brakes. For instructions, see Group 42 of the *Recreational Vehicle Chassis Maintenance Manual*.
17. Remove the safety stands from under the axle; lower the vehicle.
18. 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.

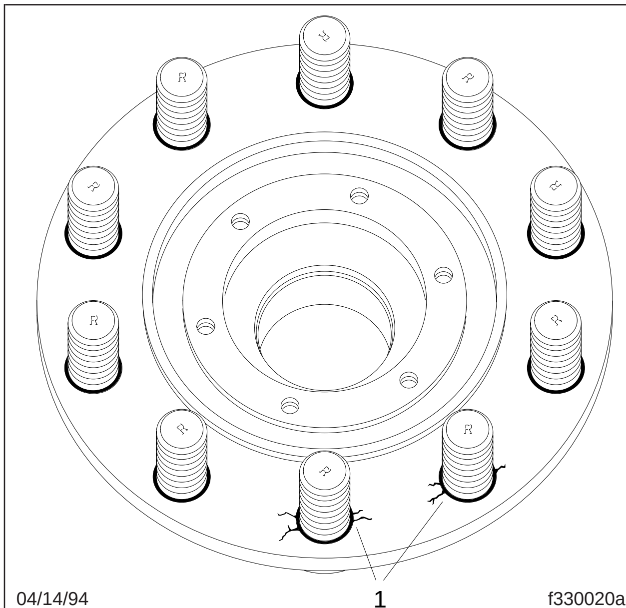
   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.



1. Wear Spots

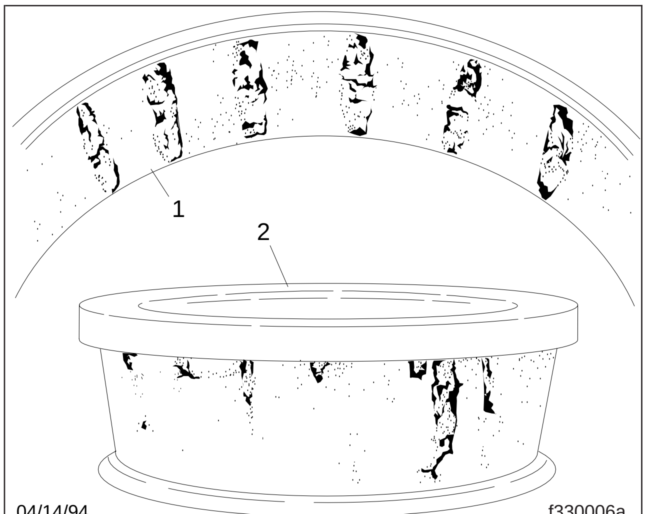
Fig. 1, Damaged Front Axle Wheel Hub

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

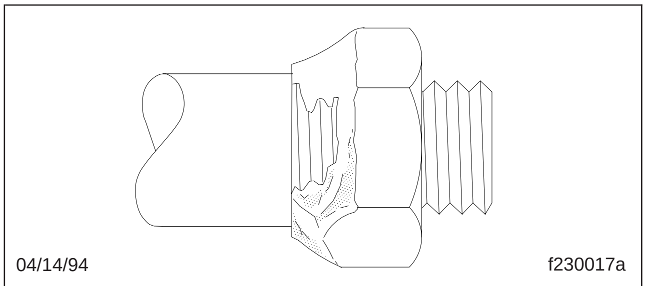


Fig. 4, Damaged Wheel Stud Nut

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

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

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.
2. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper.

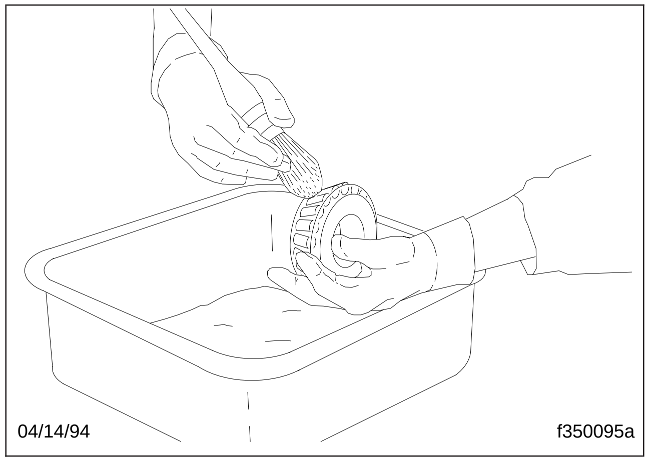


Fig. 5, Wheel Bearing Cleaning

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**.

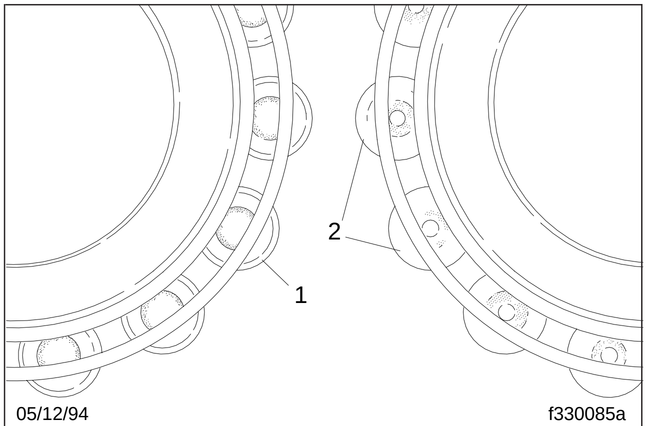
B. Visible step wear, especially at the small end of the roller track, or deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 7**.

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**.

F. Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.



1. New Bearing
2. Worn Bearing Rollers

Fig. 6, Wheel Bearing Roller Wear

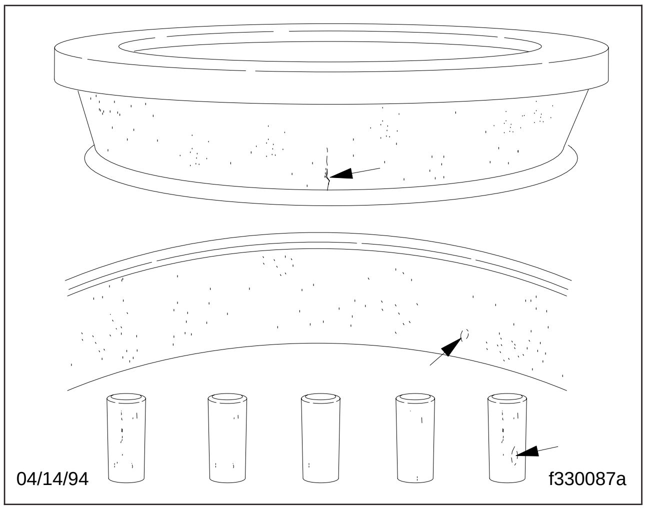


Fig. 7, Indentations, Cracks, or Breaks in Bearing Surfaces

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**.

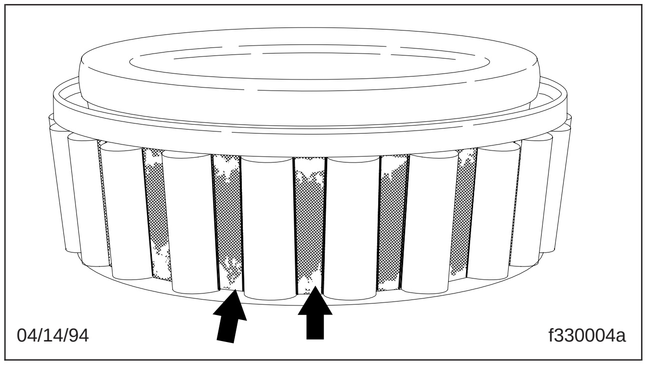


Fig. 8, Rubbing Marks on Bearing Cage

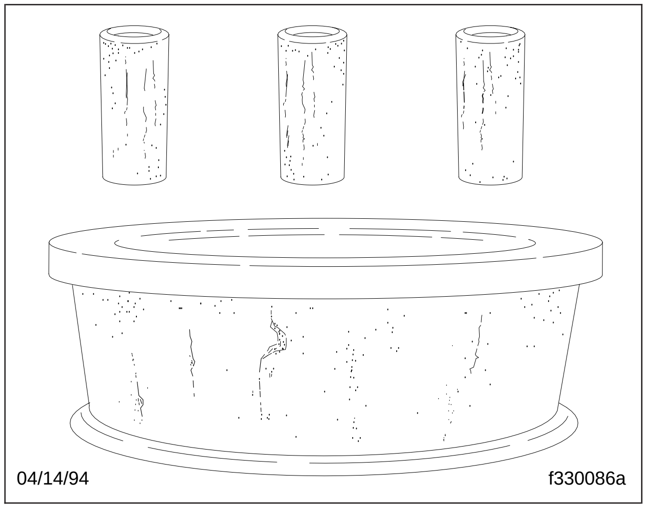


Fig. 9, Etching (Pitting) on Bearing Surfaces

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

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.

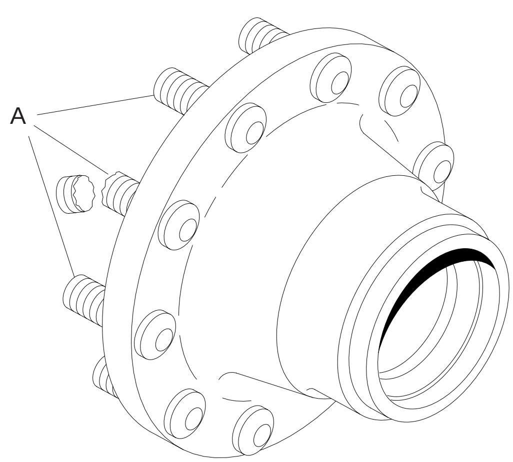
5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

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.



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A. Replace

Fig. 1, Studs to Replace

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.

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 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."

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**.

Hub Runout Measurements

If either the lateral or radial runout of the hub is beyond acceptable limits, replace the hub. For instructions, see **Subject 100** in this section.

Measurements

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

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

2. Remove the wheel and tire assembly. See **Group 40** for instructions.
3. For drum brakes, remove the brake drum. See **Group 42** for instructions.
4. Clean the hub surfaces where the measurements will be taken—see **Fig. 1** and **Fig. 2**.
5. To measure lateral runout, set up a dial indicator as shown in **Fig. 1**, then turn the hub one revolution and note the highest and lowest measurements.

   For ConMet hubs, the acceptable lateral runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable lateral runout specification.
6. To measure radial runout, set up a dial indicator as shown in **Fig. 2**, then turn the hub one revolution and note the highest and lowest measurements.

   For ConMet hubs, the acceptable radial runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable radial runout specification.

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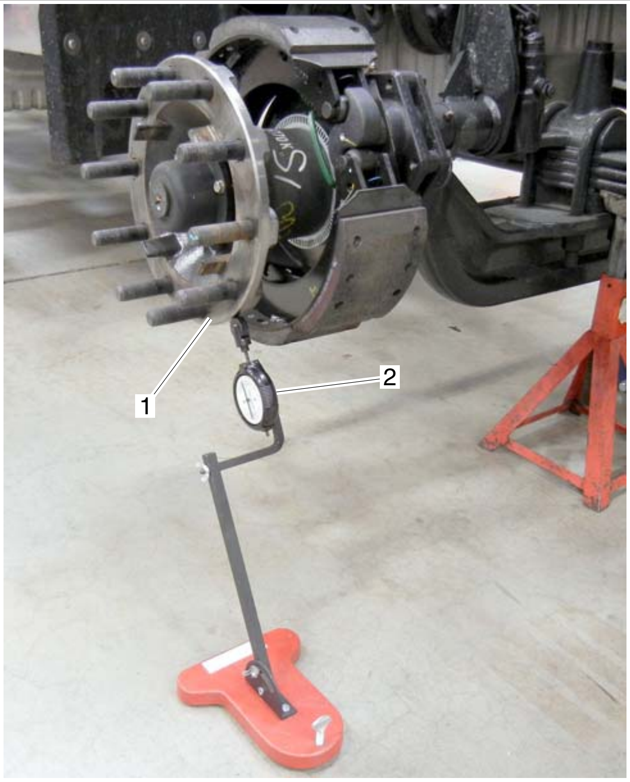
1. Hub
2. Dial Indicator (with roller point)

Fig. 1, Setup to Measure Lateral Runout

Hub Runout Measurements



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1. Hub
2. Dial Indicator (with roller point)

Fig. 2, Setup to Measure Radial Runout

Troubleshooting Tables

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil was used on the bearings, or the wrong type of oil was used.	Clean then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil. 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** in this section.
Flat spots or dents on the roller surface were caused by skidding of the roller or improper handling of the wheel bearing during installation.	Clean then inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil. For lubricant specifications, see **Specifications, 400.**

Problem—Broken Wheel Studs

Problem—Broken Wheel Studs	
Possible Cause	**Remedy**
The wheel nuts were overtightened.	Replace the wheel studs. See **Group 40** for the wheel 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.**

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.

Troubleshooting

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

Torque Values		
Fastener Application	**Size (grade 8)**	**Torque: lbf·ft (N·m)**
Hub Cap Capscrews	5/16–18	15 (20)
Disc-Wheel Brake Drum Nuts	3/4–10	240 (325)

Table 1, Torque Values

Approved Lubricants for Meritor Axles with Grease-Lubricated Bearings	
Lubricant Type	**Grease Specification**
Lithium-Based	Standard: 0–617A or equivalent
Wheel Bearing Grease	Optional: 0–617B or equivalent

Table 2, Approved Lubricants for Meritor Axles with Grease-Lubricated Bearings

Approved Lubricants for Freightliner Axles with Oil-Filled Hubs	
Recommended Lubricant Type	**Lubricant SAE Viscosity Grade**
Hypoid Gear Oil	80W–90

Table 3, Approved Lubricants for Freightliner Axles with Oil-Filled Hubs

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.

WARNING

Never work around or under a vehicle that is supported only by a jack. Jacks can slip, causing the vehicle to fall, which could result in serious injury or death. Always support the vehicle with safety stands.

2. Raise the front of the vehicle and support it with safety stands.
3. Release the system air pressure.
4. Remove the front wheel and tire assemblies. For instructions, see **Group 40** in this workshop manual.
5. Remove the brake drums.
6. Remove the front hubs from the axle. For instructions, see **Section 33.01** in this group.
7. Remove the brake shoes. For instructions, see **Group 42** in this workshop manual.
8. Remove the ABS sensors and wiring from the brake anchor plates and secure them and their wiring out of the way.
9. Remove the brake air chambers and the slack adjusters. For instructions, see **Group 42** in this workshop manual.
10. Remove the brake anchor plates from the axle ends.
11. Disconnect the drag link from the axle steering arm.
12. Disconnect the sway bar from the axle brackets.
13. Using a suitable jack, support the front axle.
14. Remove the nuts holding the axle beam to the leaf springs and the air bag brackets. There are four nuts on each side.
15. Remove the axle from the vehicle.
16. 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 holding the air bags to the leaf springs. Install the nuts and washers and tighten 220 lbf·ft (298 N·m).
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** in this workshop manual.
5. Install the brake anchor plates to the axle ends. For instructions, see **Group 42** in this workshop manual.
6. Install the brake air chambers and slack adjusters to the axle. For instructions, see **Group 42** in this workshop manual.
7. Install the ABS sensors.
8. Install the brake shoes. For instructions, see **Group 42** in this workshop manual.
9. Install the hubs and adjust the wheel bearings. For instructions, see **Section 33.01** in this group.
10. Install the brake drums.
11. Install the tire and wheel assemblies. For instructions, see **Group 40** in this workshop manual.
12. Raise the vehicle, remove the safety stands, then lower the vehicle.
13. Start the engine and build the air pressure.
14. Check that the suspension air bags are inflating correctly.
15. 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.

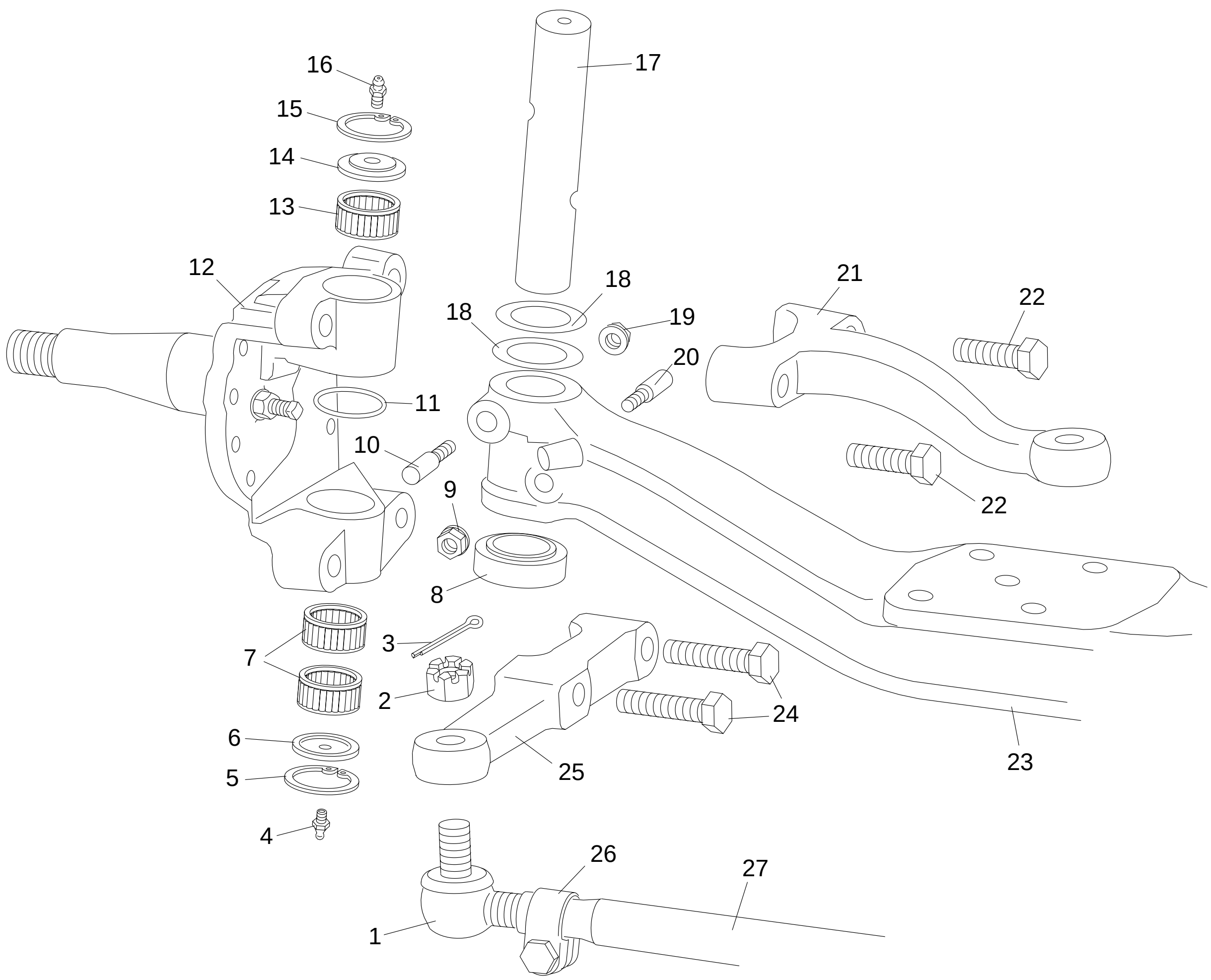
8. Remove the thrust friction bearing (driver side) or the thrust roller bearing (passenger side) from the top of the lower steering knuckle bore.

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



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).

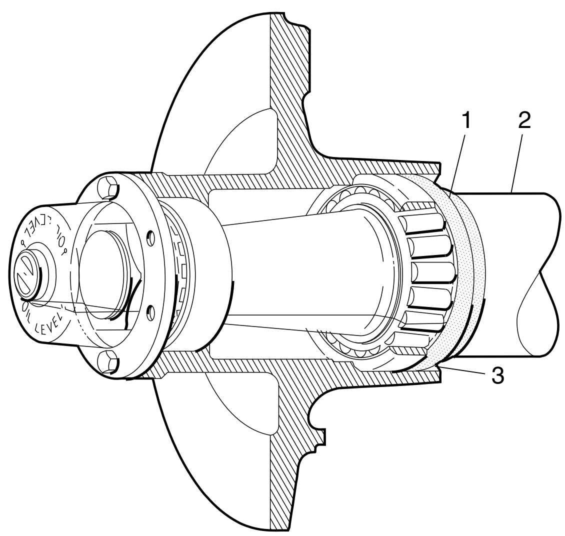
Steering Knuckle Disassembly and Assembly

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

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. Seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub.

The oil seal fits between the hub bore and the axle spindle. See **Fig. 1**.



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1. Wheel Oil Seal
2. Axle Spindle
3. Wheel Hub Bore

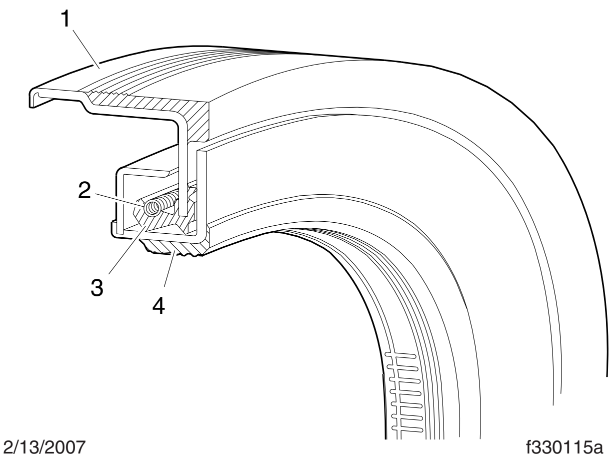
Fig. 1, Wheel Oil Seal

Most wheel oil seals consist of four basic parts (**Fig. 2**):

- the outside edge (also called the outer "cup" or "case")
- the inside edge (also called the inner "cup" or "case")
- the sealing element
- the garter spring

The outside edge is usually metal coated with rubber or another sealing agent so that it grips the hub bore tightly enough to prevent oil escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.



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1. Outside Edge
2. Garter Spring
3. Sealing Element
4. Inside Edge

Fig. 2, Wheel Oil Seal Parts

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips that will seal against the axle spindle or against the outside or inside edge described above.

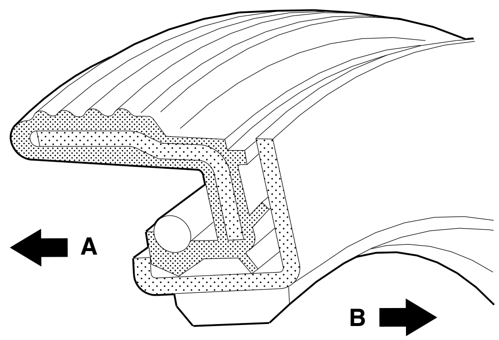
The garter spring is a loop of coiled wire spring that presses the sealing element against the sealing surface.

Chicago Rawhide Scotseal Plus XL

The Chicago Rawhide Scotseal Plus XL is a unitized, one-piece seal with one primary spring-loaded sealing lip and three secondary contacting sealing lips, which rotate with the housing. See **Fig. 3**. The outer diameter of the metallic case and the bore diameter of the seal counter face are coated with rubber. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal Plus XL directly onto the axle spindle.*

Although you install the Scotseal Plus XL into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle and seals against the outer cup, which turns with the hub.

General Information



A. Oil and Bearing Side B. Air Side

Fig. 3, Scotseal Plus XL Oil Seal

Seal Replacement, Chicago Rawhide Scotseal Plus XL

IMPORTANT: Make sure the required tools are available before beginning the service procedures described here. See **Fig. 1** for a diagram of the installation tool. See **Specifications 400** for tool and seal numbers.

Replacement

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01**.
2. Remove the inner wheel bearing assembly from the axle. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the hub is removed from the axle. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing and seal out of the inner wheel bearing cup. Discard the seal.
3. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 2** and **Fig. 3**.
4. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.

NOTICE

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

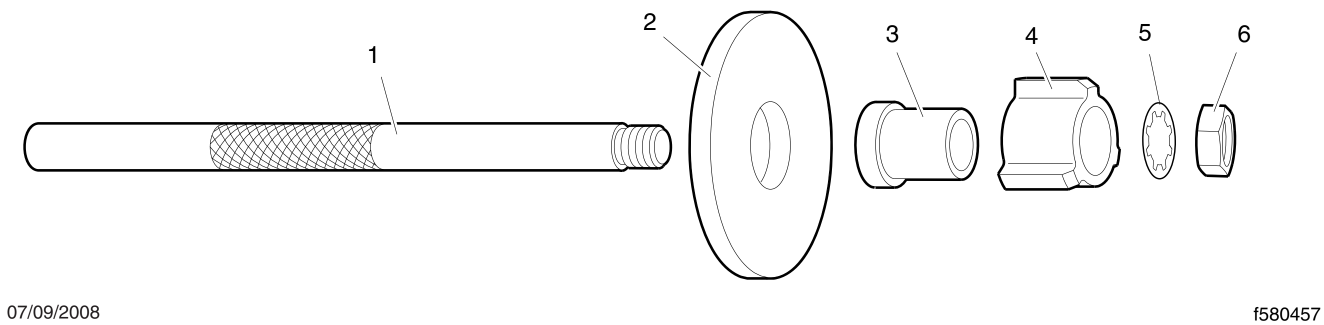
IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

5. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
6. Coat the wheel bearing cones with oil.
7. Install the inner wheel bearing cone in the inner wheel bearing cup.
8. Inspect a new seal for damage (such as cuts or being out of round) and contamination. If damage is evident, discard it and use a suitable seal.
9. Apply a thin layer of lubricant to the inside and outside diameters of the seal using the same lube used in the hub.
10. Seat the seal in the seal bore with the "air side" facing outward ("air side" is stamped on the sleeve flange of the seal), then press it down firmly with the flat side of the driver plate.
11. Insert the centering tool into the bore of the inner bearing cone. The plug prevents cocking of the seal in the bore.
12. Hold the tool handle firmly, and strike it until the seal bottoms out. See **Fig. 4**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.
13. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation. If any damage is visible, remove the seal and install a new one.
14. Install the wheel, drum, and hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

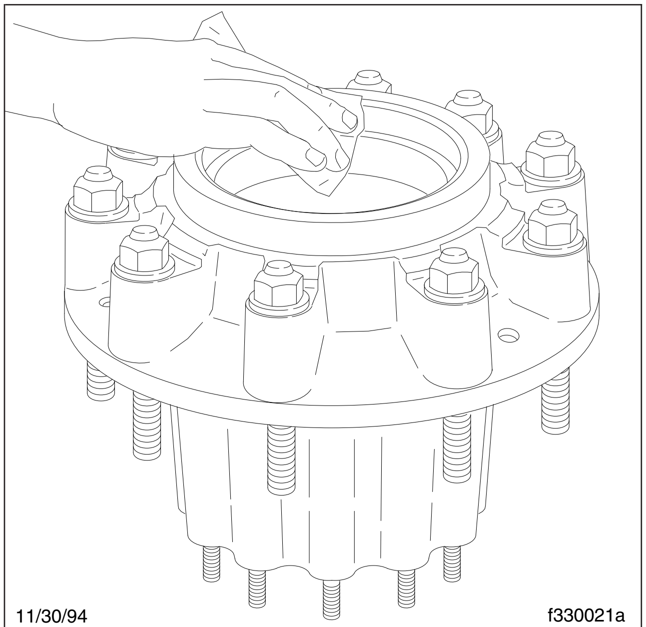
15. Adjust the brake shoe-to-drum clearance. For instructions, see **Group 42**.

Seal Replacement, Chicago Rawhide Scotseal Plus XL



1. Handle
2. Driver Plate
3. Plug Bushing
4. Centering Tool
5. Washer
6. Nut

Fig. 1, Installation Tool



NOTE: Rear hub shown.

Fig. 2, Cleaning the Hub

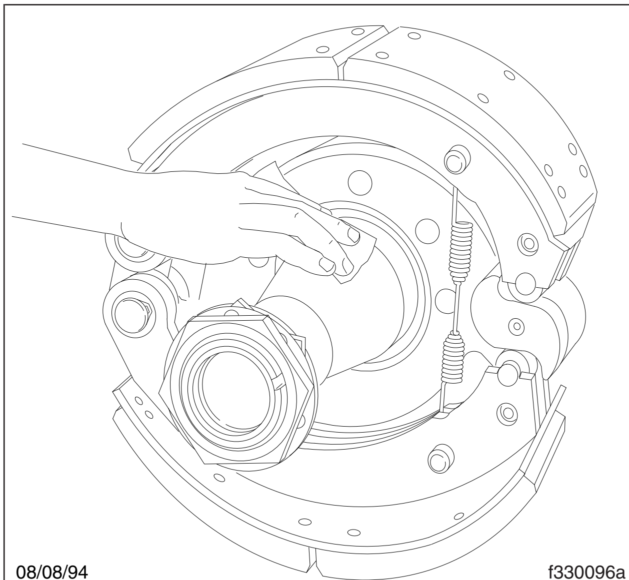
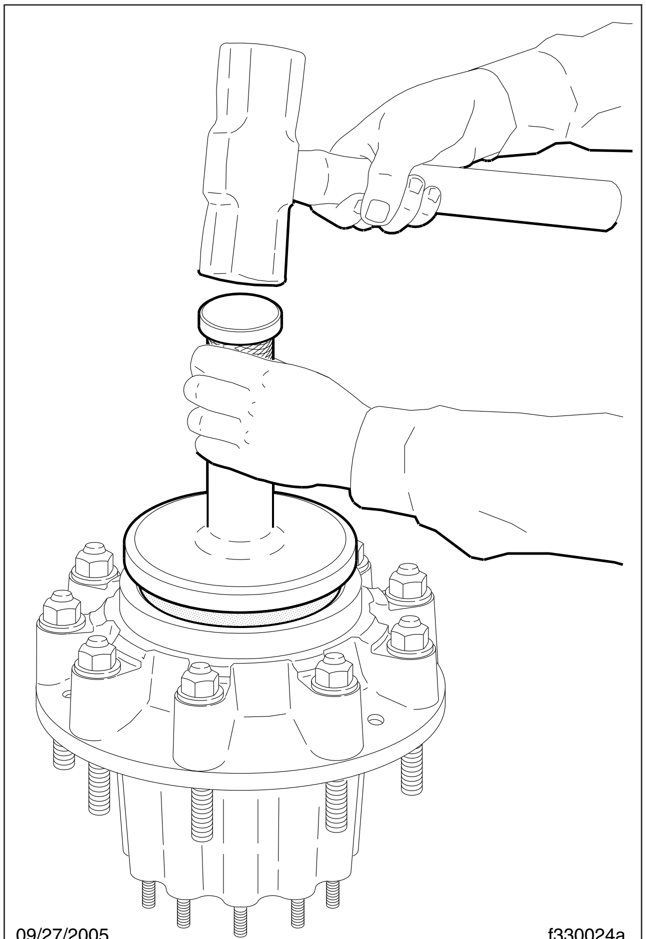


Fig. 3, Cleaning the Spindle

Seal Replacement, Chicago Rawhide Scotseal Plus XL



NOTE: Rear hub shown.

Fig. 4, Striking the Tool

Specifications

Scotseal Plus XL Tool and Seal Numbers			
Cone, Inner Bearing	Seal Stock Number	Centering Tool	Driver Plate
HM212049	35058*	706	436

* The seal stock number is listed on the air-side flange of the seal.

Table 1, Scotseal Plus XL Tool and Seal Numbers

General Information

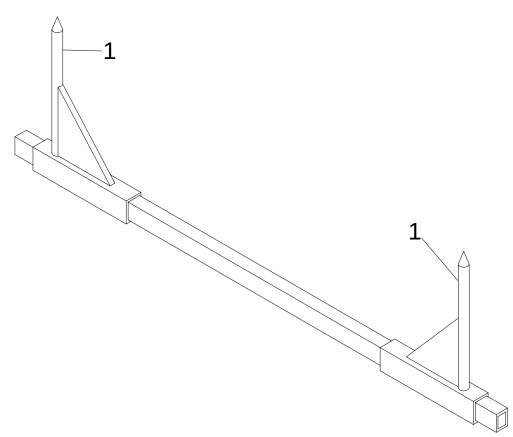
Rear axle alignment should be checked whenever rear axle or suspension components are replaced. It should also be checked when there is excessive front or rear tire wear, or hard or erratic steering.

Manufacturers of axle alignment equipment offer a variety of systems to precisely measure and correct rear axle alignment. If this type of equipment is not available, the basic tools needed for checking rear axle alignment are a straightedge (that is nonflexible and at least as long as the axle), steel tape rule, and trammel bar or center point bar (see **Fig. 1**).

The straightedge is used to see if the axle is in alignment with the frame. The distance from the straightedge to the center of the wheel hub is measured on each side of the vehicle; any difference in the measurements means that the axle is out of alignment.

Instructions and a list of materials for making a center point bar are in **Subject 120**.

Alignment specifications for Hunter and Bee Line alignment equipment, and for manual measurement, are in **Specifications, 400**.



1. Adjustable Pointer

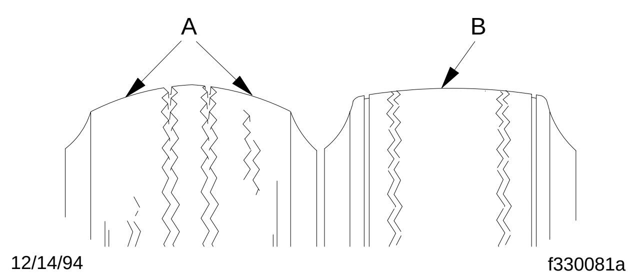
Fig. 1, Center Point Bar

The following preliminary checks should be completed before checking any alignment measurements.

Preliminary Checks

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line.

1. Wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires and suspension parts.
2. Do not mix tires of different size, type, or weight. Tire wear should be even and not worn to limits exceeding government specifications. Refer to **Group 40** in this manual and **Group 40** in the *Recreational Vehicle 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.**



A. Underinflation Wear
B. Overinflation Wear

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. FCCC dealers must have proof of this calibration history.

Follow the manufacturer's instructions for use of the alignment equipment, and use the alignment measurements given in **Fig. 1** and the applicable tables in **Specifications 400**.

Checking Using the Manual Method

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction.

1. Park the vehicle on a level surface. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line, or by jacking the axle up and letting it down.
2. Chock the front tires and place the transmission in neutral. Release the parking brakes.

NOTICE

Do not use scribe lines for marking on frame rails. Scribe lines, which cut or scratch the metal, can develop into starting points for structural damage to the frame.

3. Select a point on the frame rail forward of the rear axle, and mark it using a pencil or soapstone. Then mark two other points, about 4 inches (102 mm) forward and to the rear of the original point.

IMPORTANT: The distance from the original point to the forward and to the rear point does not have to be exactly 4 inches (102 mm), but the distance from the original point to the forward point *must* exactly equal the distance from the original point to the rear point.

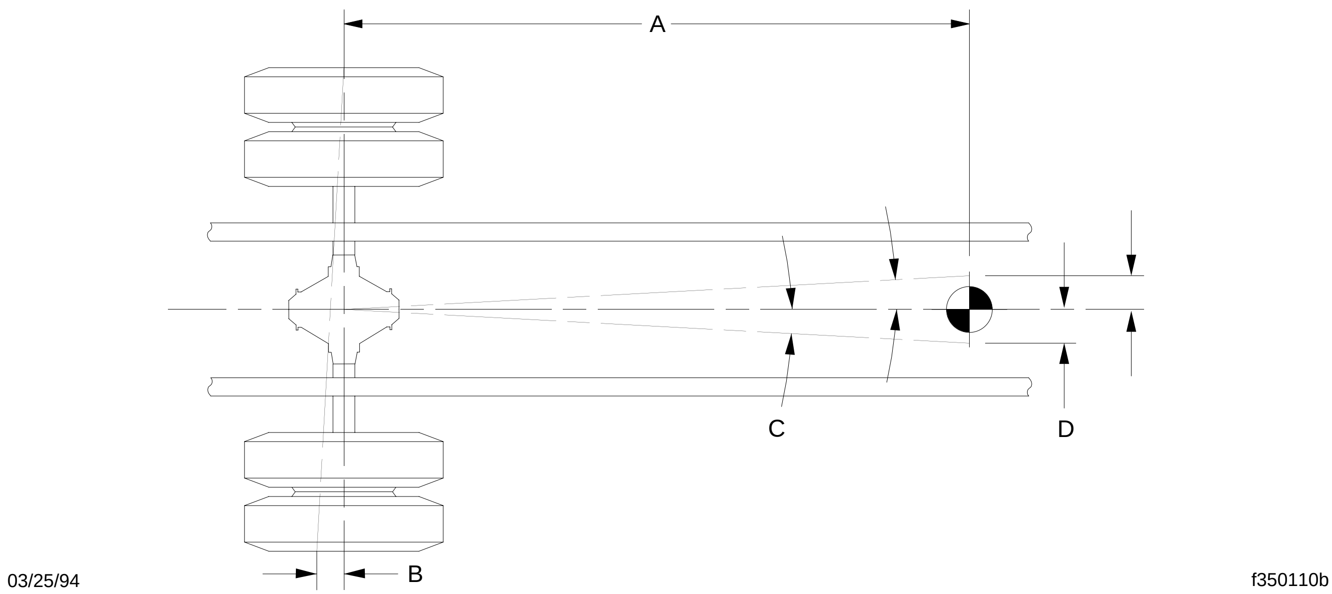
4. Make sure that all three marks are aligned and of equal distance from the outside edge of the frame rail. Using a center point or trammel bar, place one pointer on the forwardmost point, and make an arc with a pencil or soapstone on the opposite frame rail. Then place the pointer on the rearmost point and make an arc on the opposite frame rail intersecting the first arc. See **Fig. 2**. The point where the two arcs intersect and the original (or middle) point on the opposite frame rail have matching locations.
5. Line up the straightedge with the two matching points. Check that the straightedge extends out about the same distance on each side of the frame rail. Using C-clamps, clamp the straightedge to the frame; see **Fig. 3**. The straightedge must line up exactly with the points.
6. Measuring from the outside edge of each frame rail, mark the straightedge on both sides of the frame. The marks (**Fig. 3**, Ref. A) must be of equal distance from the frame and as far from the frame rail as the tires are at their farthest point from the frame.

IMPORTANT: The distance between the mark on the straightedge and the frame rail must be equal on both sides of the vehicle.

7. On each side of the vehicle, measure the distance from the mark on the straightedge to the center of the wheel hub. See **Fig. 3**.

   The difference between these measurements should be 3/8 inch (9 mm) or less. See **Fig. 1**. If the difference is more than 3/8 inch (9 mm), adjust the axle alignment. For instructions, see **Group 32** in this manual, or the suspension manufacturer's service literature.

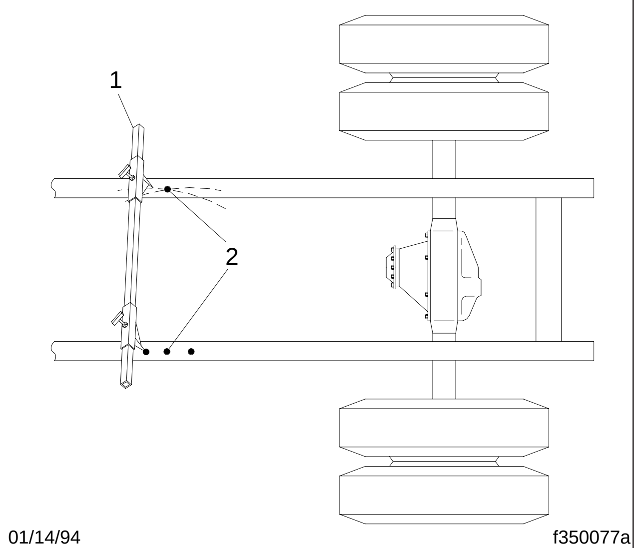
Alignment Checking, Single Axle



For items A and D, see Specifications 400.

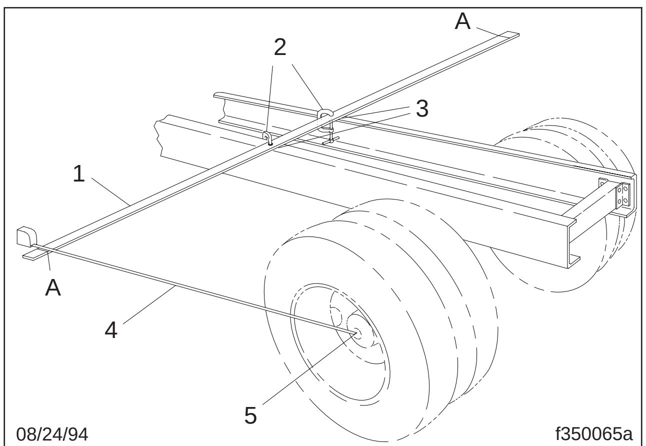
A. Distance from Rear Axle to Target (using Bee Line Alignment Tools)
B. Maximum Allowable Difference if Aligned Manually = ±3/8 inch (9 mm)
C. Maximum Allowable Tolerance if Aligned with Hunter Tools = ±0.25 degree
D. Maximum Allowable Tolerance if Aligned with Bee Line Tools

Fig. 1, Alignment Measurements



1. Center Point/Trammel Bar
2. Matching Points

Fig. 2, Marking an Arc



A. Marks

1. Straightedge
2. C-Clamps
3. Matching Points
4. Tape Measure
5. Wheel Hub

Fig. 3, Straightedge to Wheel Hub Measurement

Center Point Bar Construction

Materials Required

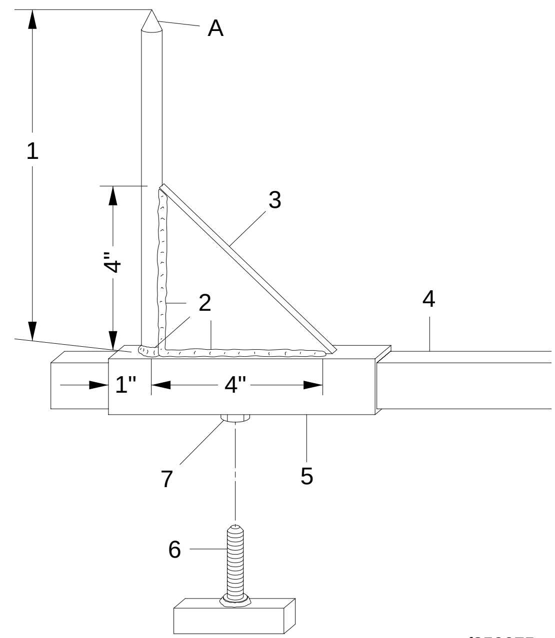
NOTE: To obtain metric conversions (millimeters), multiply the number of inches by 25.4.

The following materials are required:

- 62" of square steel tube (1" x 1", measured outside)
- 12" of square steel tube (1-1/8" x 1-1/8", measured inside)
- 20" of 3/8" steel rod
- two 1/2" x 3" pieces of steel square-bar stock
- one 4" x 4" steel plate, 1/8" thick
- two 3/8–16 capscrews (grade 5), 2" long
- two 3/8–16 hexnuts (equivalent to grade 5)

Construction

1. Cut the 1-1/8 x 1-1/8 inch (inside measurement) square steel tube in half to obtain two pieces 6 inches long. These will be the sliding members (slides) of the center point bar.
2. Cut the 4-inch by 4-inch steel plate diagonally into two pieces (gussets). Weld one gusset to each slide, as shown in **Fig. 1**.
3. Cut the steel rod in half to obtain two 10-inch rods. Grind one end of each to form a point.
4. Weld the pointed steel rods to the slides and gussets, as shown in **Fig. 1**.
5. Drill a 1/2-inch hole in the center of each slide, on the side opposite where the pointer was welded. Drill through only one side of the tube.
6. Directly over each hole drilled in the step above, weld a 3/8–16 nut (equivalent to grade 5).
7. Weld a piece of steel stock, about 1/2-inch wide by 3-inches long, over the head of each of two 3/8–16 by 2-inch long capscrews.
8. Place a slide over each end of the 60-inch piece of steel tube, with the pointed rods to the outside. Screw the handscrews (made in the step above) into the slides until they are clamped tightly to the cross tube.



A. Grind to a point.

1. 3/8-Inch Diameter Rod
2. Weld
3. Gusset
4. 1-Inch Square Steel Tube
5. 1–1/8 Inch Square Steel Tube
6. 3/8–16 Bolt
7. 3/8–16 Nut

Fig. 1, Center Point Bar Construction

Chassis Vibration Diagnosis and Repair

1. Test drive the vehicle and determine the nature of the vibration.
2. Follow the procedures in **Section 40.00, Subject 300**, to determine if the vibration is being caused by the wheels or tires. If the vibration is not wheel- or tire-related, go to the next step.
3. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the tires.
4. Check and, if necessary, adjust the tire pressures. See Chapter 7 of the *Recreational Vehicle Chassis Operator's Manual* for recommended tire pressures.

IMPORTANT: Measure ride height from the bottom of the frame rail to the center of the lower shock absorber mounting bolt. The ride height measurement must be within 1/4 inch (6.4 mm) of specification. It is the body builder's responsibility to ensure that chassis ride height is within specification after the body is installed on the chassis.

5. Check the suspension ride height at both the front and the rear end of the vehicle. See **Table 1**.
6. Check to be sure that there is adequate clearance between the flywheel isolator washer and the lower frame flange. Ensure that there is no interference between the isolator washer and the relay bracket.

Suspension Ride Height			
Front/Rear of Vehicle	**Axle Type**	**Ride Height Measurement: inch (cm)**	**Maximum Tolerance: inch (mm)**
Front	—	10 (25.4)	1/4 (6.4)
Rear	RS-15-120	9-3/8 (23.8)	1/4 (6.4)
Rear	RS-17/19	9-3/4 (24.8)	1/4 (6.4)

Table 1, Suspension Ride Height

NOTE: Caterpillar engines have a D-shaped washer.

7. Check the clearance between the exhaust system and other components. Check for signs of contact between the exhaust and other components.
8. Check the rear axle data plate and verify that the vehicle has coach gearing.

NOTE: The gearing may need to be verified by a Meritor representative.

IMPORTANT: For accurate measurements, ensure that ride height is within specification before attempting the next three steps.

9. Check the rear axle thrust angle using four-wheel laser alignment equipment. The thrust angle must be less than 0.25 of a degree.
10. Verify that the rear axle pinion angle is correct. See **Table 2**.
11. Verify that the engine power angle is correct. See **Table 3**.
12. Verify that the engine isolator/mount part numbers are correct. See **Table 4**.
13. Check the driveshaft and ensure that the part number and phasing are correct. If the phasing is incorrect, the driveshaft must be rephased and then rebalanced.

NOTE: The driveshaft should be phased and balanced by the supplier. The supplier stamps timing marks on the yoke and on the shaft. If the driveshaft is disassembled and then reassembled incorrectly, a vibration can occur. If the driveshaft is disassembled, rephase it by realigning the timing marks. Proper alignment of the marks is important because the driveshaft can appear to be phased correctly but, if the timing marks are 180 degrees apart, vibration can occur.

14. If a vibration or tingling sensation is present in the original steering wheel, replace it with a new steering wheel.

Troubleshooting

Rear Axle Pinion Angle				
Engine	**Transmission**	**Pinion Angle: degrees**	**Axle Seat Part Number**	**Production Date**
Cummins ISB	MD 3060	5	16-15233-000 (Neway p/n 90501374)	—
Cummins ISB	MT 643	7.5	GAF P115527	—
Cummins ISB	2000 MH	8	NEW 90501414	—
Caterpillar	—	8	NEW 90501342	—
Cummins ISC	—	8	NEW 90501342	Through April 29, 1999
Cummins ISC	—	6	NEW 90501281	Beginning April 30, 1999

Table 2, Rear Axle Pinion Angle

Engine Power Angle			
Engine	**Engine Power Angle: degrees**	**Radiator Location**	**Production Date**
Cummins ISB	4.87	—	—
Caterpillar	4.0	Side	—
Caterpillar	4.87	Rear	—
Cummins ISC	5.0	—	Through April 29, 1999
Cummins ISC	6.0	—	Beginning April 30, 1999

Table 3, Engine Power Angle

Engine Isolator/Mount Part Numbers			
Engine	**Axle**	**Upper Flywheel Mount**	**Front Mount**
Cummins ISB	RS-15	GAF RE35591	—
Cummins ISB	RS-17/19	J20120-14 (white dot)	SSB331001-8
Caterpillar	RS-17/19	J20120-12 (orange dot)	SSB331001-37 (blue dot)
Cummins ISC	—	J20120-4 (blue dot)	SSB331001-8

Table 4, Engine Isolator/Mount Part Numbers

NOTE: If the steering wheel is replaced, you must also replace the horn button.

15. If vibration is still present, remove the driveshaft and inspect the yoke and splines for premature wear. If the yoke or splines are worn, replace the driveshaft. If the yoke and splines are not worn, balance the driveshaft.

IMPORTANT: The rear axle service damper kit below does not apply to vehicles equipped with Neway ADL rear suspensions. The kit applies only to vehicles equipped with RS-17 or RS-19 rear axles, Allison MD 3060 or 3000 MH transmissions, and Neway AD-200 suspensions.

16. If none of the above procedures resolve a vibration complaint, install a rear axle damper service kit (11-24531-000).

Specifications

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.

Maximum Tolerance from Perpendicular, Manual Method	
Method	**Maximum Tolerance ± from Perpendicular**
Manual	3/8 inch (9 mm)

Table 1, Maximum Tolerance from Perpendicular, Manual Method

Maximum Tolerance from Perpendicular, Hunter Equipment*	
Method	**Maximum Tolerance ± from Perpendicular**
Hunter	0.25 degree

* To use Hunter alignment equipment, refer to the applicable Hunter service literature.

Table 2, Maximum Tolerance from Perpendicular, Hunter Equipment

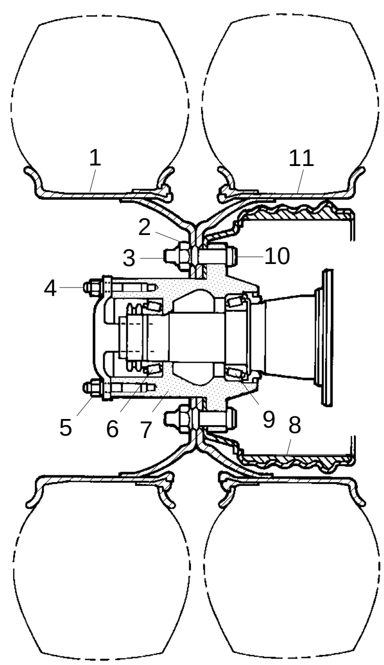
Maximum Tolerance from Perpendicular at Target, Bee Line Equipment*	
Distance from the Forward or Rear Drive Axle to Target: inches (mm)	**Maximum Tolerance ± from Perpendicular: inches (mm)**
100 (2540)	7/16 (11)
120 (3048)	9/16 (14)
140 (3556)	5/8 (16)
160 (4064)	11/16 (17)
180 (4572)	13/16 (21)
200 (5080)	7/8 (22)
220 (5588)	1 (25)
240 (6096)	1-1/16 (27)
260 (6604)	1-1/8 (29)

* To use Bee Line alignment equipment, refer to the applicable Bee Line service literature.

Table 3, 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**.



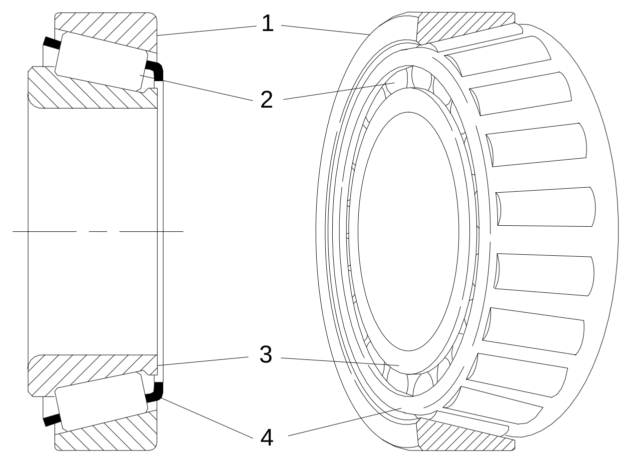
1. Outer Wheel
2. Outer Wheel Nut
3. Wheel Stud
4. Drive Axle Stud
5. Drive Axle Stud Nut
6. Outer Wheel Bearing
7. Wheel Hub
8. Brake Drum
9. Inner Wheel Bearing
10. Wheel Stud Head
11. Inner Wheel

Fig. 1, Disc Wheel and Hub Assembly

TAPERED WHEEL BEARINGS

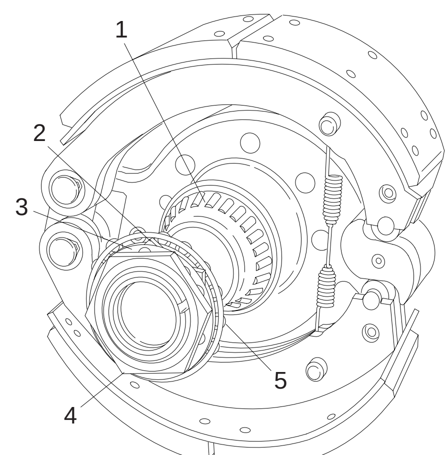
A typical tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

Each hub has a set of inner and outer tapered wheel bearing assemblies. The bearing setting is locked in place on the axle spindle by an adjusting nut, lockring, and jam nut. See **Fig. 3**.



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

General Information

DRIVE AXLE SPINDLE ASSEMBLY

The drive axle spindle assembly is made up of a drive axle flange and shaft, drive axle studs and stud nuts, a flange gasket, an axle spindle, an oil seal, and the nut/lockring assembly described above. See **Fig. 4**.

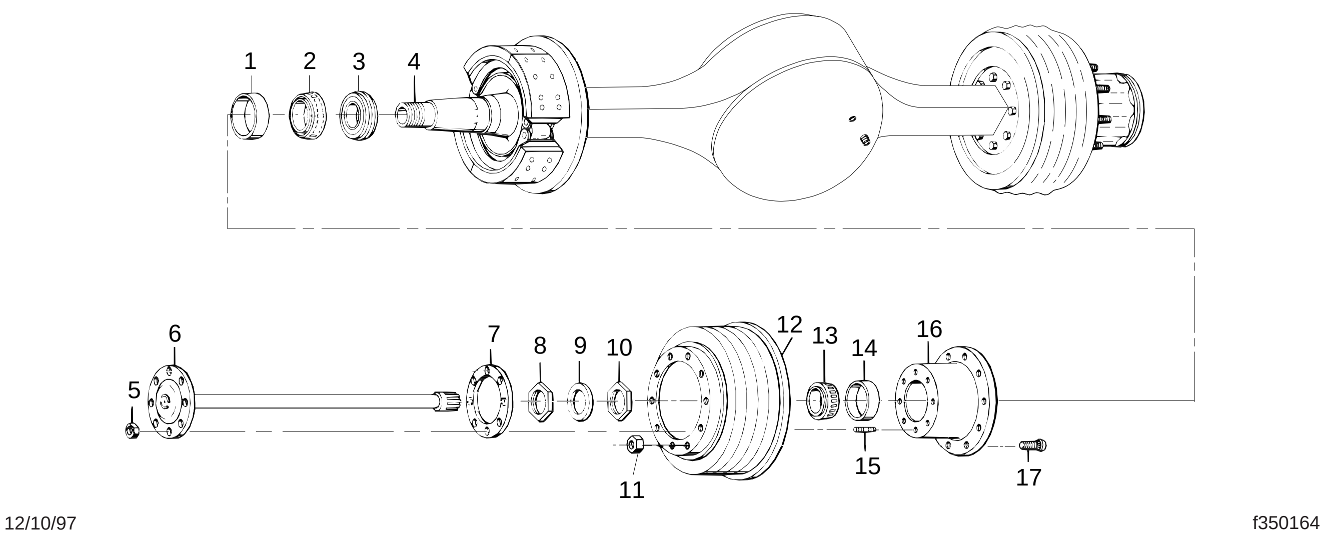
The surfaces of the spindle and the nut threads are machined. When these surfaces become damaged, repairs are necessary. There are standard methods for performing those repairs that preserve the proper alignment of the axle spindle assembly. Refer to the axle manufacturer for instructions.

CAUTION

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.



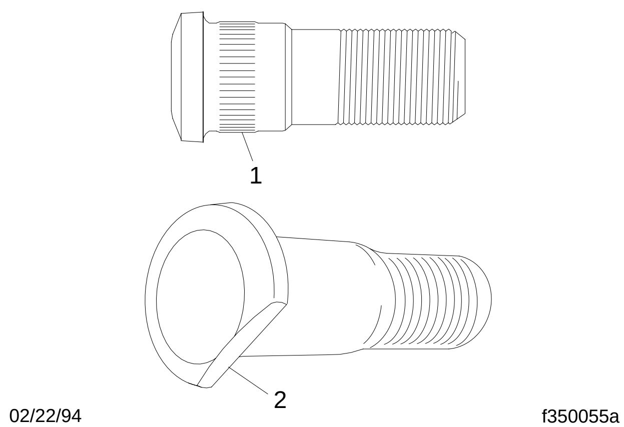
1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Brake Drum Nut
12. Brake Drum
13. Outer Wheel Bearing
14. Outer Wheel Bearing Cup
15. Drive Axle Stud
16. Wheel Hub
17. Wheel Stud

Fig. 4, Typical Drive Axle (exploded view)

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



1. Serrations
2. Clipped Head

Fig. 5, Typical Headed Wheel Studs

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.

Hub Assembly Removal and Installation, Disc Wheels

Removal

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. 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. 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.
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.

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.

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.

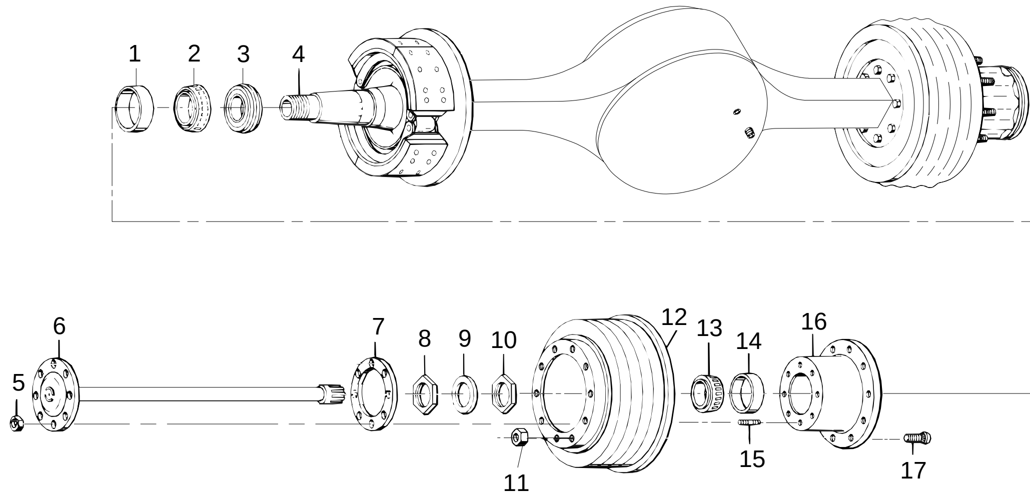
14. Move the hub about 1/2 inch (13 mm) to jar loose the outer wheel bearing (allow the hub-only assembly to rest on the axle spindle; be careful not to damage the axle spindle threads).
15. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap them in either clean 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.

Hub Assembly Removal and Installation, Disc Wheels



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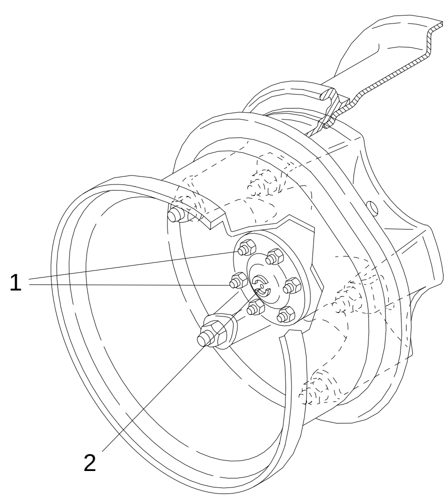
1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Brake Drum Nut
12. Brake Drum
13. Outer Wheel Bearing
14. Outer Wheel Bearing Cup
15. Drive Axle Stud
16. Wheel Hub
17. Wheel Stud

Fig. 1, Typical Drive Axle (exploded view)



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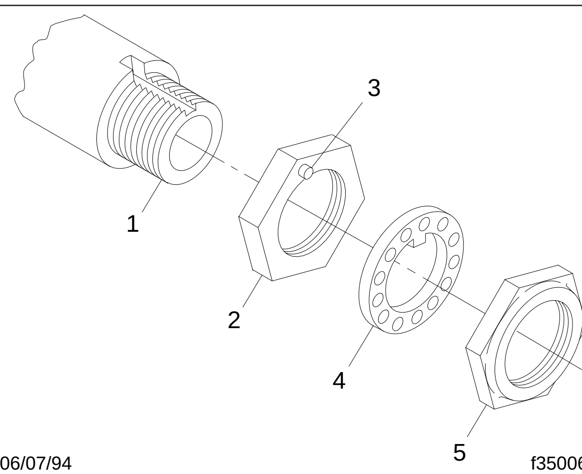
1. Drive Axle Studs and Nuts
2. Center Portion of Drive Axle Flange

Fig. 2, Wheel Assembly and Hub



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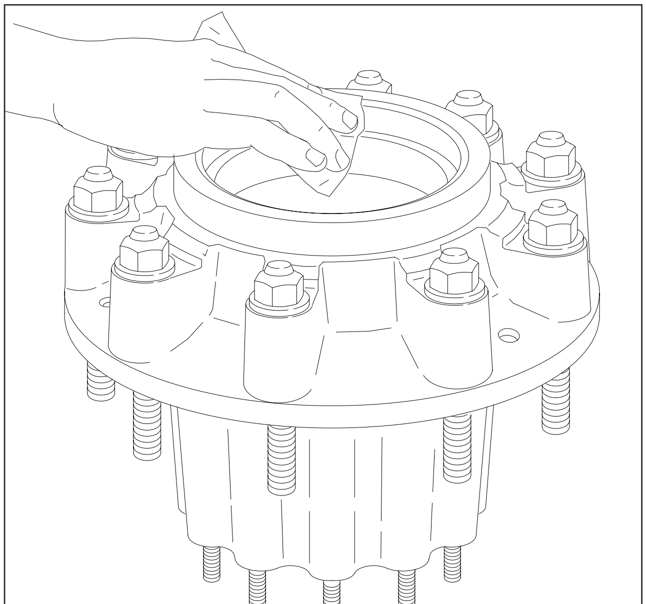
1. Axle Spindle
2. Adjusting Nut
3. Pin
4. Pierced Lockring
5. Jam Nut

Fig. 3, Axle Secured With a Lockring

17. Using a seal removal tool, remove the oil seal from the hub, if not already removed.

Hub Assembly Removal and Installation, Disc Wheels

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.

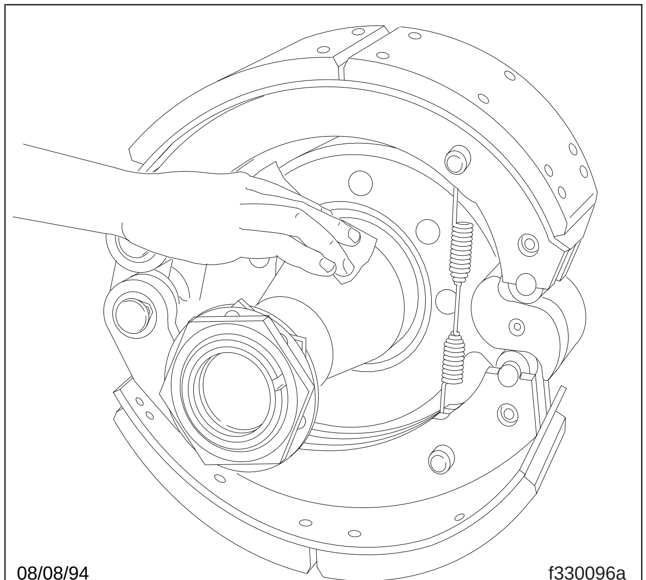


NOTE: Typical application.

Fig. 4, Cleaning 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**.



NOTE: Typical application.

Fig. 5, Cleaning 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, 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**.

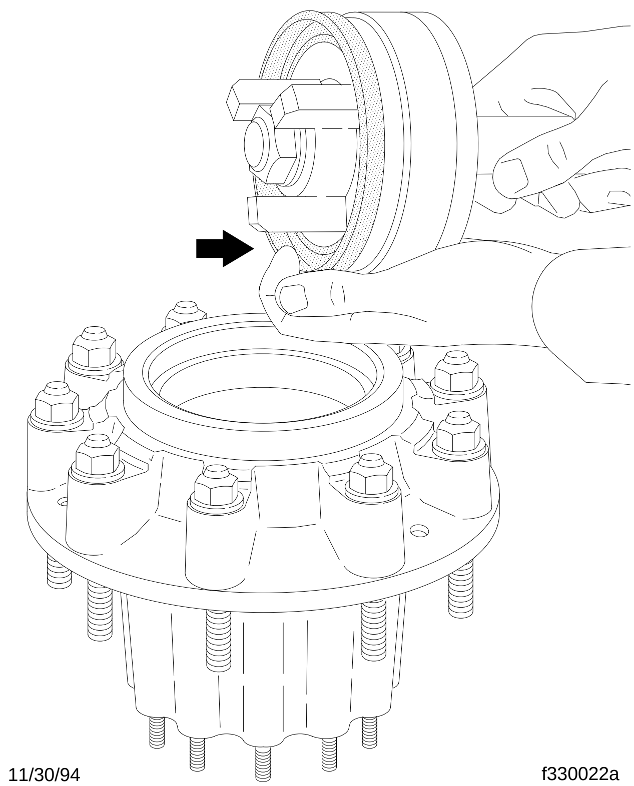
⚠ CAUTION

Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both

Hub Assembly Removal and Installation, Disc Wheels

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.



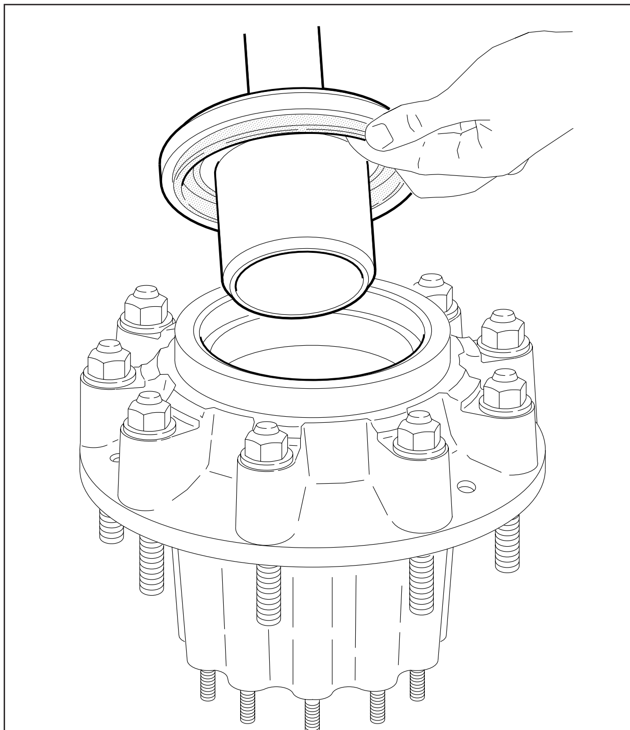
NOTE: Typical application.

Fig. 6, Seating 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.



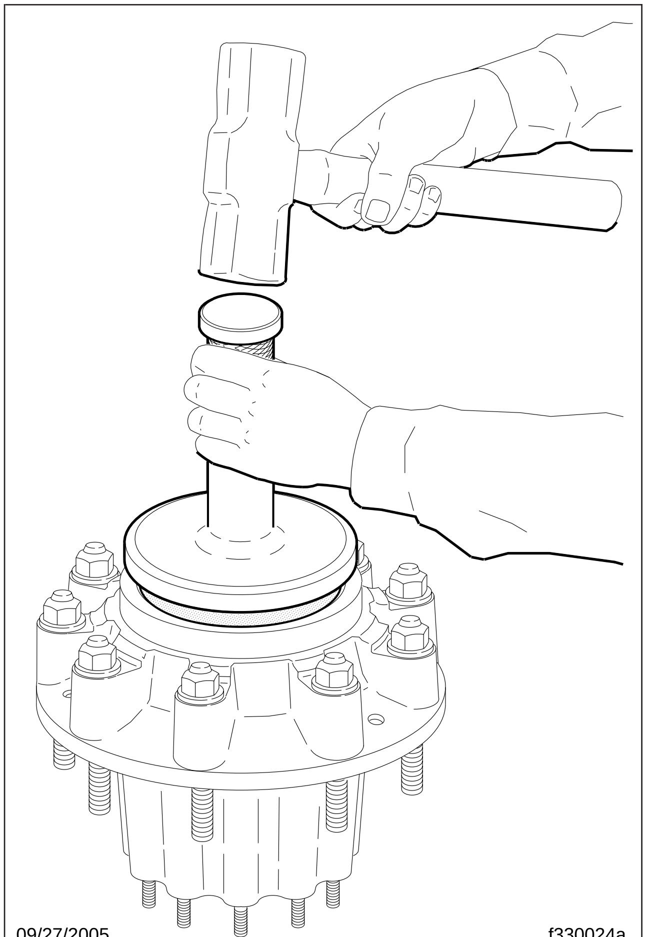
NOTE: Typical application.

Fig. 7, Inserting the Tool

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.
5. Fill the hub cavity with oil, then install the outer wheel bearing; handle the bearings with clean, dry hands. Use care not to damage the bearings as they are seated in the bearing cups. Remove the friction tape from the axle spindle threads.
6. Install the wheel bearing adjusting nut. See **Fig. 9**.

   6.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

Hub Assembly Removal and Installation, Disc Wheels



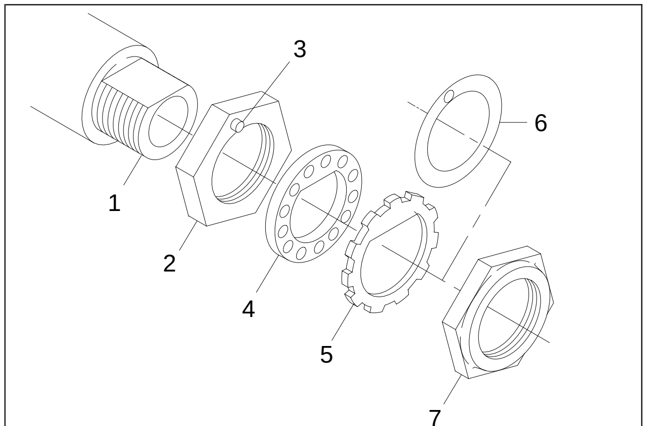
NOTE: Typical application.

Fig. 8, Striking the Tool

6.2 While rotating the wheel hub assembly, tighten the adjusting nut 100 lbf·ft (136 N·m).

6.3 Back off the adjusting nut completely.

6.4 Tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.



1. Axle Spindle
2. Adjusting Nut
3. Dowel
4. Lockring
5. Nut-Lock
6. Retaining Washer (may be used in place of nut-lock)
7. Jam Nut

Fig. 9, Axle With Nut-Lock (or washer) and Lockring

6.5 Back off the adjusting nut one-third turn.

7. Install the locking device and jam nut.

7.1 Install the locking device.

NOTE: If no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If a hole still doesn't align with the dowel, loosen the adjusting nut, but only enough to align the dowel with a hole in the lockring.

7.2 Then install the jam nut, and tighten it to the applicable torque value in **Table 1**.

Jam Nut Torques		
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 to 300 (271 to 407)	
Lockring		

Hub Assembly Removal and Installation, Disc Wheels

Jam Nut Torques		
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 and Lockring	200 to 300 (271 to 407)	250 to 400 (339 to 542)
Lockwasher and Lockring		

Table 1, Jam Nut Torques

8. With the jam nut installed and tightened, adjust the bearings.

   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.

   8.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

   If using aluminum hubs, you may have to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot, then adjust the brake or have someone apply the brakes to hold the drum securely while you secure the drum using the stud at the 12 o'clock position, then the studs at about the 4 o'clock and 8 o'clock positions.

   NOTE: If using a stud-piloted hub and a steel drum, install 1-1/4 inch washers between the nuts and the drum.

   8.2 Release the brakes if you used them to hold the drum while installing it.

   8.3 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

   8.4 Once again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator, and note the end play.

   8.5 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

9. The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). If the end play is not within this range, adjust the end play.

   9.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

   9.2 Install the locking device and jam nut as described earlier, and measure the end play. If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), turn the adjusting nut again.

   9.3 Once the end play is correct, bend two tabs of the nut-lock over opposing flats on the jam nut.

   9.4 Rotate the hub in both directions. It should turn freely with no dragging or binding. End play should be between 0.001 and 0.005 inch (0.03 to 0.13 mm).

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. 10**, tighten the nuts to the torque values in the torque table in **Specifications, 400**.
15. Install the brake drum on the wheel hub.
16. Install the inner and outer wheel and tire assemblies. For instructions, see **Group 40**.

Hub Assembly Removal and Installation, Disc Wheels

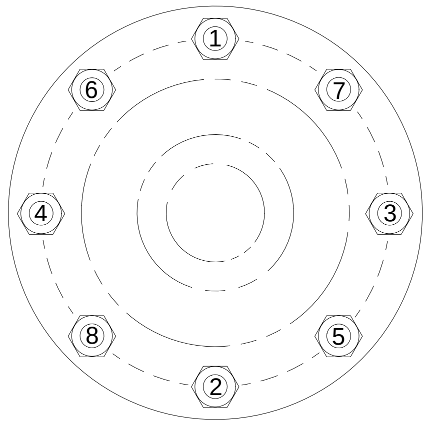


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Fig. 10, Axle Shaft Flange Nut-Tightening Sequence

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.

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 hub have been serviced will damage the wheel bearings and cause them to seize during vehicle operation. See Fig. 11. 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. 12** and **Fig. 13**. See **Specifications, 400** for the recommended axle lubricants. Tighten the plug 35 lbf·ft (47 N·m).

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.

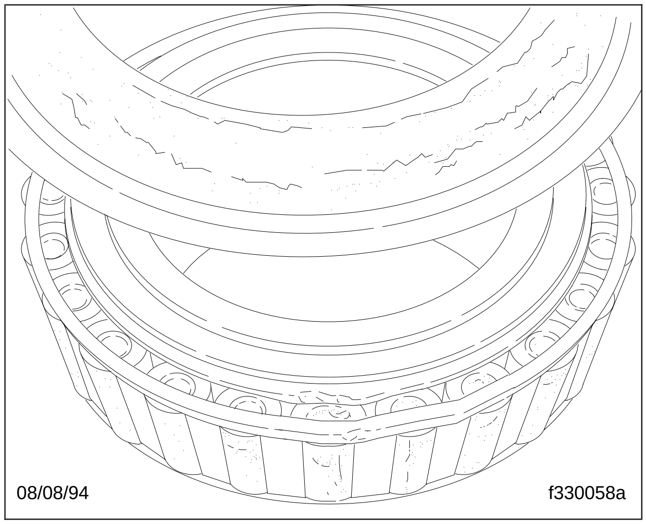

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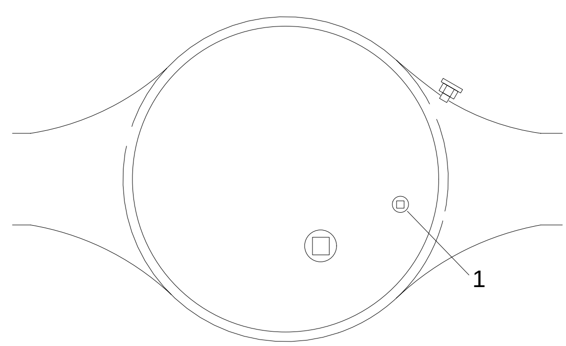
Fig. 11, Bearing Damage Resulting from Inadequate Lubrication



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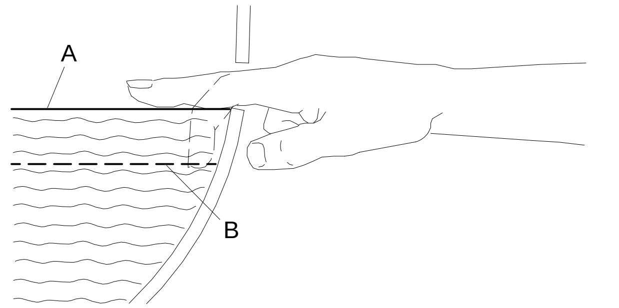
1. Bowl Fill Plug

Fig. 12, Filler Hole

17.3 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



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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.

18. Turn the wheels, and check the lubricant level.
19. Adjust the rear axle brakes at the slack adjuster. For instructions, see **Group 42** of the *Recreational Vehicle Chassis 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.

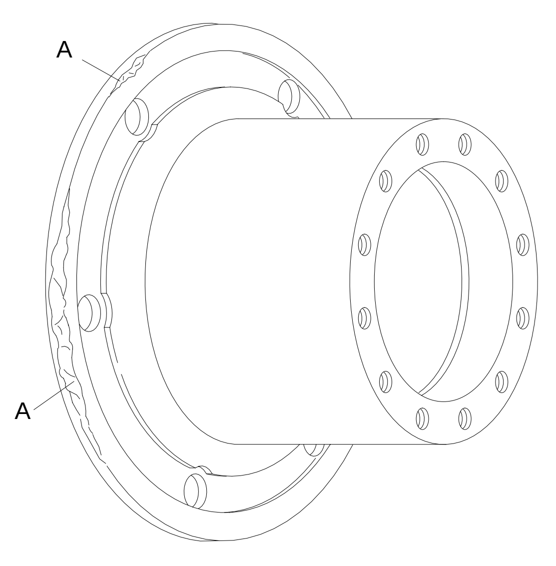
Wheel Hub Assembly and Drive Axle Inspection

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**.



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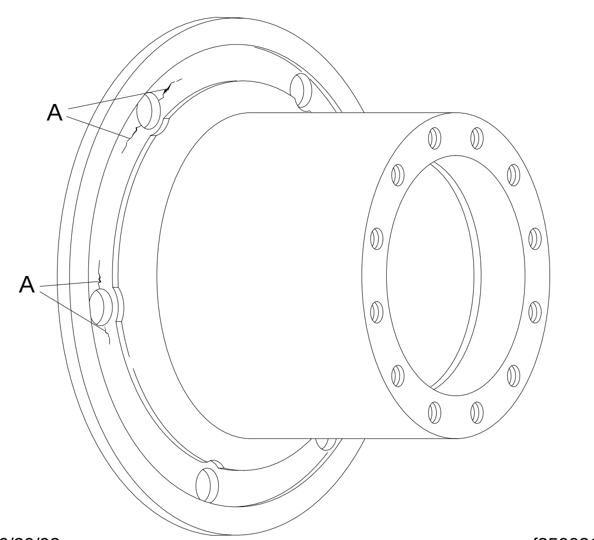
A. Wear spots.

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. Replace studs that are stripped, broken, bent, or otherwise damaged. See **Fig. 5**. For instructions, see **Subject 130**.



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A. Cracked stud grooves.

Fig. 2, Typical Wheel Hub, Damaged

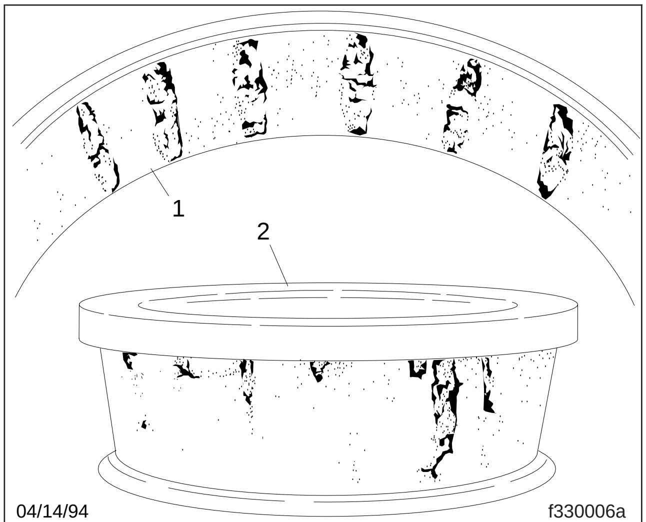
5. Inspect the drive axle studs. Replace the studs that have stripped threads or are broken. Also, replace bent or otherwise damaged studs; for instructions, see **Subject 130**.

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

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 shaft and flange

Axle Components Cleaning and Inspection



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

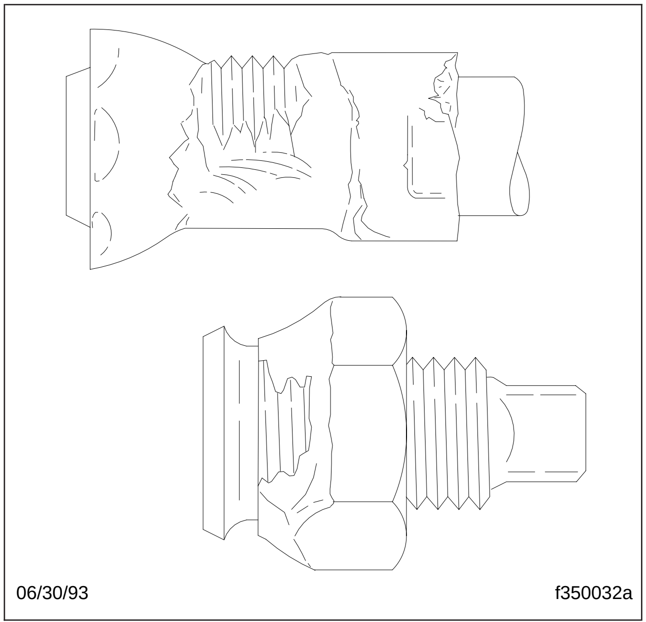


Fig. 4, Damaged Wheel Stud Nuts

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.

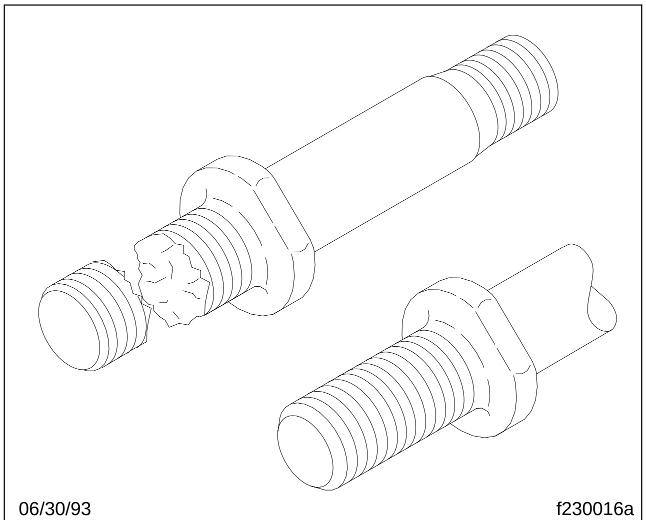
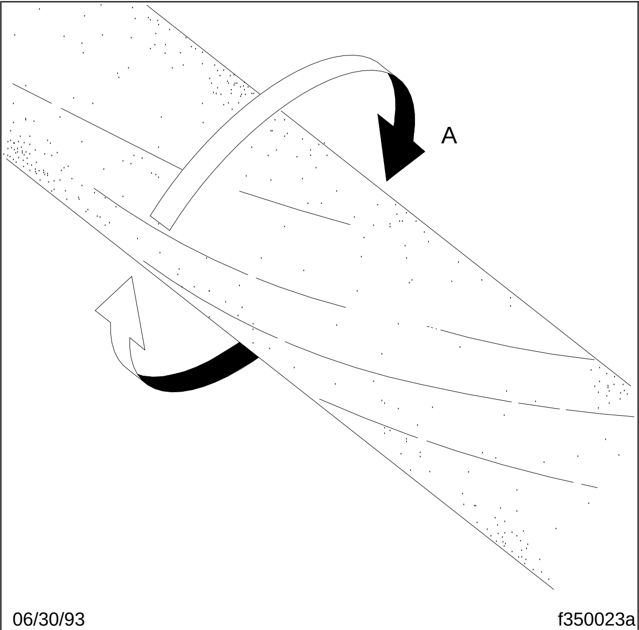


Fig. 5, Damaged Wheel Studs (shouldered type)

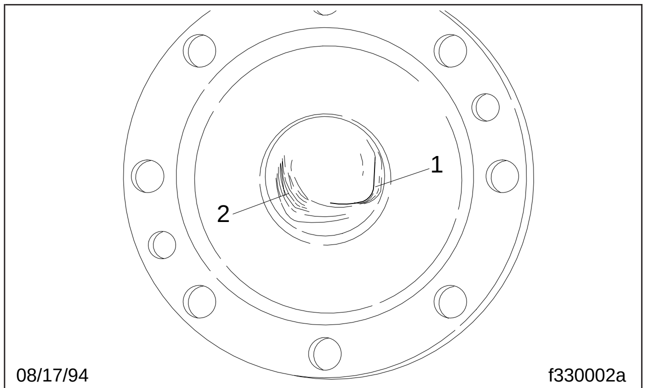


A. Direction of twist.

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

Axle Components Cleaning and Inspection



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

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

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**.

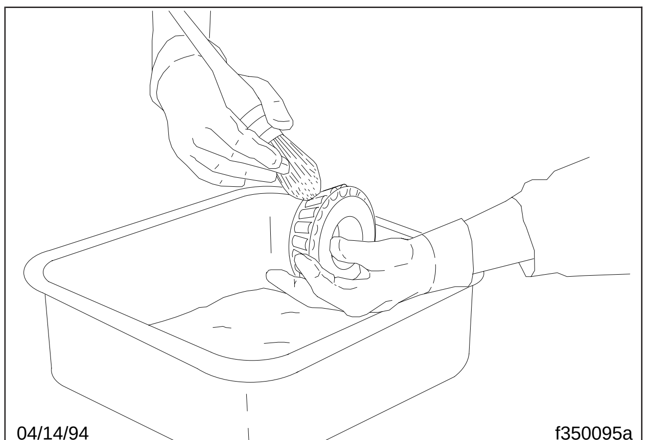
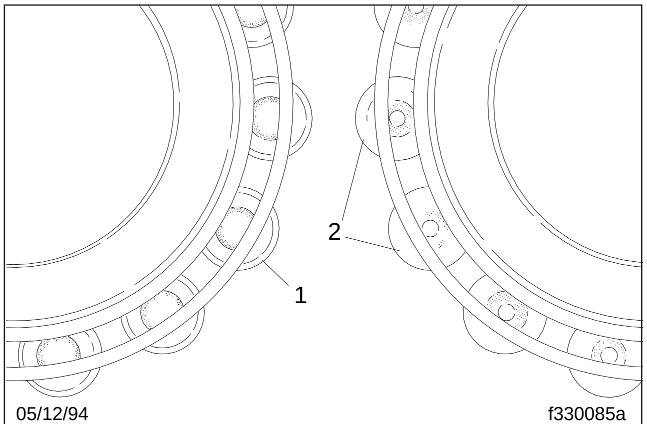


Fig. 8, Cleaning the Bearings

2. Visible step wear, especially at the small end of 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**.

Axle Components Cleaning and Inspection



1. New Bearing
2. Worn Bearing Rollers

Fig. 9, Signs of Wear

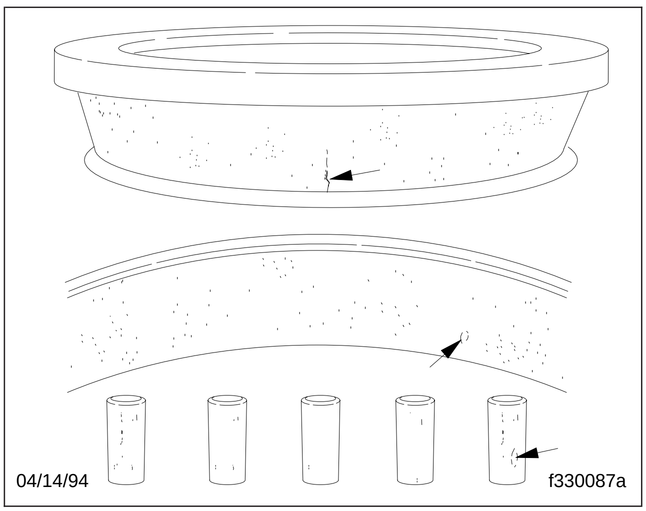


Fig. 10, Indentations, Cracks, or Breaks in Bearing Surfaces

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.

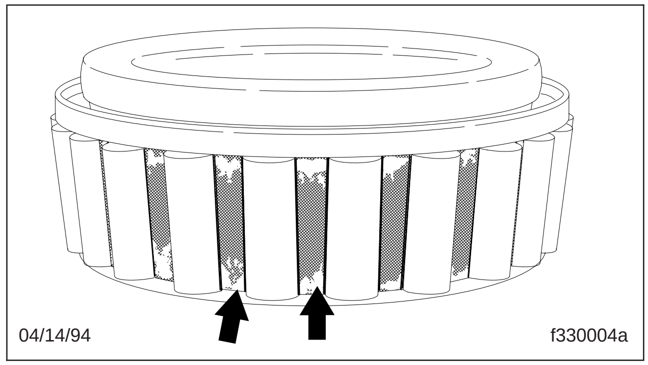


Fig. 11, Rubbing Marks on Bearing Cage

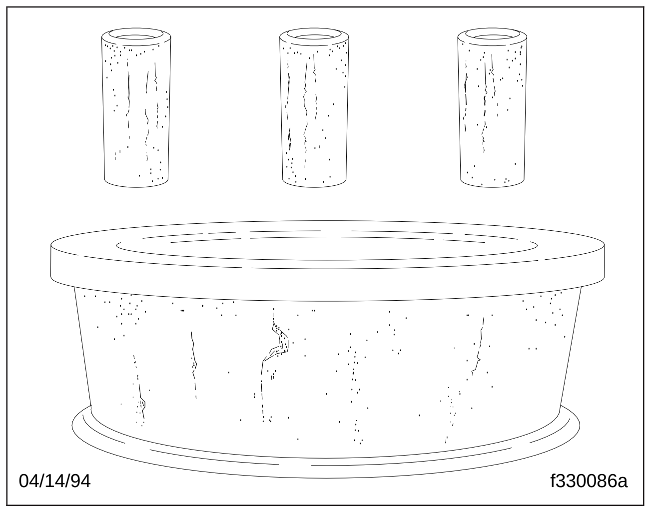


Fig. 12, Etching (Pitting) on Bearing Surfaces

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

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.

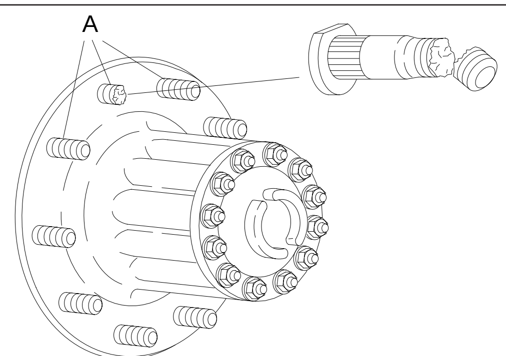
5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

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.



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A. Replace all three studs.

Fig. 1, Replacing Damaged Studs

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

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

Wheel studs with heads embedded in the wheel hub will weaken the wheel hub flange. Weakness in the wheel hub can result in the loss of a wheel or loss of steering control, possibly resulting in personal injury.

9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Wheel Stud Replacement, Disc Wheels

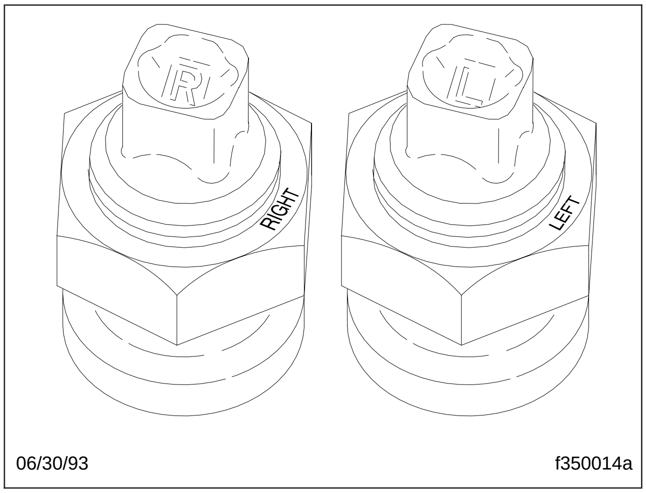

Fig. 2, Wheel Nuts

Hub Runout Measurements

If either the lateral or radial runout of the hub is beyond acceptable limits, replace the hub. For instructions, see **Subject 100** in this section.

Measurements

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

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

2. Remove the wheel and tire assembly. See **Group 40** for instructions.
3. For drum brakes, remove the brake drum. See **Group 42** for instructions.
4. Clean the hub surfaces where the measurements will be taken—see **Fig. 1** and **Fig. 2**.
5. To measure lateral runout, set up a dial indicator as shown in **Fig. 1**, then turn the hub one revolution and note the highest and lowest measurements.

   For ConMet hubs, the acceptable lateral runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable lateral runout specification.
6. To measure radial runout, set up a dial indicator as shown in **Fig. 2**, then turn the hub one revolution and note the highest and lowest

   For ConMet hubs, the acceptable radial runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable radial runout specification.

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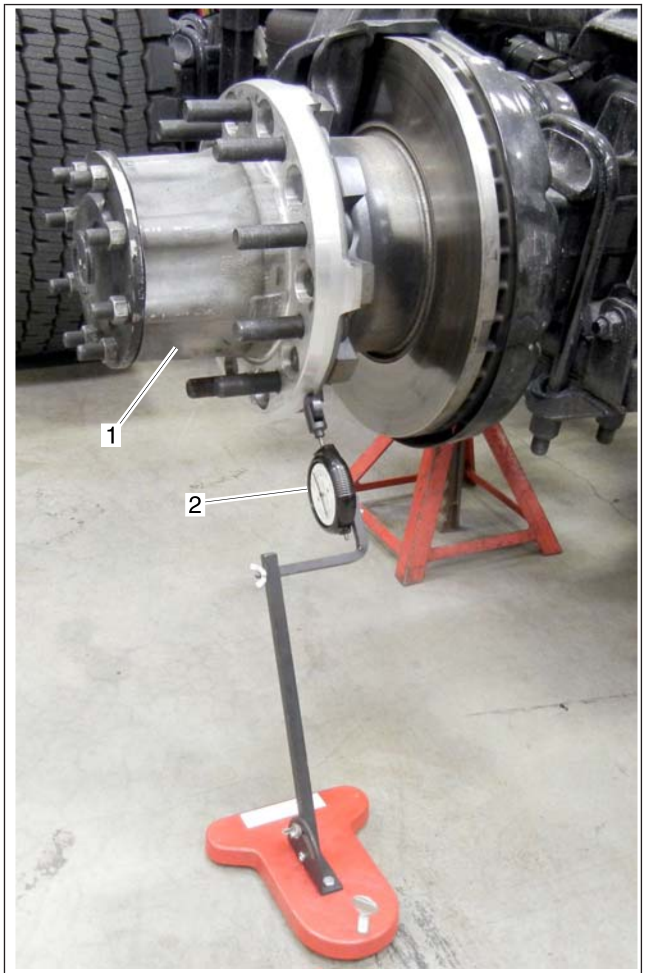
1. Hub
2. Dial Indicator (with roller point)

Fig. 1, Setup to Measure Lateral Runout

Hub Runout Measurements



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1. Hub
2. Dial Indicator (with roller point)

Fig. 2, Setup to Measure Radial Runout

Troubleshooting

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** 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**.

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

Torque Values		
Fastener Description	**Size (grade 8)**	**Torque lbf·ft (N·m)**
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	150-170 (203-230)
Drive Axle Studs (to hub)	1/2–13	70 (95)
	5/8–11	135 (185)

Table 1, Torque Values

Meritor Drive Axle Lubricant Capacities*, Single Axle†			
Axle Model	**Capacity: pints (liters)**	**Axle Model**	**Capacity: pints (liters)**
RS–13–120	16 (7.6)	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 (1 ounce [30 ml] of additive for each 1 pint [0.5 liter] of lube capacity) or Lubrizol No. 797 or 762 (one ounce [30 mL] of additive for each 1 pint [0.5 liter] of lube capacity).

Table 2, Meritor Drive Axle Lubricant Capacities, Single Axles

Meritor Drive Axle Recommended Lubricant			
Lubricant Type	**Ambient Temperature**	**Viscosity Grade**	**Meritor 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 3, Meritor 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

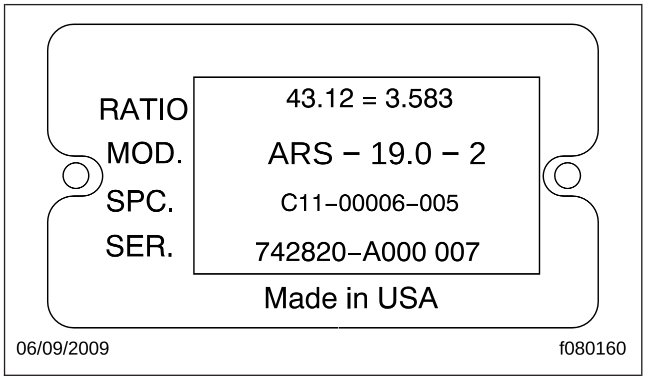


Fig. 1, Rear Axle ID Tag

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 110**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
9. Release the parking brakes.
10. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
11. 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.

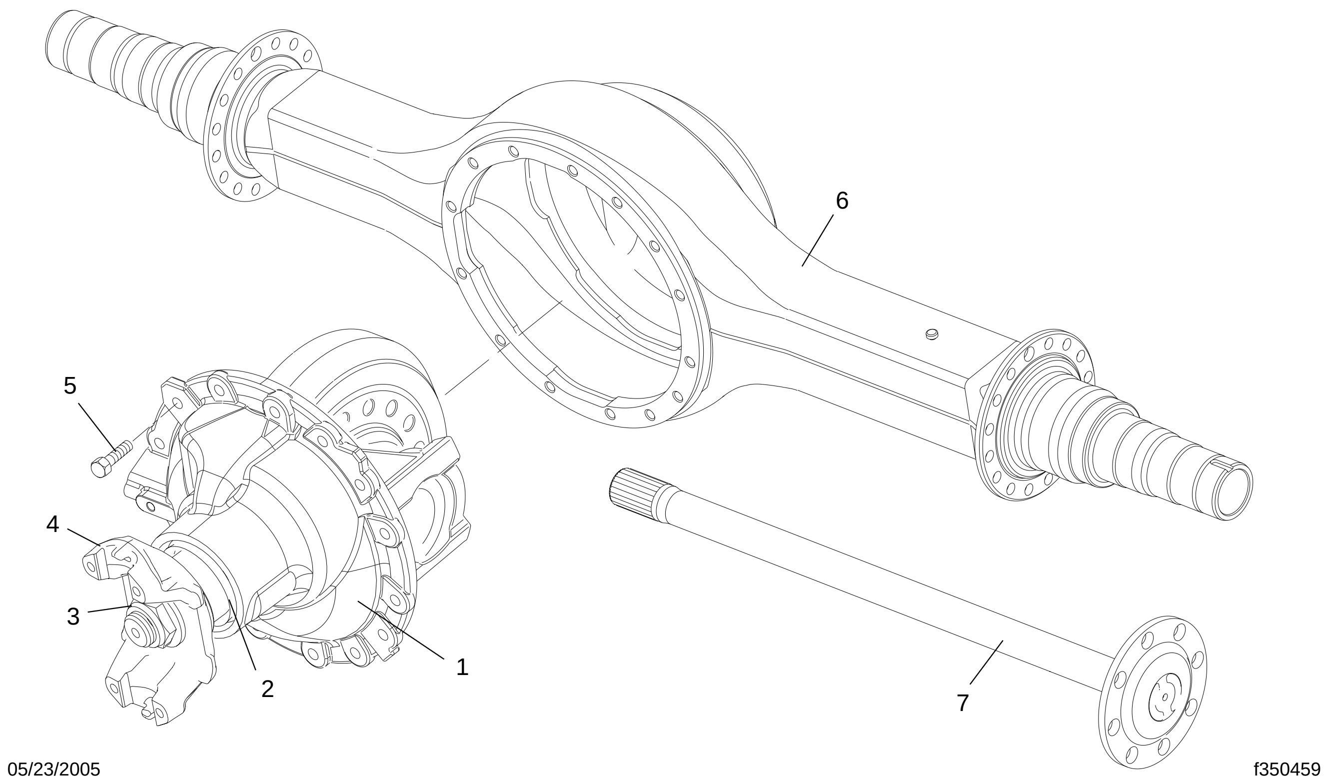
Installation

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 110**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers (if removed) and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.
7. Connect the air lines to the brake air chambers.
8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. Fill each hub with approved axle oil until you can see a small amount of oil trickling out of the back of the hub (fill with about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see **Section 35.01**.

NOTE: See **Table 1** for approved axle oils.

10. 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 110**. 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).

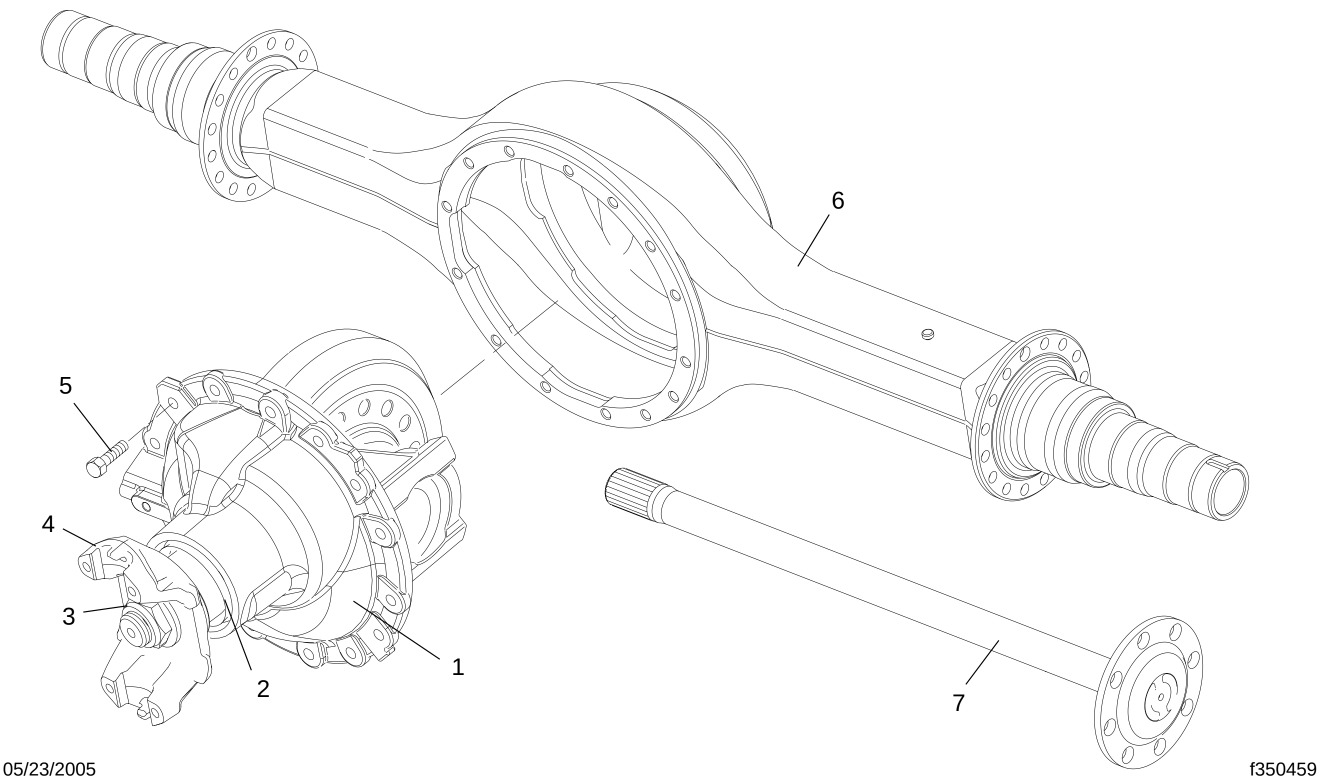
4. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.

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.

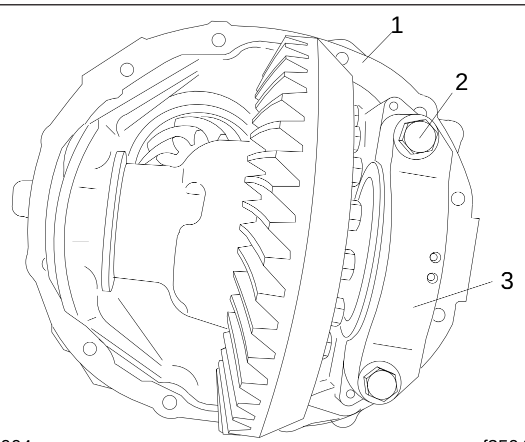
5. Using a hoist (if the axle is removed from the vehicle) or a suitable transmission jack, install the differential carrier into the axle housing. Use the alignment dowels to center the carrier on the axle housing.
6. Install the end caps at the sides of the carrier into the corresponding slots in the 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.

Single Axle Differential Carrier Removal and Installation

8. Connect the driveshaft to the carrier input yoke. For instructions, see **Section 41.00, Subject 110**.
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.

Axle Shaft Removal and Installation

Removal

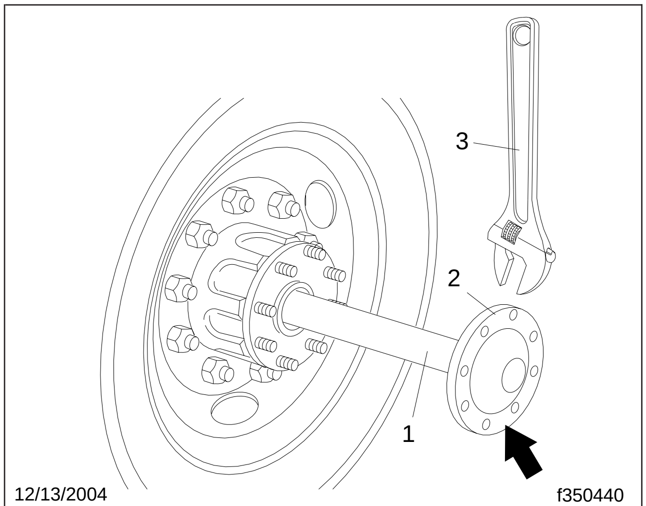
1. Chock the front tires.
2. Raise the rear of the vehicle with a suitable jack high enough to clear the axle. Support the axle with jack stands.
3. Place a basin under the axle shaft flanges to catch any oil. Dispose of used oil properly.
4. If necessary, remove the rear wheels and tires. For procedures, 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

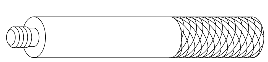
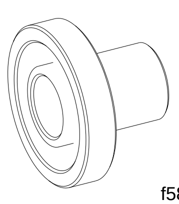
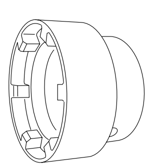
1. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 110**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the yoke nut from the center of the carrier yoke. If the yoke nut is round and slotted, use the yoke nut socket shown in **Table 1**. See **Fig. 1**. Be careful not to damage the seal bore.
3. Remove the carrier yoke from the input shaft.
4. Pry up the seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings. See **Fig. 2**.
5. Install the rear pinion seal on the rear input shaft, as follows. See **Fig. 3**.

   5.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

   5.2 Assemble the rear pinion seal installer onto the threaded end of the universal handle. See **Table 1**.

   IMPORTANT: Be careful not to cock the seal during installation.

   5.3 Using the rear pinion seal installer assembly, press the seal into the bore until the seal surface is flush with the bottom surface of the counterbore.
6. Install the carrier yoke on the input shaft. If the yoke is damaged or worn, install a new yoke.

Special Tools for Single Axle Yoke and Seal Replacement, Model 4 Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools for Single Axle Yoke and Seal Replacement, Model 4 Axles

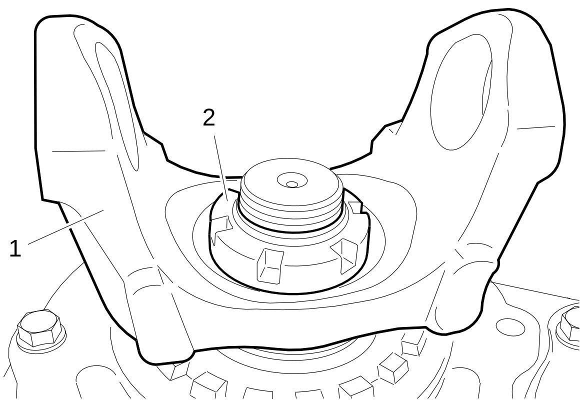
Single Axle Yoke and Seal Replacement, Model 4 Axles

NOTE: It is not necessary to replace the yoke when replacing the seal.

7. Install a new M45 x 1.5 yoke nut on the carrier yoke and tighten 627 lbf·ft (850 N·m).
8. Punch in the cylindrical area at the pinion groove to lock the nut in place.

IMPORTANT: The bent area has to reach the bottom of the pinion groove.

9. Connect the driveshaft. For instructions, see **Section 41.00, Subject 110**.



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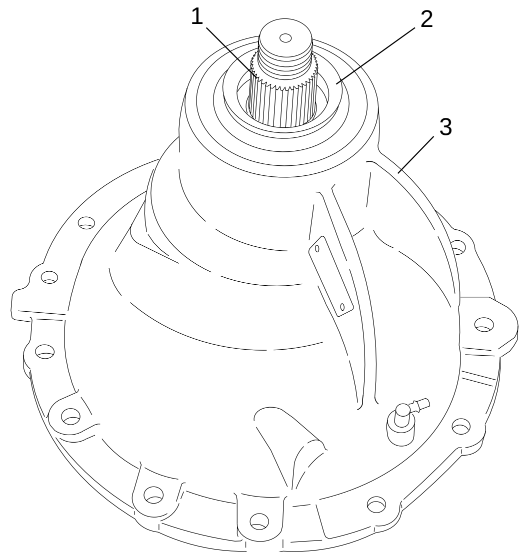
NOTE: The yoke nut may be a hexnut rather than the round, slotted nut shown here.

1. Yoke
2. Yoke Nut

Fig. 1, Yoke Nut on the Carrier



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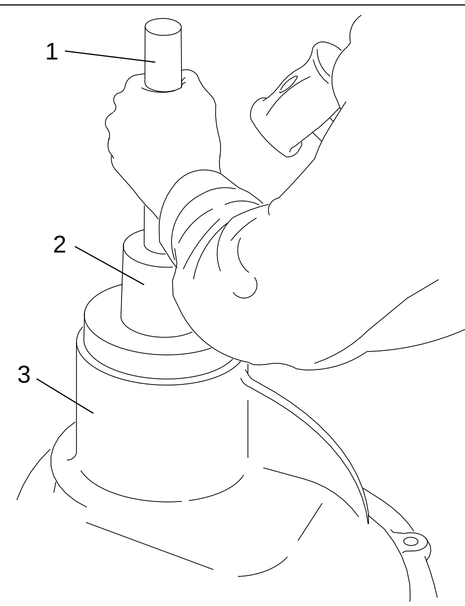
1. Input Shaft
2. Rear Pinion Seal
3. Carrier Housing

Fig. 2, Rear Pinion Seal



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1. Universal Handle
2. Rear Pinion Seal Installer
3. Carrier Housing

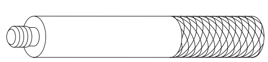
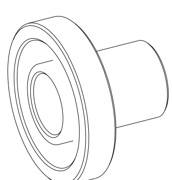
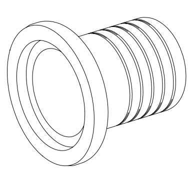
Fig. 3, Installing the Rear Pinion Seal

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)

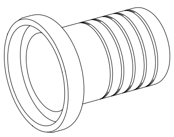
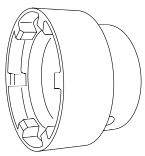
Table 1, Torque Values

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

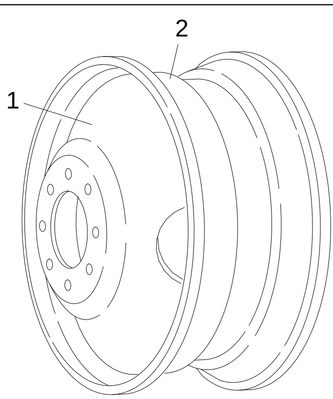
The tires support the weight of the vehicle, and are integral parts of the drivetrain and braking systems. The wheels serve as load carrying members between the tires and the axle.

The disc wheels consist of a rim and disc. The rim, the portion of the wheel on which the tire is mounted and supported, is welded to the disc. See **Fig. 1**. After the tire is mounted on the wheel, the assembly is held in place on the hub with 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 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. 2**. 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. 3**. 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.



1. Disc
2. Rim

Fig. 1, Disc Wheel

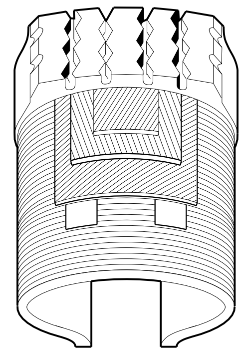


Fig. 2, Radial Ply Tire Construction

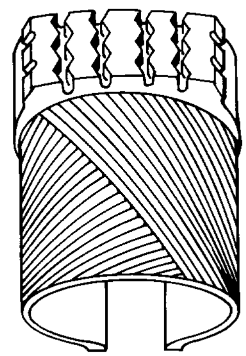


Fig. 3, Bias Ply Tire Construction

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 steel body/steel belt, polyester body/fiberglass belt, or nylon body/steel belt.

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

General Information

certification label. See the vehicle chassis operator's manual for the location of these labels.

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. 4** and **Fig. 5**. 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. 6**, **Fig. 7**, and **Fig. 8**.

When pairing tires of unequal diameters (but within the above limits), mount the larger tire on the outside.

CAUTION

Driving a vehicle on one tire of a dual assembly dangerously exceeds the carrying capacity of the single tire and wheel. Operating in this manner can cause damage to the wheel and tire.

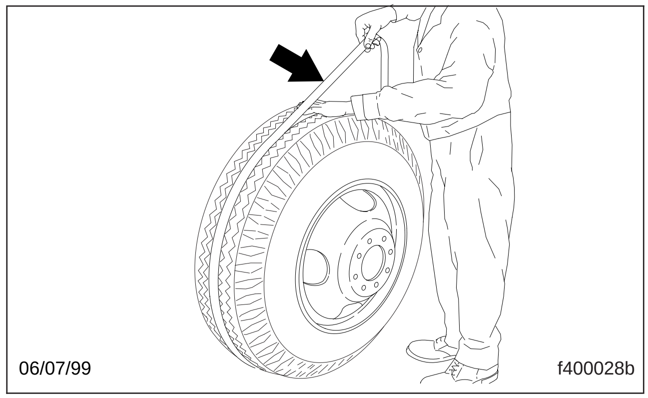


Fig. 4, Endless Pi Tape

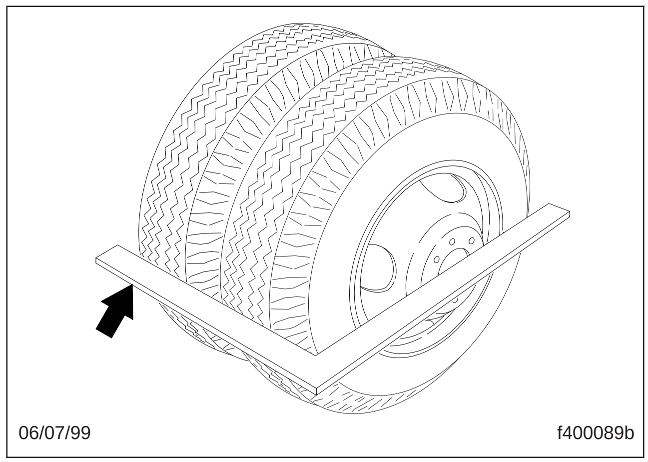


Fig. 5, Square

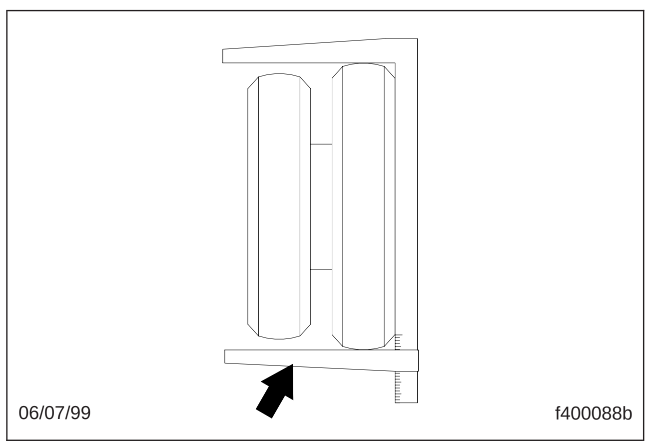


Fig. 6, Matching Stick

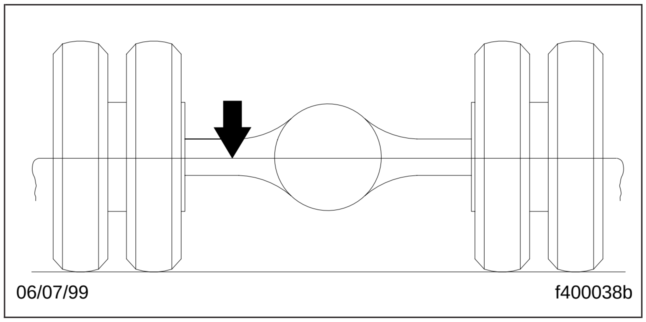


Fig. 7, String Gauge

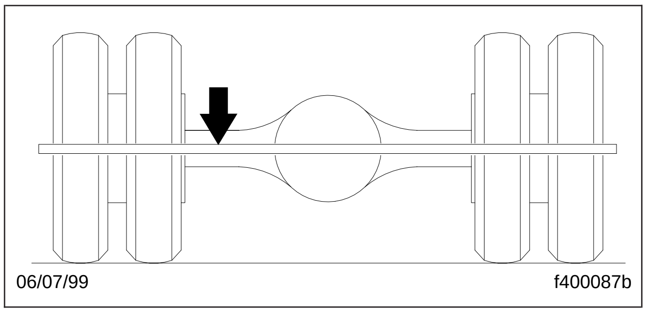


Fig. 8, Tire Straight Edge

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.

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.

Cleaning Aluminum Wheels

Follow the directions below when cleaning the Accuride® Accu-Shield™ Aluminum Wheels.

1. Rinse the wheels with high-pressure water to remove any debris, grit, or dirt particles.
2. Use a cotton cloth dipped in a mild soap solution to help remove stuck on dirt and grease.
3. Rinse the remaining soap residue from the wheels.
4. Dry the wheels thoroughly with a cotton cloth.
5. To repair scratches in the surface, refer to Accuride technical bulletin 2.0038.

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 130**.
2. Apply a few drops of light engine oil to the wheel studs and the area between the body and the flange of each two-piece flange nut. 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.

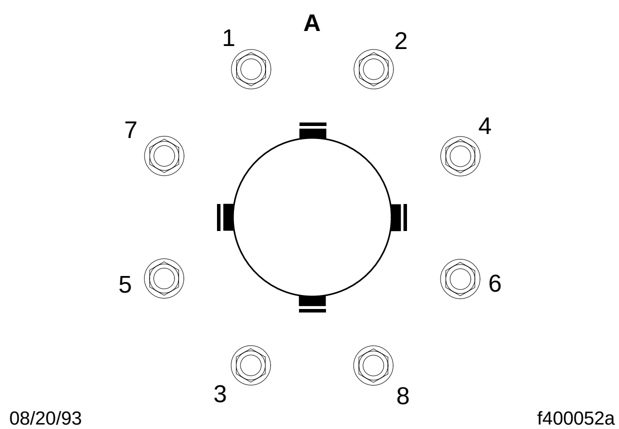
CAUTION

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**.

8-Hole Disc Wheel With Two-Piece Flange Nuts Removal and Installation

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).



A. Top

Fig. 1, 8-Stud Disc Wheel Tightening Sequence

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the studs could be turning in the hub flange, having lost their locking ability. In this case, the wheel hub assembly is damaged and must be replaced with a new assembly.

Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts. Again, damaged parts must be replaced with new parts. Failure to replace damaged parts could result in the loss of a wheel or loss of vehicle control, causing property damage or personal injury.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35** 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 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 130**.
2. Apply a few drops of light engine oil to the wheel studs and the area between the body and the flange of each two-piece flange nut. 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.

10-Hole Disc Wheel With Two-Piece Flange Nuts Removal and Installation

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**.

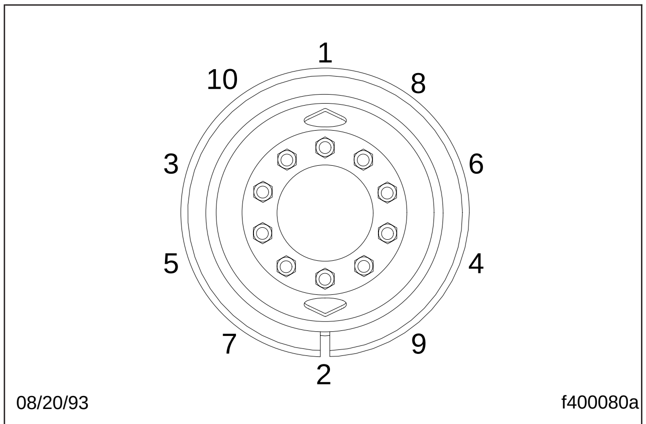


Fig. 1, 10-Stud Disc Wheel Tightening Sequence

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, the studs could be turning in the hub flange, having lost their locking ability. In this case, the wheel hub assembly is damaged and must be replaced with a new assembly.

Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts. Again, damaged parts must be replaced with new parts. Failure to replace damaged parts could result in the loss of a wheel or loss of vehicle control, causing property damage or personal injury.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35** 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 50 to 100 miles (80 to 160 km), retighten the wheel nut 450 to 500 lbf·ft (610 to 678 N·m). Follow the sequence in **Fig. 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. 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. 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 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 inflated using the procedures in **Subject 130**.
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. See the applicable table in **Specifications, 400**.

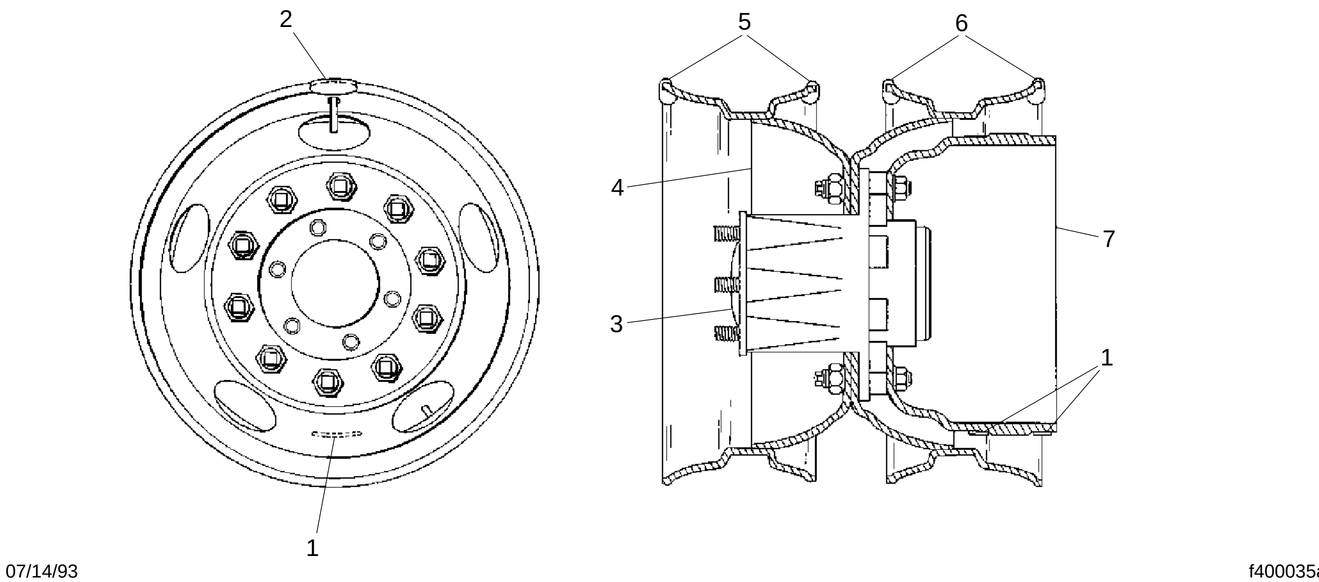
WARNING

If the wheel nuts cannot be tightened to minimum torque values, the studs could be turning in the hub flange, having lost their locking ability. In this case, the wheel hub assembly is damaged and must be replaced with a new assembly.

Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts. Again, damaged parts must be replaced with new parts, as described in the front axle or rear axle group of this manual. Failure to replace damaged parts could result in the loss of a wheel and loss of vehicle control, causing property damage or personal injury.

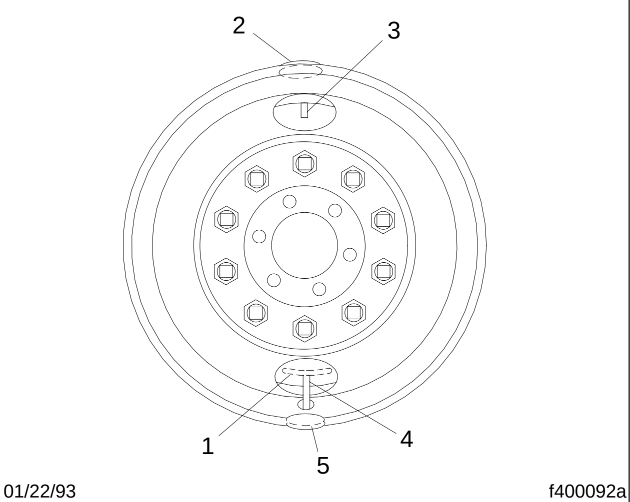
6. For front wheel assemblies, go to the next step. For rear wheel assemblies, use a jack or wheel-and-tire dolly to mount the outer dual wheel on the inner wheel nuts. Be careful not to damage the threads of the inner wheel nuts when installing the wheel assembly. Install the outer wheel nuts following 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**.

10-Hole Disc Wheel With Inner and Outer Nuts Removal and Installation



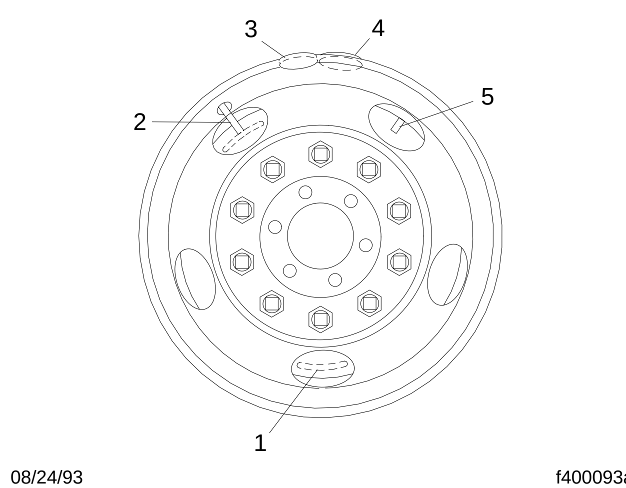
1. Brake Drum Balance Weight(s)
2. Inner and Outer Wheel Balance Weight(s)
3. Hub
4. Disc Wheel
5. Outer Wheel Balance Weight(s)
6. Inner Wheel Balance Weight(s)
7. Brake Drum

Fig. 1, Recommended Location of Wheel and Brake Drum Balance Weights



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



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

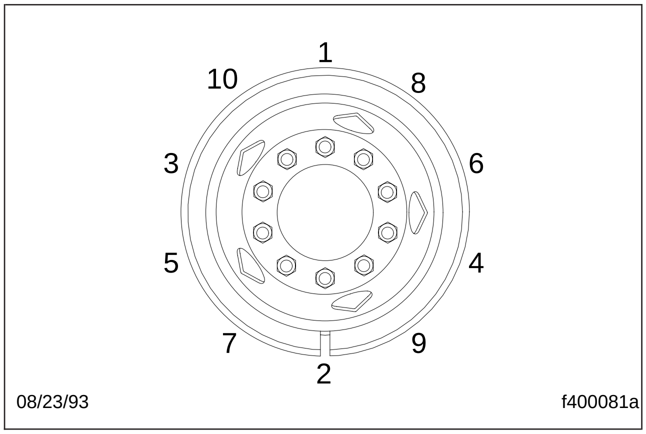


Fig. 4, 10-Stud Disc Wheel Tightening Sequence

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 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. Retighten the inner and outer wheel nuts.

Tire Inflation

⚠ WARNING

During initial tire inflation, there is the possibility of an explosion of the assembly. Observe the following safety rules to reduce the possibility of serious physical injury in the event of an explosion.

NOTE: Inflate tires in a safety cage or an approved portable restraining device. Always use a clip-on chuck with an inline valve and gauge. Make sure the inflation hose is long enough to permit standing to the side of the tire during inflation. Never sit on or stand in front of an assembly that is being inflated.

1. Check all parts to make sure they are correctly seated prior to inflation.

IMPORTANT: Inflate tires immediately after mounting, before the tire lubricant dries. Once the lubricant dries, bead positioning is not possible, even with increased inflation pressure.

2. 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.

   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.

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 the applicable tables under **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.

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.

4. After the initial inflation, completely deflate the tire by removing the valve core. This ensures correct bead seating. Then inflate the tire to the applicable recommended cold inflation pressure listed in tables under **Specifications 400**. Install valve caps and tighten them finger-tight.

⚠ WARNING

Tire underinflation or overinflation will damage wheels and tires, and could result in a blowout causing possible property damage and personal injury.

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.

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.

Safety Precautions

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

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.
3. Place the wide side of the rim down. Lubricate the tire bead and the rim. Insert the curved end of two tire tools between the bead and the rim, and just to one side of the tire valve. Step on the side of the tire, opposite from the valve, to force the first bead into the rim well. See Fig. 2. Hold one of the tools in place with your foot and pry with the second tool, forcing the bead over the rim flange. Continue to work the first bead off of the rim.
4. When the first bead is off the rim, and the second bead is in the rim well, stand the assembly upright with the valve stem near the top. Lubricate the second bead and rim. Insert the straight end of the tool between the tire bead and the back rim flange, hooking the tool over the second flange. Lean the tire assembly toward the tool and use a rocking or bouncing action to pry the rim out of the tire. See Fig. 3.
5. Clean and inspect all parts. Refer to Subject 160 and Subject 170 for procedures.

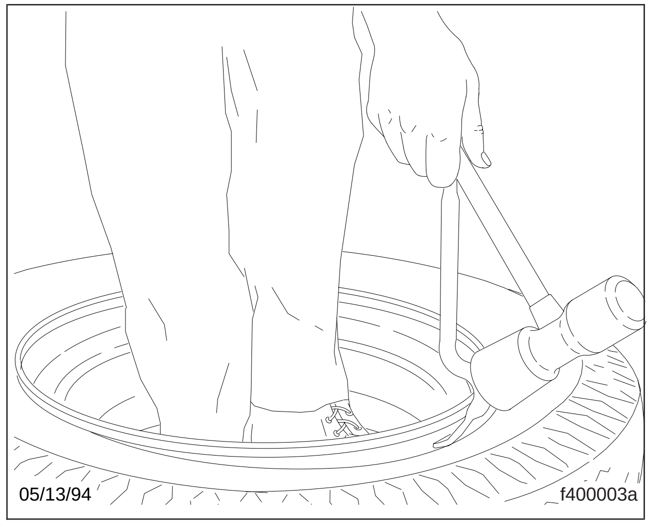


Fig. 1, Loosening the Beads

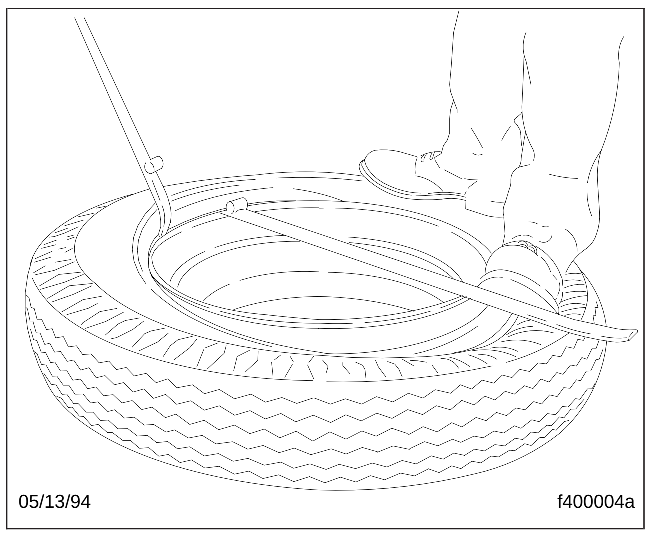


Fig. 2, Forcing Bead into the Rim Well

MOUNTING

1. Place the valve stem, with a rubber washer, through the valve hole from the tire side of the rim. Screw on the valve nut from the opposite side. Make sure the rubber bushing and metal 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

Demounting and Mounting Tubeless Tires on One-Piece Drop Center Wheels or Rims

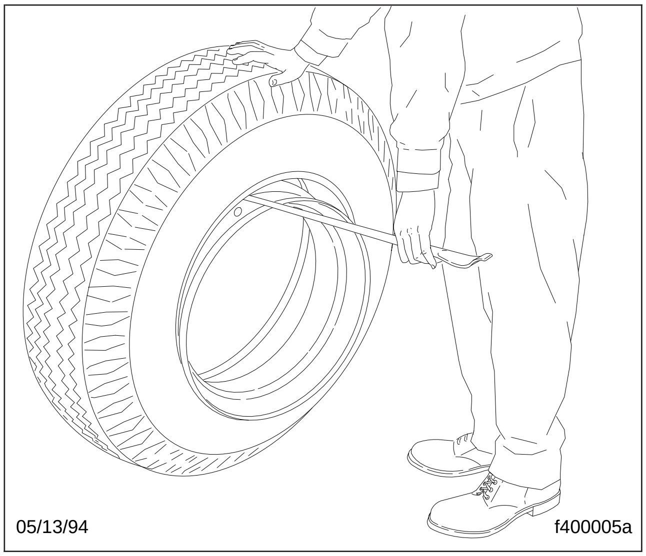


Fig. 3, Prying the Rim Out of the Tire

Fig. 4, Valve Stem Installation

lubricant to enable correct bead seating, and to make mounting easier. Don't let excess lubricant run inside the tire.

3. Lay the tire on the rim. If there is a balance mark on the tire, line up this mark with the valve stem. Push the lower bead over the flange and into the rim well. Using the straight end of the tire tool (with the stop resting on the rim flange), take small bites to work the remaining section of the bead into the rim. See **Fig. 5**.
4. Start the upper bead over the rim flange and into the rim well by standing on the tire. If necessary, push a section of the bead into the rim well, and anchor it by attaching Vise-Grip® pliers to the rim flange (snub side toward the tire). Using the spoon end of the tire iron, with the stop toward the rim, work around the bead. See **Fig. 6**. Use small bites until the bead slips over the flange and into the rim well. If necessary, insert a second tire iron and relubricate the last 8 inches (20 cm) of bead.
5. Inflate the tire. Refer to **Subject 130** for procedures.

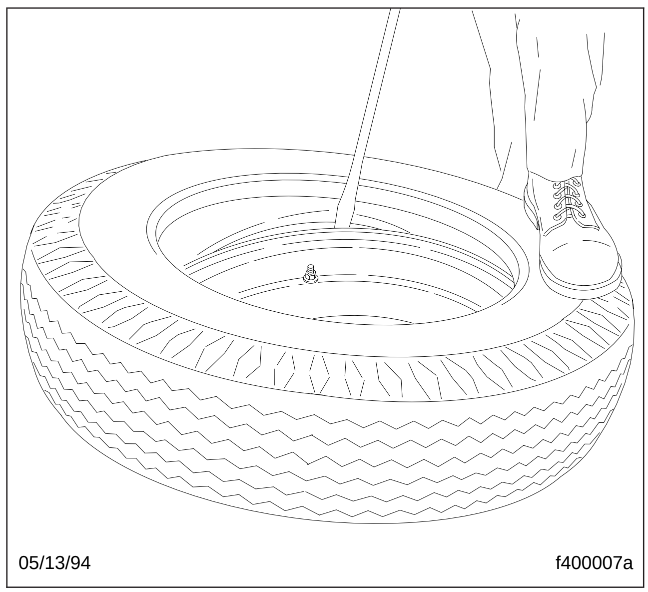


Fig. 5, Working the Lower Bead into the Rim

Demounting and Mounting Tubeless Tires on One-Piece Drop Center Wheels or Rims

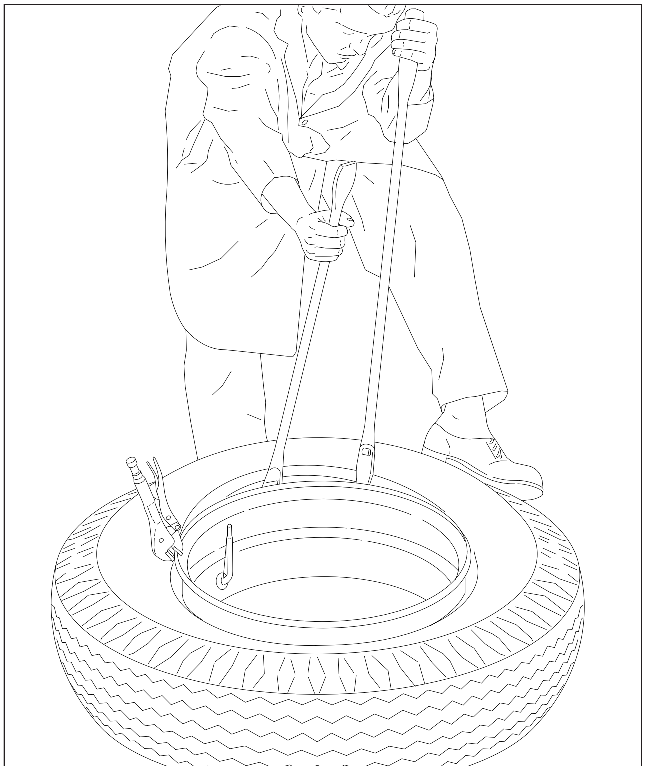


Fig. 6, Working the Upper Bead into the Rim

Inspection

WARNING

Failure to inspect the tires and wheels and correct any problems, 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 brake drum, damaged inner or outer wheel nuts, or an out-of-round wheel or rim makes the replacement of the damaged part necessary. See **Fig. 1**. Replace the wheel if it has out-of-round stud holes.

NOTE: Refer to the **Group 33** or the **Group 35** for inspection and service procedures for the hub, wheel studs, wheel, and brake drum or disc rotor assemblies.

Inspect valve cores for cracks, bends, and air retention. Replace damaged or leaky cores.

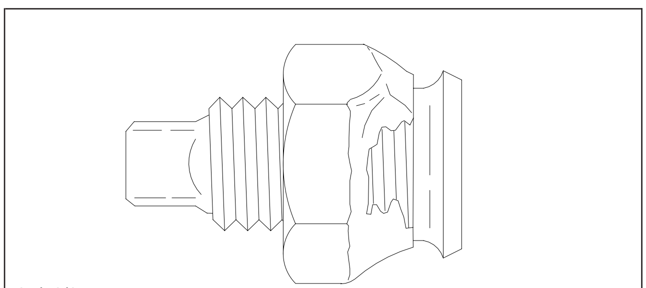


Fig. 1, Damaged Outer Wheel Nut

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.

Inspection

WARNING

Failure to inspect the tires and wheels and correct any problems, 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.

Michelin Tire Corporation recommends using only new valve cores, caps, and O-rings in a new mounting.

Wheel and Tire Runout Measurements

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".

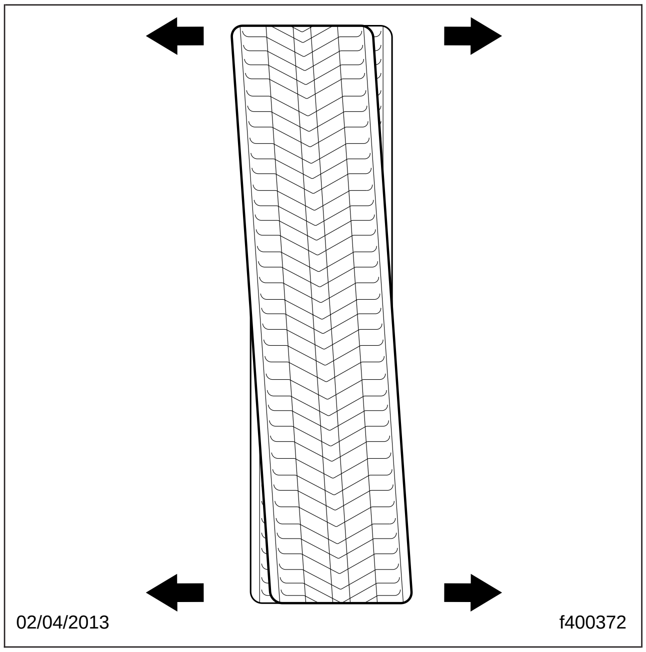


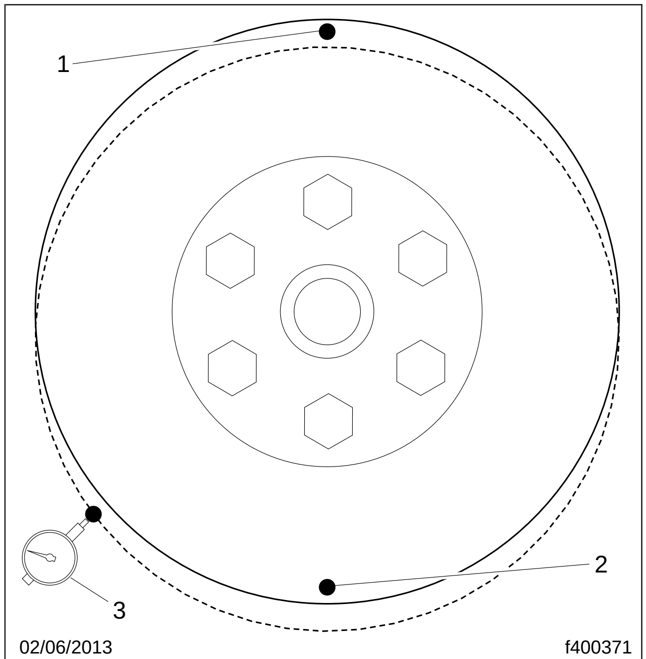
Fig. 1, Lateral Runout

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:



1. High Spot
2. Low Spot
3. Dial Indicator

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)

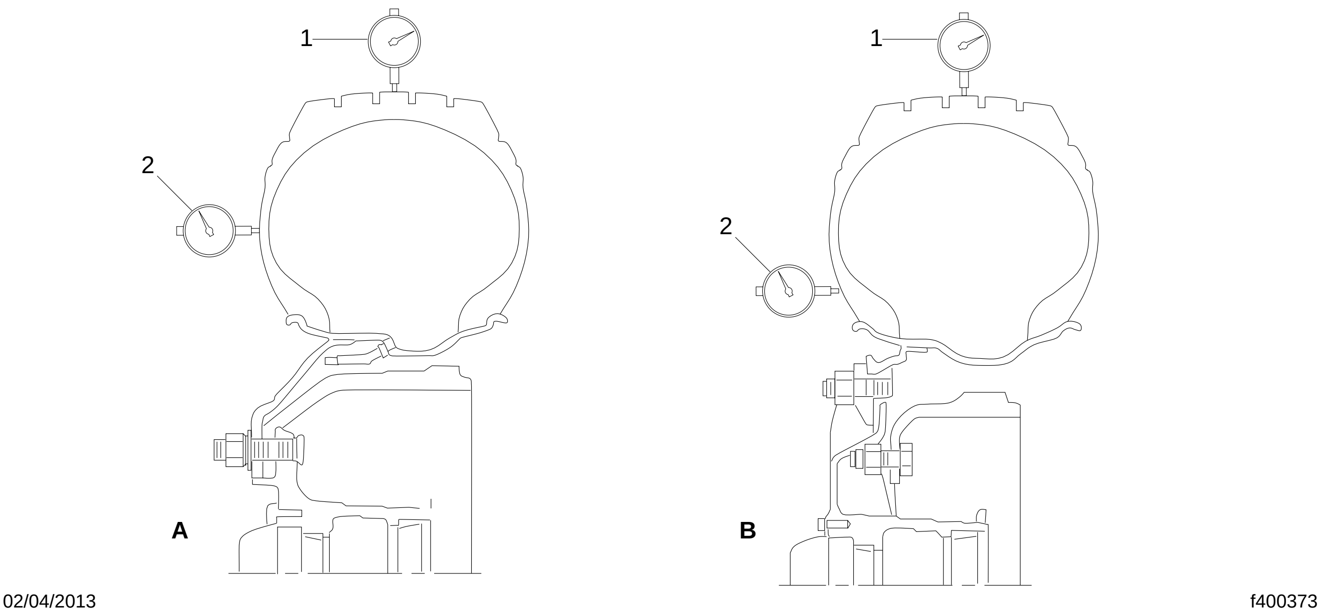
Wheel and Tire Runout Measurements

- 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)

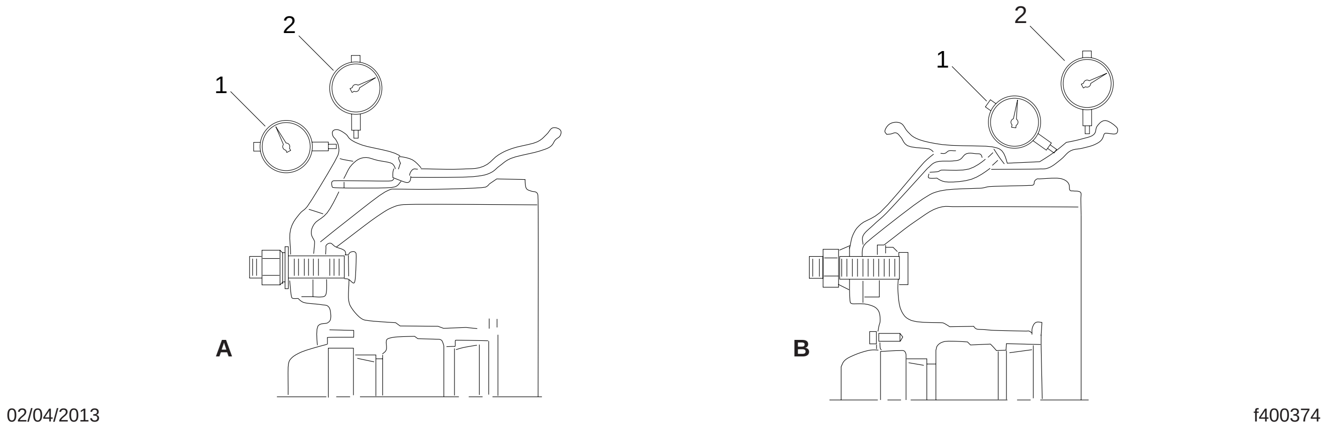
Table 1, Wheel Runout Specifications



A. Tubeless Steel Disc Wheel
B. Tubeless Demountable Wheel
1. Radial Runout
2. Lateral Runout

Fig. 3, Runout Check for Tires

Wheel and Tire Runout Measurements



A. Tubeless Aluminum Disc Wheel
1. Lateral Runout
B. Tubeless Steel Disc Wheel
2. Radial Runout

Fig. 4, Runout Check for Wheels

Troubleshooting Tables

Problem—Abnormal Tire Wear

Problem—Abnormal Tire Wear	
Possible Cause	**Remedy**
Tires are not inflated to the correct pressure.	Operate the tires at the recommended inflation pressure and use the proper size tires, wheels, and rims for the load to be carried. Refer to the applicable tables in **Specifications 400** for specifications.
Inflation pressures in a dual assembly are unequal.	Inflate all tires to a uniform pressure, within 5 psi (35 kPa). Refer to the applicable tables in **Specifications 400** for the proper cold inflation pressures.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in this section.
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 the **Group 42**.
Axles are improperly aligned.	Align the axles. **Group 33** and **Group 35** 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**.
Wear is uneven among tire sets.	Rotate the tires according to the instructions in the wheels and tires group of 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. **Group 33** and **Group 35** 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.
Driveline, suspensions, or steering components are loose or worn.	Determine the location of the vibration, then repair or replace the loose or worn components.

Problem—Excessive On-the-Road Tire Failures

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Tires are not inflated to the correct pressure.	Operate the tires at the recommended inflation pressure and use the proper size tires, wheels, and rims for the load to be carried. Refer to the applicable tables in **Specifications 400** for specifications.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in this section.

Troubleshooting

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Water or foreign material is inside the casing.	Clean and dry the tires prior to mounting. Make sure excess lubricant does not flow down into the tire. Store unmounted tires indoors, or under cover, to prevent moisture from collecting inside.
Tires are contaminated with oil.	Clean the tires and inspect the engine seals, transmission seals, axle-end and drive axle seals, oil filters and oil lines for leakage. Make sure the lubricant used in mounting does not contain a petroleum derivative.
Vehicle is vibrating severely.	Follow the recommendations under "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.

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)‡
		Accuride and Motor Wheel	450–500 (610–678)
Rear Wheel Inner Nut	3/4–16	Alcoa	400–500 (540–678)†
		Budd, Accuride, and Motor Wheel	450–500 (610–678)
Rear Wheel Outer Nut	1-1/8–16	Alcoa	450–500 (610–678)†
		Budd, Accuride, and Motor Wheel	450–500 (610–678)
Wheel Stud Retainer Nut	3/4–16	All	175–200 (235–270)

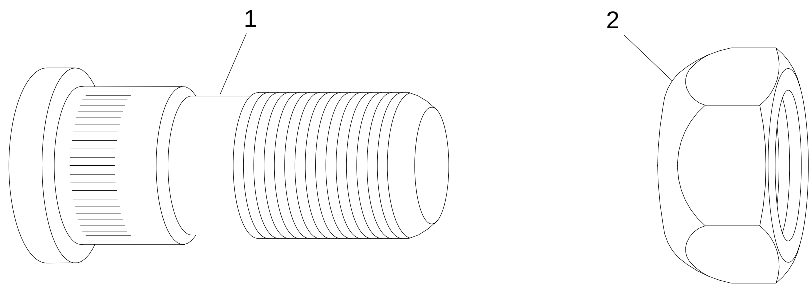
* Torque values are given for lubricated threads.

† 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



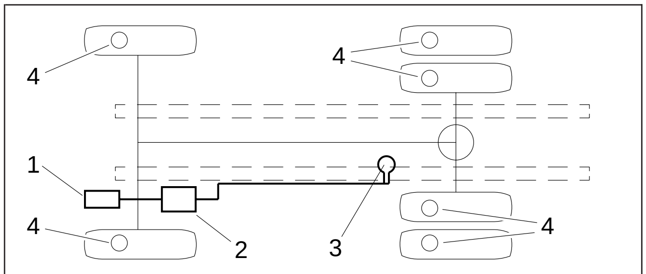
1. Head-Type Wheel Stud (1-1/8–16)
2. Wheel Nut

Fig. 1, Head-Type Wheel Stud

General Information

IMPORTANT: See the SmarTire Tire Pressure Monitoring System (TPMS) Owner's Manual included with this vehicle for additional information, including operation, TPMS warnings, and proper tire removal/installation.

The Tire Pressure Monitoring System (TPMS) constantly monitors the pressure and temperature of each tire on the vehicle, and provides tire status information to warn the driver about a tire-related problem before it becomes dangerous. Tire sensors mounted on each wheel measure tire pressure and temperature every 12 seconds (when the vehicle is moving) and transmit data every 3 to 5 minutes. See **Fig. 1**. If a temperature change or tire pressure change of 3 psi (21 kPa) or greater is detected, the sensor breaks its regular schedule and transmits tire data immediately.



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1. The SmartWave gauge connects to a wireless gateway receiver via the J1939 datalink.
2. A wireless gateway receiver connects to the underside of the vehicle.
3. An antenna at the rear axle(s) connects to the wireless gateway receiver.
4. Sensors are mounted to the wheels.

Fig. 1, TPMS Overview

Tire Pressure Monitoring System (TPMS) Component Replacement

Replacement

IMPORTANT: If any TPMS component(s) should ever need to be replaced, it should be done so that the component(s) are installed in the exact same location when the TPMS was originally installed. Each TPMS component was strategically placed in its original location for optimum system performance. Moving component locations could limit the functionality of the TPMS.

NOTE: This subject includes replacement procedures for three different components.

Antenna

1. Unscrew the antenna from the antenna base assembly.
2. Remove the antenna from the bracket and the antenna base assembly.
3. Get the new antenna. Remove the red rubber cap from the threaded connector on the antenna base assembly and unscrew the 1-inch locknut. Be careful not to lose or damage the thin rubber seal that is pressed into the locknut.
4. Pass the threaded connector through the main hole in the bracket, and orient the base assembly, so that the cable points in the direction of the cable it will connect to without being bent. The base assembly must be properly centered in the hole so that the grooved tabs prevent it from being pulled through when the locknut is tightened.
5. With the rubber seal pressed into the locknut and facing the bracket, screw the locknut back on the connector using a 1-inch (25-mm) adjustable wrench.
6. Press the rubber base seal against the base of the antenna. When done correctly, the rubber base seal will adhere to the antenna base on its own.
7. Carefully thread the antenna on the locknut. Use one hand to tighten the antenna and the other hand to ensure the antenna base assembly does not turn. Hand-tighten the antenna until it is firmly assembled and can not be turned further, and the rubber base seal slightly overlaps the edges of the metal bracket on all sides.

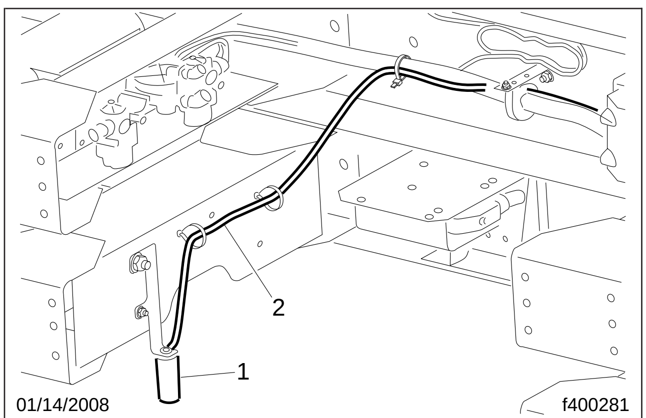
Receiver

The existing receiver is externally mounted near the front of the vehicle and is in a position as close to the vehicle's centerline as possible. The receiver can be mounted with the SmarTire® logo right-side up or upside down (to protect the wiring from possible road debris damage). The receiver must always be within a clear line of sight to the front wheels.

1. Disconnect the wiring harness from the receiver.
2. Remove the two 1/4–20 (or, M6 x 1) flange-head capscrews and remove the receiver.
3. Use the existing bolt holes and the two 1/4–20 (or, M6 x 1) flange-head capscrews to attach the new receiver to the vehicle. Tighten the capscrews 7 to 10 lbf·in (79 to 158 N·cm).
4. With the ignition off, connect the wiring harness to the main connector on the receiver.

Wiring

1. Remove the existing wiring. Take note of how the wiring is routed along the chassis.
2. Route the new wiring. See **Fig. 1** and **Fig. 2**. The new wiring should follow the existing wiring routing as closely as possible.

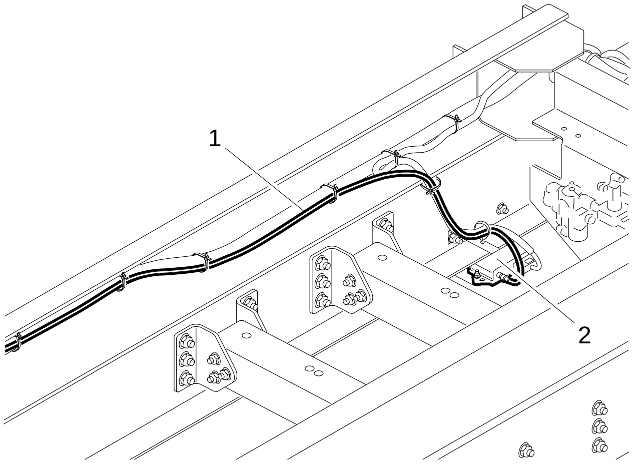


1. Antenna
2. Wiring

Fig. 1, TPMS Wiring From the Antenna

3. Apply wiring ties every 2 feet (0.6 m) to ensure a secure attachment. Avoid chafing by not overtightening.
4. Tighten hexhead screws 17 to 23 lbf·ft (23 to 31 N·m).

Tire Pressure Monitoring System (TPMS) Component Replacement



1. Wiring 2. Receiver

Fig. 2, TPMS Wiring to the Receiver

5. Make sure all wiring harness connections are correctly locked and secured.

Replacement

IMPORTANT: Tire sensors can be broken when mounting and demounting a tire if the specific instructions listed here are not followed. If steps are not taken to avoid the sensor located in the drop center well of the rim, it can be crushed by the beads as the tire is removed.

Each sensor, however, is mounted inside a break-away sensor cradle that is designed to absorb the impact of damage. If damage does occur during the tire mounting/demounting process, most often the inexpensive sensor cradle will break instead of the tire sensor.

If a sensor cradle is damaged, both the sensor cradle and metal strap must be replaced. Carefully remove the tire sensor from the damaged cradle, insert it into a new cradle, and continue the mounting process.

Replacement Using Tire Irons

1. Remove the tire/wheel assembly from the vehicle, and lay the assembly on a floor mat. Make certain that the mounting side of the wheel is facing upward and both the bead and wheel flange are properly lubricated.
2. Look for the rim-mounted decal that indicates the location of the sensor. See **Fig. 1**.
3. The sensor should be located at the valve stem. Unseat both beads directly opposite the sensor. Do not unseat the bead at or near the sensor/valve stem.
4. Starting near the sensor, lift the top bead over the wheel flange using tire irons and progressively work away from the sensor until the top bead is free. Be careful not to contact the sensor with the tire irons.
5. Repeat the process for the bottom bead, again starting near the sensor, until the tire is free from the wheel.
6. Cut the metal strap that holds the tire sensor in place and remove the sensor.
7. Get a new metal strap, and wrap it around the rim in the lowest point of the drop center well. Mark it 1 inch (2.5 cm) past the worm gear. See **Fig. 2**. Cut the metal strap at the mark. Any excess metal strap must be removed or it could break off and damage the tire.
8. Slide the sensor in place.

IMPORTANT: The sensor must always be installed at the valve in order to know its approximate location after the tire has been mounted.

9. With the strap and sensor positioned in the lowest point of the drop center well, feed the end of the strap into the worm gear and pull it tight. Orient the sensor so that it is positioned at the valve with the worm gear 4 inches (10 cm) away from the edge of the sensor.
10. Use a 5/16-inch (8-mm) hexagon driver and tighten the strap by hand 35 lbf·in (395 N·cm). Do not overtighten the strap.
11. If a new rim was used, indicate the location of the sensor by applying the supplied rim label.
12. Mount the tire, so that the last part of the bead to slip over the flange happens directly at the sensor.

    Start at one end of the tire and work towards the opposite end, with the tire oriented so that the beads are first pushed under the rim flange directly opposite the sensor, and then worked over the flange toward the sensor. See **Fig. 3**. The bead will finally slip over the rim flange at the sensor without contacting it.
13. Repeat the step above for the remaining bead.

Replacement Using A Tire Mounting Machine

1. Remove the tire/wheel assembly from the vehicle. Make certain that the mounting side of the wheel is facing upward and both the bead and wheel flange are properly lubricated.
2. Look for the rim-mounted decal that indicates the location of the sensor. See **Fig. 1**.
3. The sensor should be located at the valve stem; do not break the bead at or near the sensor and valve stem. Unseat the beads directly opposite the sensor and valve stem.
4. Position the lubricated tire/wheel assembly on the machine so that the dismount head and the sensor are approximately aligned.

Tire or Tire Sensor Replacement

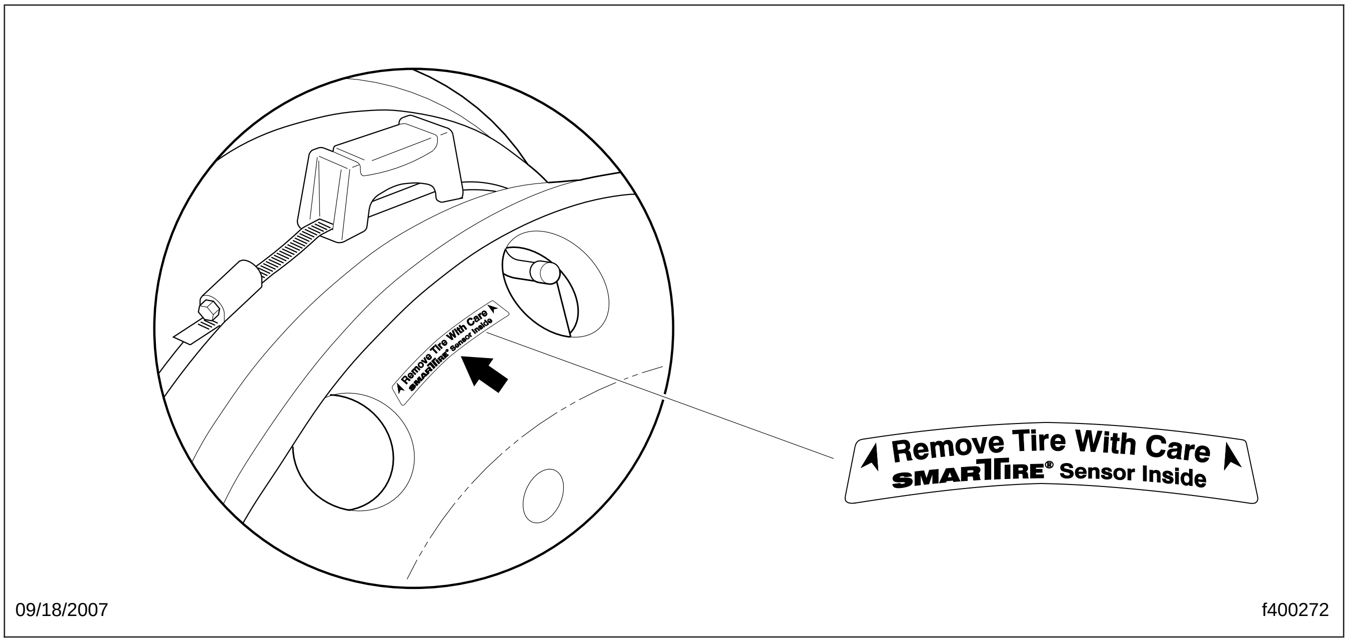
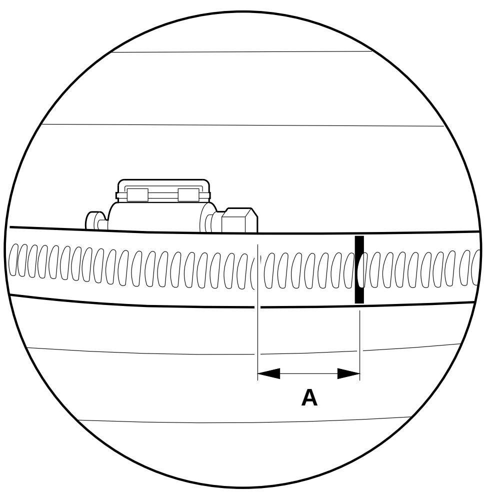


Fig. 1, Sensor Location Decal



A. Distance Past the Worm Gear, 1 inch (2.5 cm)

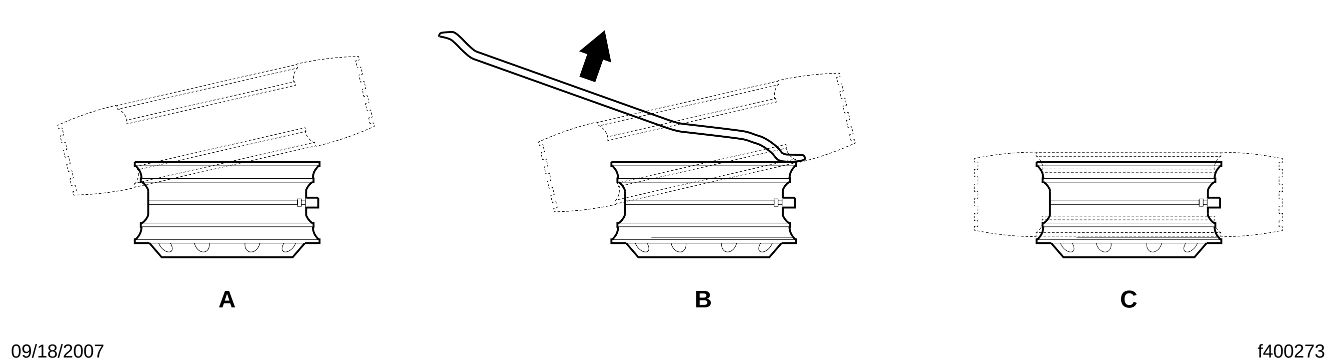
Fig. 2, Marking the Metal Strap

5. Lift the bead over the rim flange with the bead lifting bar, and then advance the assembly/ dismount head clockwise to remove the top bead.
6. Repeat the last two steps to remove the bottom bead.
7. Cut the metal strap that holds the tire sensor in place and remove the sensor.
8. Get a new metal strap, and wrap it around the rim in the lowest point of the drop center well. Mark it 1 inch (2.5 cm) past the worm gear. See **Fig. 2**. Cut the metal strap at the mark. Any excess metal strap must be removed or it could break off and damage the tire.
9. Slide the sensor in place.

IMPORTANT: The sensor must always be installed at the valve in order to know its approximate location after the tire has been mounted.

10. With the strap and sensor positioned in the lowest point of the drop center well, feed the end of the strap in to the worm gear and pull it tight. Orient the sensor so that it is positioned at the valve with the worm gear 4 inches (10 cm) away from the edge of the sensor.
11. Use a 5/16-inch (8-mm) hexagon driver and tighten the strap by hand 35 lbf·in (395 N·cm). Do not overtighten the strap.
12. If a new rim was used, indicate the location of the sensor by applying the supplied rim label.

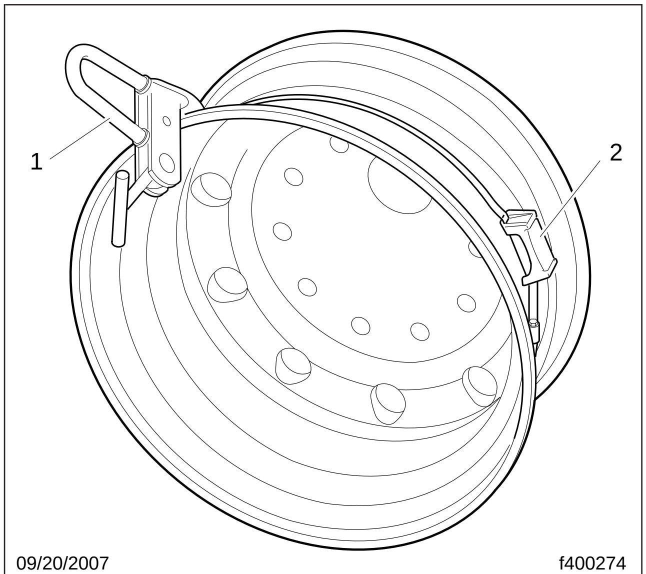
Tire or Tire Sensor Replacement



A. Beads are pushed under the rim flange opposite the sensor.
B. The beads are worked over the flange toward the sensor.
C. The bead slips over the rim flange at the sensor without contacting it.

Fig. 3, Remounting Tires Using Tire Irons

13. Place the rim on the machine so that the rim flange clamp is at a 12 o'clock position, the sensor is at a 2 o'clock position, and the mounting hook is at an 8 o'clock position. See **Fig. 4**.



1. Rim Flange Clamp
2. Sensor

Fig. 4, Remounting Tires Using a Vertical Tire Machine

14. Advance the wheel clockwise to pass both beads over the rim flange simultaneously. The tire should mount onto the wheel without contacting the sensor. See **Fig. 5** and **Fig. 6**.

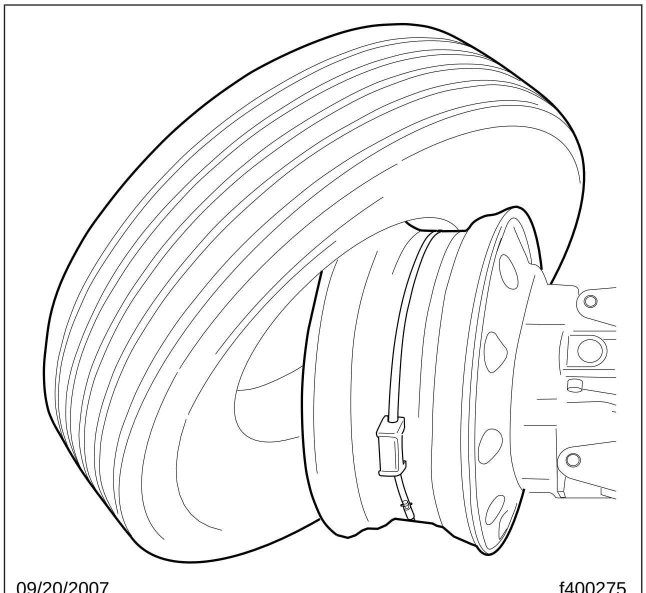
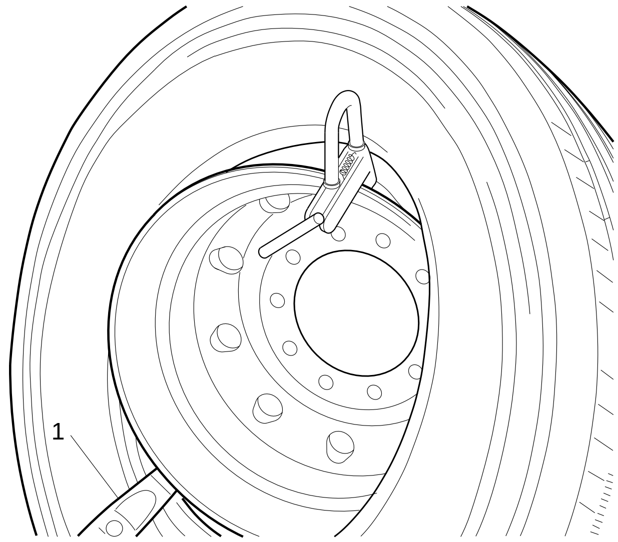


Fig. 5, Passing Both Beads Over the Rim Flange at the Same Time

Tire or Tire Sensor Replacement



1. Mounting Hook

Fig. 6, Mounting Hook Placement

System Programming

If a tire sensor is damaged, it will have to be replaced and the new sensor will have to be programmed into the Tire Pressure Monitoring System (TPMS). Follow the instructions below to program the TPMS.

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brake.
2. Use an electric lift to raise the vehicle just high enough to remove the tires.
3. Remove the damaged sensor(s). For instructions, see **Subject 110**.
4. Install the new sensor(s) on the wheels. For instructions, see **Subject 110**.
5. Turn the ignition switch to the ON position.
6. Connect the laptop connector to the diagnostic connector on the chassis. See **Fig. 1**.

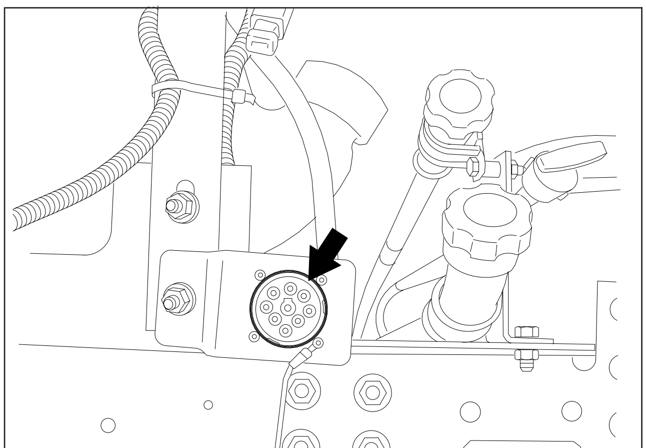


Fig. 1, Rear Diagnostic Connector (actual location will vary)

7. On a laptop computer, open the SmartWave Diagnostic Tool. The SmartWave software can be downloaded for free at www.smartire.com.
8. At the "Info" tab, select the adaptor you are going to use. This allows communication between the software and the receiver. Then click "Connect J1939".
9. Go to the "Setup" tab. Pick the last axle that is on the vehicle being serviced. Multiple axles will be listed as 1 through 12. Remove the extra axles by clicking them on the screen. Once the axle is removed, it will no longer be highlighted. Dual wheel axle can also be selected on the screen if it is present on the vehicle. Click "Save" to save the selected axle configuration.

NOTE: There is a preset cold inflation pressure (CIP) of 100 psi (690 kPa).

10. Either the Assign Selected Sensor method or the Learning Method are used to program the tire sensors for the TPMS. The learning method requires the use of a hand-held LF Initiator, available from Dana/Roadranger®. Place the stickers from the factory with the assigned names for each sensor on the correct sensor before proceeding with either method.

    10.1 **Assign Selected Sensor**

    - On the laptop, choose "Sensor Configuration".
    - From the sensor label, enter the last seven digits of the sensor number into the green-dashed text box.
    - Next, click "Assign Selected Sensor". On the laptop, the sensor ID will appear on the selected tire.
    - Continue selecting each tire with a new sensor, and entering the number for each individual sensor on the laptop, until all tire sensors have been assigned.

    10.2 **Learning Method**

    - On the laptop, choose a tire, and then click "Learn Selected Sensor".
    - Take the LF Initiator and hold it at the valve stem (where the sensor is located).
    - Push "learn" on the LF Initiator. It can take up to 30 seconds for the transmission to be received and complete the learning method. The sensor number will appear on the laptop and the tire icon will turn green.
    - Repeat this process for each tire with a new sensor.
    - Verify all sensors with the LF Initiator. Choose "Verify Selected Sensor"

System Programming

on the laptop. Next, push "initiate" on the LF Initiator. Each tire will appear in red on the laptop screen. Once each tire has been verified, it will appear in white on the laptop screen.

NOTE: For vehicles with dual rear tires, the sensors must be 180° apart. Get in as close as possible to the inner valve stem with the LF Initiator to complete the Learning Method.

Troubleshooting

SmartWave Gauge Display Troubleshooting

Smartwave Gauge Display Troubleshooting	
Problem	**Solution**
When the gauge is turned on, the screen goes black or shows black lines but no SmarTire logo.	Cycle ignition power for the vehicle one more time to restart the display and clear the screen. If the screen remains black, contact Freightliner Custom Chassis Corporation.
The gauge only displays dashes for the tire information; there is no pressure, temperature, or deviation value.	Depending on the type of tire sensor purchased, the vehicle may need to be driven above 15 mph (24 km/h) to wake up the sensors. If the vehicle is stationary with the ignition on, a time interval of up to 15 minutes may be required for all tire locations to be registered on the gauge.
There is no audible alarm when the gauge shows a deviation or severe underinflation.	Make sure the optional buzzer is connected to the SmartWave harness and that the buzzer option is set to ON in the gauge setup menu.
The gauge stops part way through the initialization process and will not show the TPMS Ready screen.	Ensure that the latest version of the gauge display is installed by checking the version number below the initialization progress bar. If it does not read ’Version 1.5’ contact Freightliner Custom Chassis Corporation.
When the gauge first powers up, the alert lamp is blinking and an exclamation mark is displayed. A few minutes later the alert clears and the display returns to normal. Was there an alert?	During the start up sequence, the gauge may clear itself of a previous alert condition or issue a momentary alert if a tire sensor has not reported in. As soon as the tire sensors report their latest readings and they do not constitute an alert condition, the gauge will clear the alert.
The gauge appears to turn itself on and off or flicker repeatedly.	Check the gauge power and ground wire connections in the fuse box to ensure they are properly seated in their respective sockets. In case terminal rings are used, ensure that the terminal screws are properly fastened. If the problem persists, contact Freightliner Custom Chassis Corporation.

SmartWave Receiver Troubleshooting

SmartWave Receiver Troubleshooting	
Problem	**Solution**
The gauge or diagnostics software is not receiving any information from the receiver.	Check to make sure the LED indicator light on the front of the receiver lights up when the ignition is switched on. The receiver LED will turn on at the same time the ignition key is turned and remain on for 2 seconds, then turn off or blink depending on its configuration. If the light does not turn on at all, check the power supply connections and 5 amp fuse, if installed, in the fuse panel that connects to the receiver power line. If the receiver continues to be unresponsive, contact Freightliner Custom Chassis Corporation.

SmartWave System Troubleshooting

Tire Pressure System Troubleshooting	
Problem	**Solution**
Several tires on the rear axle(s) are reporting sensor faults.	Check the rear antenna to make sure it has not been damaged, bent, or moved. Also check the condition of the antenna cable leading to the front of the vehicle, as well as the connection of the antenna cable to the receiver. If the sensor faults continue to show up, contact Freightliner Custom Chassis Corporation.

Troubleshooting

Tire Pressure System Troubleshooting	
Problem	**Solution**
A tire continues to show a deviation value/ warning although it has the correct amount of air.	Check the CIP value in the gauge to make sure it matches that of the intended inflation value for the tire in question. To do so, refer to section 4.2.4 in the SmartWave system manual, included with this vehicle. See the inflation tables in **Subject 400**. If the CIP value is matched to the recommended inflation pressure for the vehicle and the prevailing ambient temperature, but the deviation continues to show up, the tire has a slow leak. Take the appropriate steps to have the tire inspected for any damage or leaks.
Pressure readings for a tire location do not change on the gauge when the tire pressure value is corrected.	When the transmitters are in stationary mode, they sense pressure and transmit every 15 minutes. Wait for a new transmission to be received or initiate a transmission with the SmartWave hand tool or LF Initiator.
Pressure readings for a tire location do not change on the gauge when the tire pressure value is corrected and a new transmission has been received.	Tire/wheel assemblies may have been relocated on the vehicle without the receiver being updated. Power-down and then power-up the receiver, initiate a transmission from that tire location and note the location where pressure is registered on the display. Correct the preprogrammed tire locations as necessary using the gauge or diagnostics software and hand tool.

Figure 1 shows a wiring schematic for the Tire Pressure Monitoring System (TPMS). See **Figure 2** for low range cold inflation pressure (CIP) and **Figure 3**.

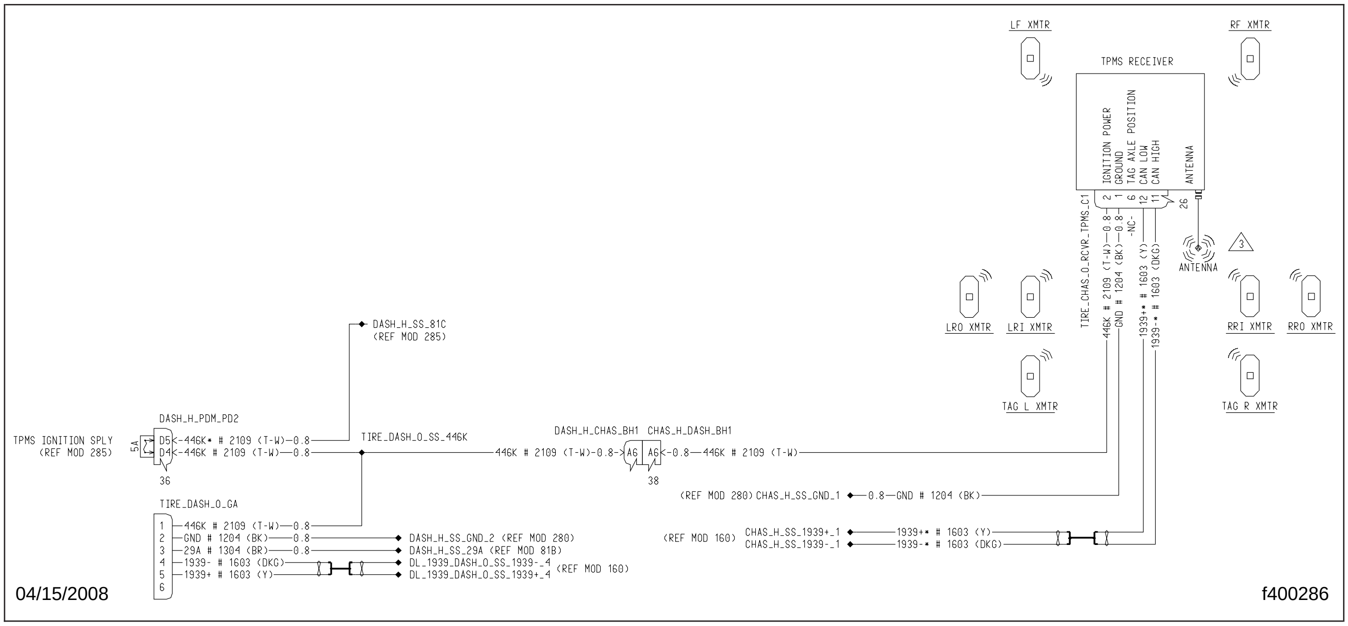


Fig. 1, TPMS Wiring Schematic

Pressure / Temperature Correlation Chart: Low Pressure Range

RECOMMENDED COLD INFLATION PRESSURE (PSI) — *AMBIENT / TIRE TEMPERATURE*

°C	°F	25	30	35	40	45	50	55	60	65	70	75	80
7	45	24	28	33	38	43	48	52	57	62	67	72	76
13	55	24	29	34	39	44	49	54	59	64	69	73	78
18	65	25	30	35	40	45	50	55	60	65	70	75	80
24	75	26	31	36	41	46	51	56	62	67	72	77	82
30	85	27	32	37	42	47	53	58	63	68	73	79	84
35	95	27	33	38	43	48	54	59	64	70	75	80	86
40	105	28	33	39	44	50	55	60	66	71	76	82	87
46	115	29	34	40	45	51	56	62	67	73	78	84	89
52	125	30	35	41	46	52	58	63	69	74	80	85	91
57	135	30	36	42	47	53	59	64	70	76	81	87	93
62	145	31	37	42	48	54	60	66	71	77	83	89	94
68	155	32	38	44	49	55	61	67	73	79	85	90	96
74	165	33	39	45	51	56	62	68	74	80	86	92	98

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Fig. 2, Cold Inflation Pressure—Low Pressure Range

Pressure / Temperature Correlation Chart: High Pressure Range

RECOMMENDED COLD INFLATION PRESSURE (PSI) — *AMBIENT / TIRE TEMPERATURE*

°C	°F	85	90	95	100	105	110	115	120	125	130	135	140
7	45	81	86	91	96	100	105	110	115	120	125	129	134
13	55	83	88	93	98	103	108	113	118	123	127	132	137
18	65	85	90	95	100	105	110	115	120	125	130	135	140
24	75	87	92	97	102	107	113	118	123	128	133	138	143
30	85	89	94	100	105	110	115	120	126	131	136	141	146
35	95	91	96	101	107	112	117	123	128	133	138	144	149
40	105	93	98	103	109	114	119	125	130	136	141	147	152
46	115	95	100	106	111	117	122	127	133	138	144	149	155
52	125	97	102	108	113	119	125	130	136	141	147	152	158
57	135	98	104	110	115	121	127	132	138	144	149	155	161
62	145	100	106	112	117	123	129	135	140	146	152	158	164
68	155	102	108	114	120	126	131	137	143	149	155	161	167
74	165	104	110	116	122	128	134	140	146	152	158	164	170

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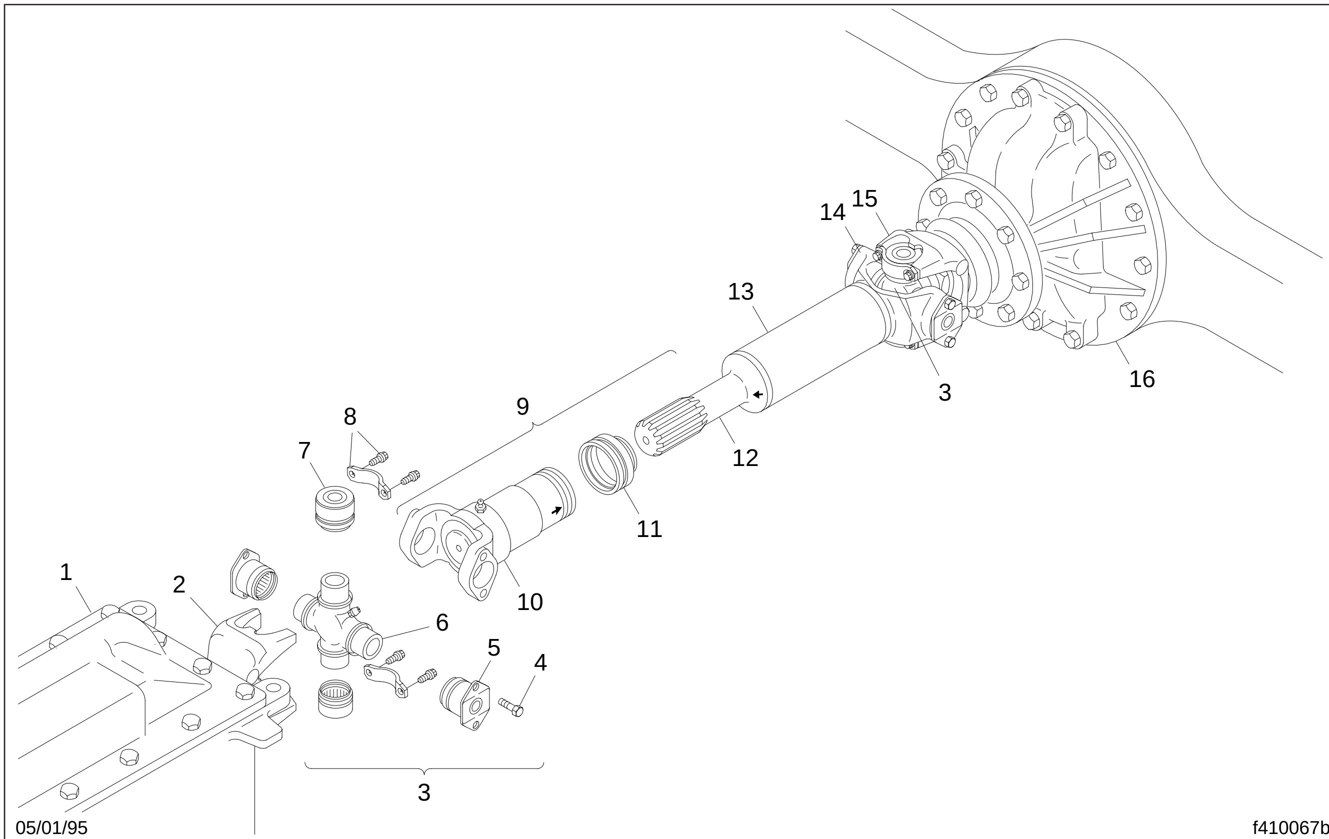
Fig. 3, Cold Inflation Pressure—High Pressure Range

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.

SLIP-JOINTS, U-JOINTS, AND YOKES

The basic function of the driveline is to send torque from the transmission to the axle in a smooth and continuous action. Because the vehicle axles are not attached directly to the frame, but are suspended by springs, they ride in an irregular, floating motion



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

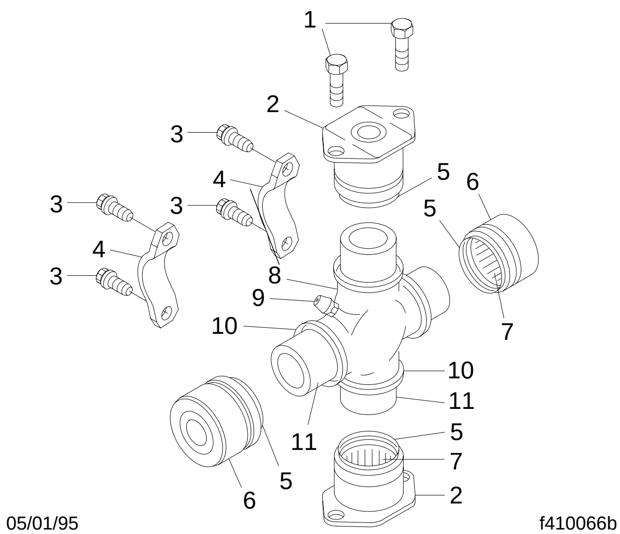
(when going over bumps or depressions), thus changing the distance between the transmission (or

General Information

coupling shaft) and the rear axle, and the distance between the rear axles.

Motion of the rear axle also causes changes to the relative angles between drivetrain components. U-joints allow transfer of torque from an output shaft to an input shaft, even though the angles between the shaft may be constantly changing.

Each U-joint consists of a cross with a close-tolerance ground cylindrical surface (trunnion) at the end of each of the four arms. Installed on each trunnion is a bearing cup lined with bearing needles. All bearing cups are sealed to retain lubricants, and to prevent entry of foreign material. See **Fig. 2**. In operation, the four bearing cups are held stationary in a pair of yokes, while the U-joint cross pivots on its trunnions.

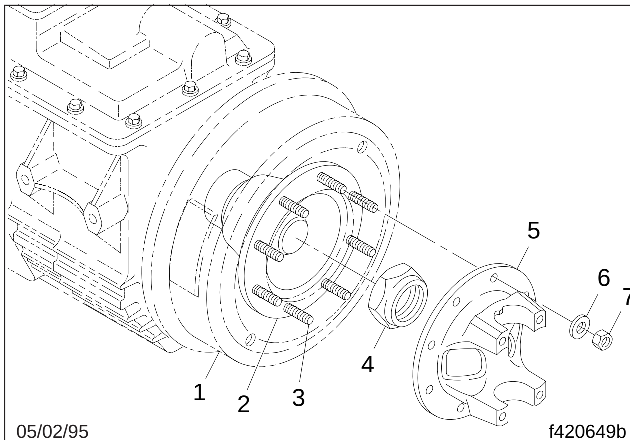


NOTE: Components shown are typical of all U-joints installed on Freightliner chassis with half-round end-yokes.

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. 2, Typical U-Joint

An end-yoke is an internally splined yoke, held on an externally splined shaft by a locknut. End-yokes are installed on the transmission output shaft and the axle input shaft. A half-round flange-yoke is used with the driveline parking brake, and fastens with locknuts to the studs of a companion flange that installs on the transmission output shaft or the rear axle input shaft in the same manner as an end-yoke. See **Fig. 3**.



NOTE: Not all fasteners are shown.

1. Parking Brake Drum
2. Companion Flange
3. 3/8–24 Threaded Stud
4. Companion-Flange Locknut
5. Half-Round Flange-Yoke
6. Bearing Washer
7. Flange-Yoke Locknut

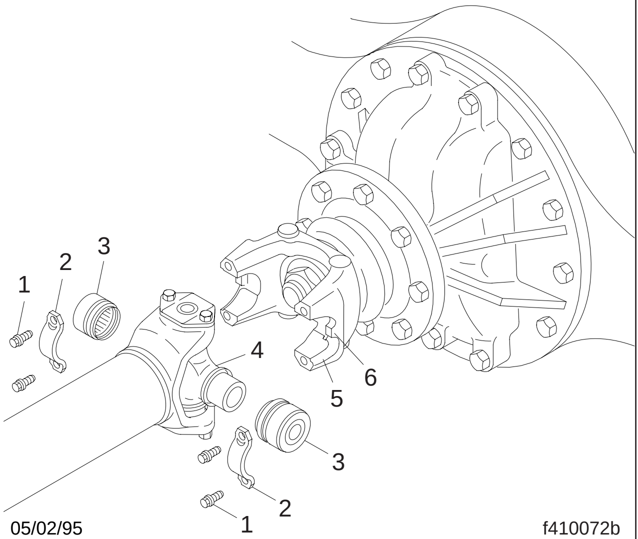
Fig. 3, Companion Flange and Flange-Yoke Installation

U-joints are coupled to half-round end-yokes and flange-yokes by capscrews inserted through semicircular bearing straps that hold the bearing cups in place under tabs in the yoke cross-holes. See **Fig. 4**.

U-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).

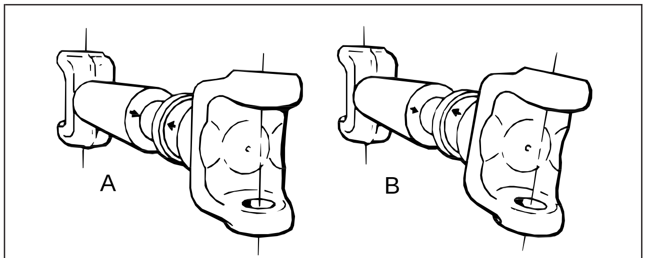
The U-joint working angle is the angle formed by the intersection of the driveshaft centerline and the extended centerline of the shaft of any component (or other driveshaft) to which the U-joint connects. See



1. Bearing-Strap Capscrew
2. Bearing Strap
3. Bearing Cup
4. U-Joint Cross
5. Half-Round Yoke
6. Yoke Cross-Hole Tab

Fig. 4, Coupling of a Spicer or Meritor U-Joint With a Half-Round End-Yoke

Fig. 5. 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. 6.



A. In Phase
B. Out of Phase

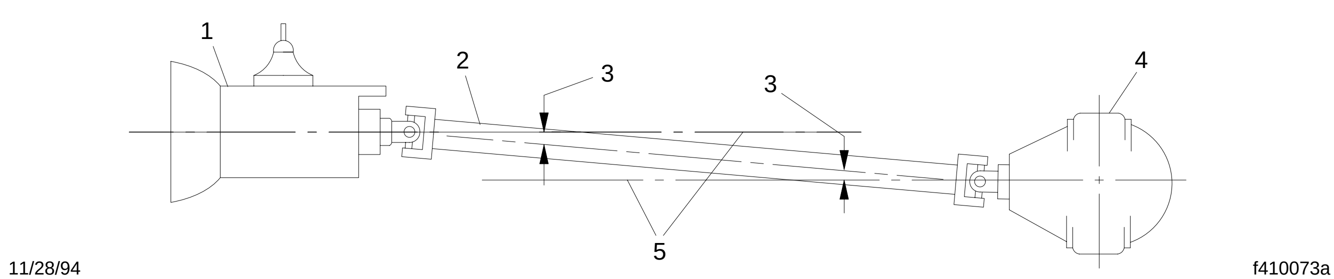
Fig. 6, U-Joint Phasing

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 design specifications will cause an out-of-balance vibration. Any condition which allows excessive



1. Transmission
2. No. 2 Driveshaft
3. U-Joint Working Angles
4. Rear Axle
5. Extended Centerlines

Fig. 5, U-Joint Working Angles

General Information

movement of a driveshaft will cause driveline imbalance: loose end-yoke nuts, loose U-joint bearing cup retaining capscrews, worn U-joint trunnions and bearings, and worn slip-joint splines.

Among the most common causes of U-joint and slip-joint damage is lack of lubrication.

To keep a vehicle operating smoothly and economically, the driveline must be carefully checked and lubricated at regular intervals. For inspection and lubrication intervals and procedures, see Group 41 in the chassis maintenance manual.

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 110**.

Many service operations do not require driveshaft removal from the vehicle: end-yoke or companion-flange nut tightening; drive component shaft seal, end-yoke, or flange-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. Apply the parking brakes, and chock the tires.
2. Turn the appropriate end-yoke (or flange-yoke) until the centerline through its cross-holes is horizontal. See **Fig. 1**, details *A* and *B*. If the half-round bearing cups do not already have a retaining wire installed, install a bearing-cup retaining wire. See **Fig. 1**. Or, install safety wire from the retaining-wire groove of one half-round bearing cup to the other.
3. Support the driveshaft with a nylon support strap.
4. Remove the capscrews that secure the bearing straps to the half-round yoke. Remove the bearing straps.
5. 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

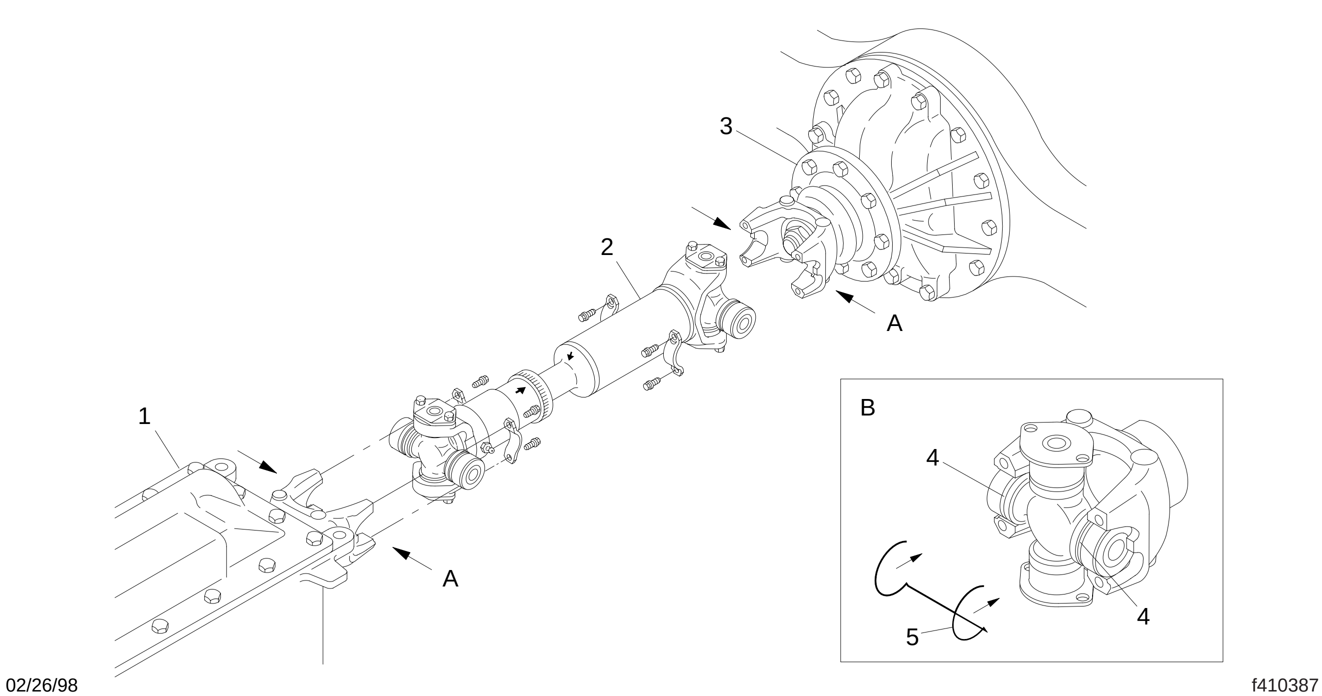
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut; see the applicable table in **Specifications, 400**.
   - 1.2 Check the end-yoke (or flange-yoke) cross-holes for burrs or raised metal. Using a half-round file, remove burrs or raised metal.
   - 1.3 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes and bearing straps.
   - 1.4 Turn the end-yoke (or flange-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**.

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. 2**.
   - 2.3 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 120**.
   - 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. 3**.
   - 2.6 Install the bearing cups on the cross.
   - 2.7 Install a bearing-cup retaining wire. See **Fig. 1**. 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-holes. Using a rubber or plastic mallet, gently tap the bearing cups to seat them in the yoke. See **Fig. 4**.

U-Joint Uncoupling and Coupling

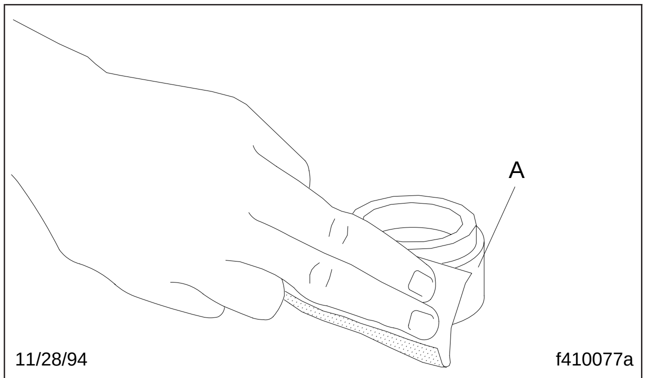


NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is horizontal.
B. Install a half-round bearing-cup retaining wire (or safety wire) before removing the bearing straps.

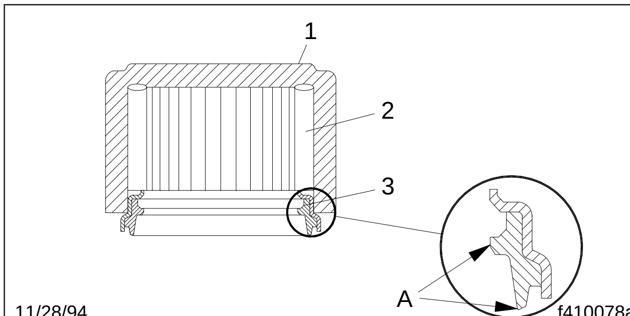
1. Transmission
2. Driveshaft
3. Axle
4. Retaining-Wire Groove
5. Half-Round Bearing-Cup Retaining Wire

Fig. 1, U-Joint Uncoupling/Coupling for Drivelines With Half-Round End-Yokes



A. Use fine emery cloth on this surface.

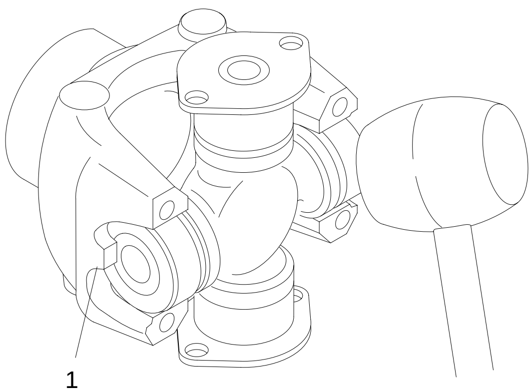
Fig. 2, Smoothing a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 3, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup



1. Retaining Tab

Fig. 4, Seating a U-Joint in a Half-Round End-Yoke

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. Driveline separation can cause loss of vehicle control that could result in serious personal injury or death.

Separation of the driveline can also cause damage to the driveline, driveline components, or other areas of the vehicle.

5. Alternately tighten the bearing-strap capscrews in increments of 20 lbf·ft (27 N·m) to the applicable torque value in **Specifications, 400**.
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 chassis maintenance manual.
8. Remove the nylon support straps, then remove the chocks.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke or companion-flange nut tightening; drive component shaft seal, end-yoke, or flange-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**.

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

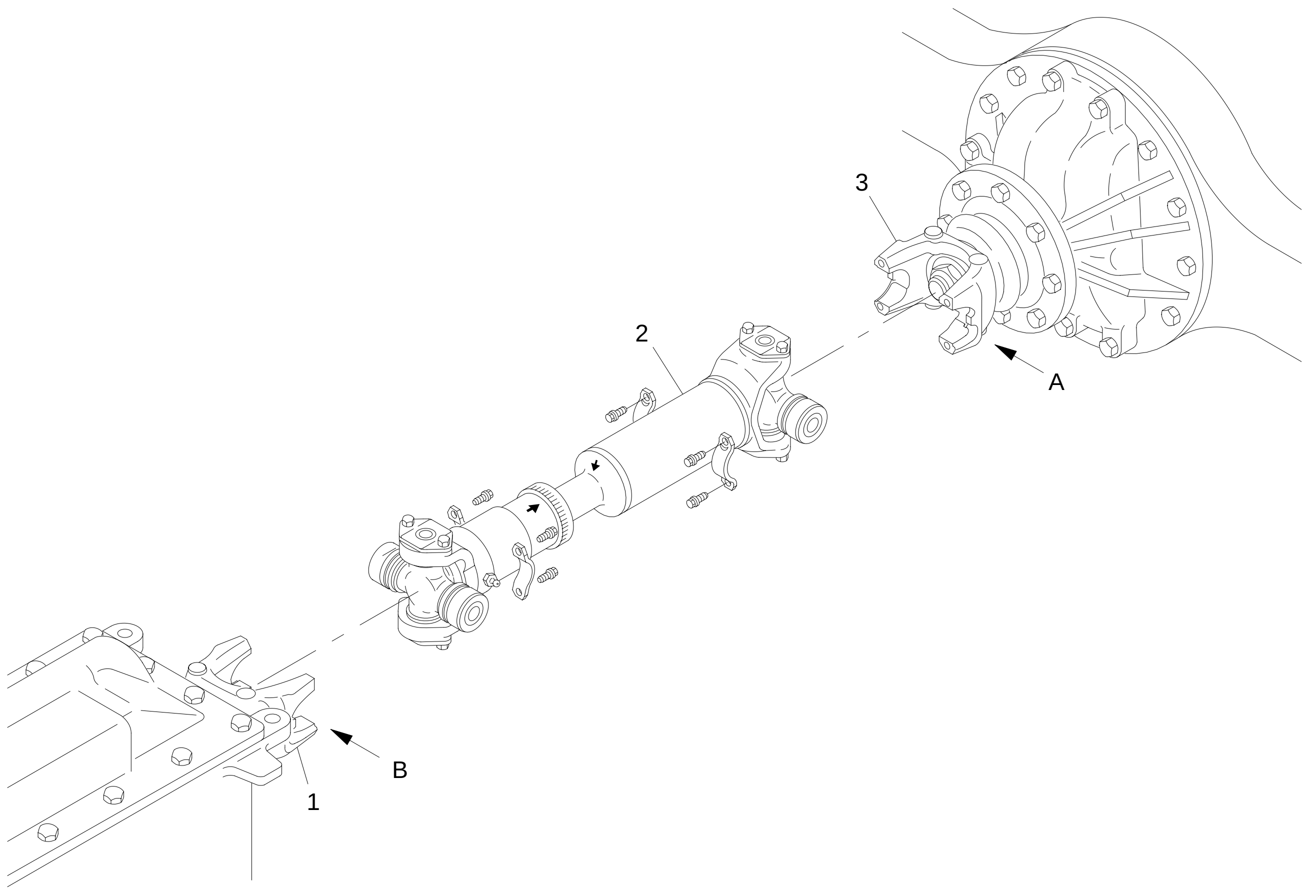
1. Uncouple the driveshaft from the rear axle. See **Fig. 1**. See **Subject 100**.
2. Lower the driveshaft out of the chassis.

Driveshaft Installation

IMPORTANT: Before installing a driveshaft that has a sleeve-yoke (not a splined reverse-slip shaft) at its forward end, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase; see **Fig. 2**.

1. Place the driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap. See **Fig. 1**.
2. Couple the sleeve-yoke to the transmission output-shaft end-yoke. See **Subject 100**.
3. Couple the driveshaft to the axle input-shaft end-yoke. See **Subject 100**.

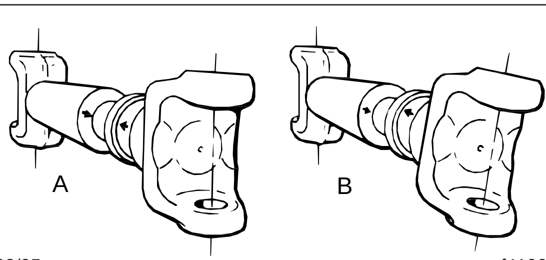
Driveshaft Removal and Installation



NOTE: Not all fasteners are shown.

A. Uncouple this end first; couple this end last.
B. Uncouple this end last; couple this end first.
1. Transmission Output-Shaft Half-Round End-Yoke
2. Driveshaft
3. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke

Fig. 1, Removal/Installation of the Driveshaft



A. In Phase
B. Out of Phase

Fig. 2, U-Joint Phasing

Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly

U-Joint Removal

1. Remove the driveshaft from the vehicle; see **Subject 110**.
2. Clamp the driveshaft in a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove the U-joint snap rings from the yoke.

   3.1 Using a hammer and a soft drift, tap the outside of the bearing cup to loosen the snap ring. See **Fig. 1**. Tap the bearing only hard enough to break the assembly away from the snap ring.

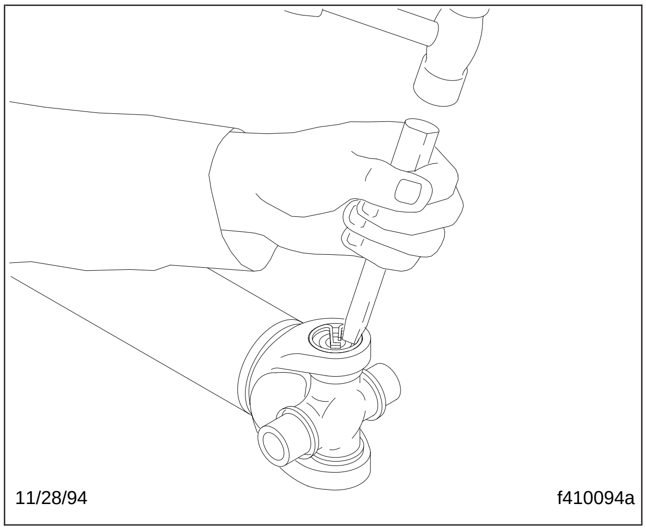


Fig. 1, Loosening the U-Joint Snap Ring

   3.2 Using pliers, remove the snap ring. See **Fig. 2**.

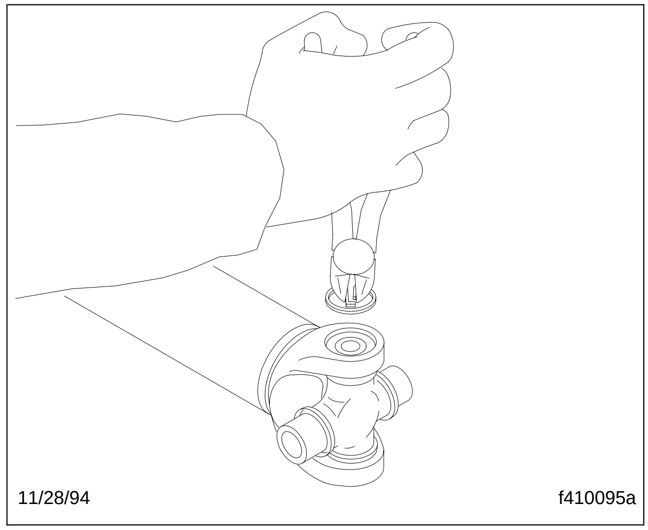


Fig. 2, Removing/Installing the U-Joint Snap Ring

   3.3 Turn the shaft (or sleeve-yoke) over, then repeat this step for the opposite snap ring.

4. Press the U-joint bearing assemblies and cross out of the yoke. See **Fig. 3**.

   4.1 Set the yoke in an arbor press, on a piece of tube stock with an inside diameter larger than the outside diameter of the bearing cup. See **Fig. 3**.

   4.2 Place a solid plug with an outside diameter slightly smaller than the inside diameter of the yoke cross-holes, on the upper bearing assembly. Press it through the upper cross-hole to release the lower bearing assembly.

   If the bearing assembly will not pull out by hand after pressing, tap the base of the yoke lug near the bearing assembly to dislodge it.

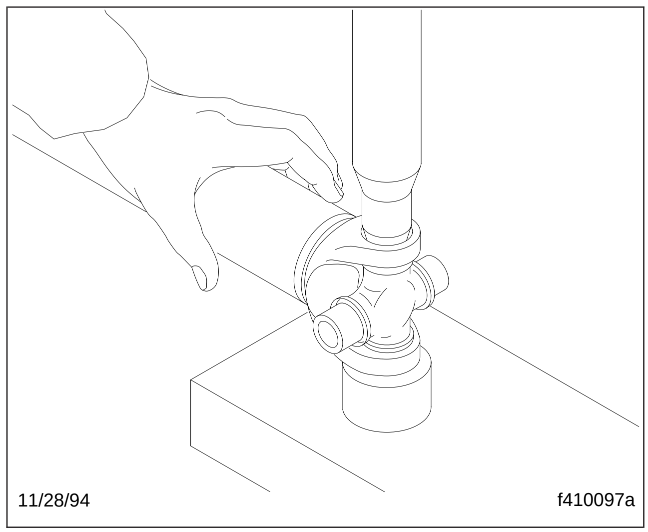


Fig. 3, Pressing the U-Joint Out-of/Into a Yoke

   4.3 Remove the opposite bearing assembly by turning the yoke over, and straightening the cross in the open cross-hole. Then carefully press on the end of the cross so

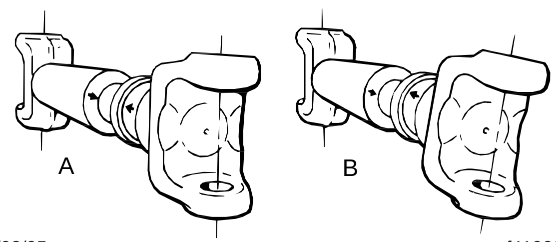
Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly

the remaining bearing assembly moves straight out of the cross-hole.

IMPORTANT: If the cross or bearing assembly is cocked, the bearing assembly will score the walls of the cross-hole and ruin the yoke.

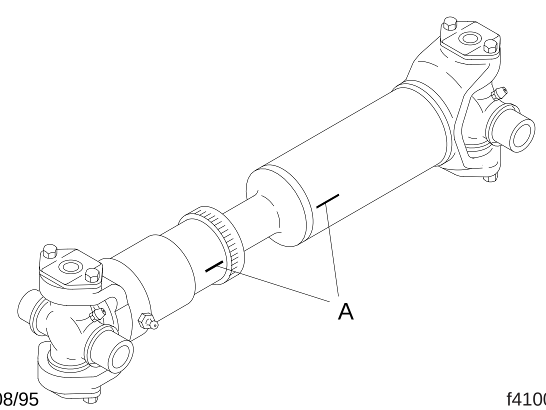
Slip-Joint Disassembly

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.



1. In Phase
2. Out of Phase

Fig. 4, U-Joint Phasing

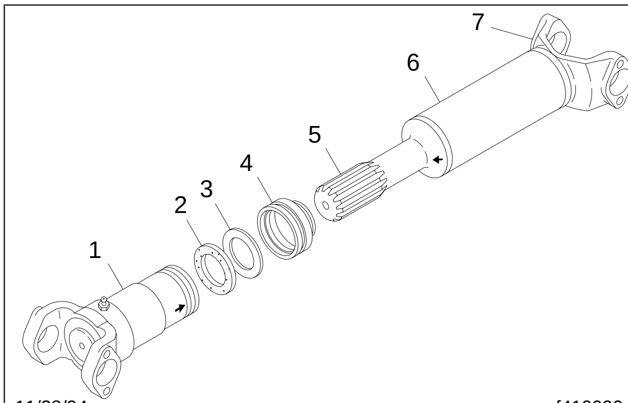


A. Use a marking stick or paint to add alignment marks.

Fig. 5, Slip-Joint Alignment Marks

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a strap wrench to unscrew the slip-joint dust cap from the sleeve-yoke, then pull the sleeve-yoke off of the splined shaft. Remove the dust cap, and (if so equipped) the steel washer and cork seal. See **Fig. 6**.



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

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."

1. Uncouple the driveshaft from the end-yoke , or remove the driveshaft from the vehicle. See **Subject 100** or **Subject 110**.
2. Remove the end-yoke locknut. See **Fig. 7**.
3. Using a yoke puller, remove the end-yoke. See **Fig. 8**.

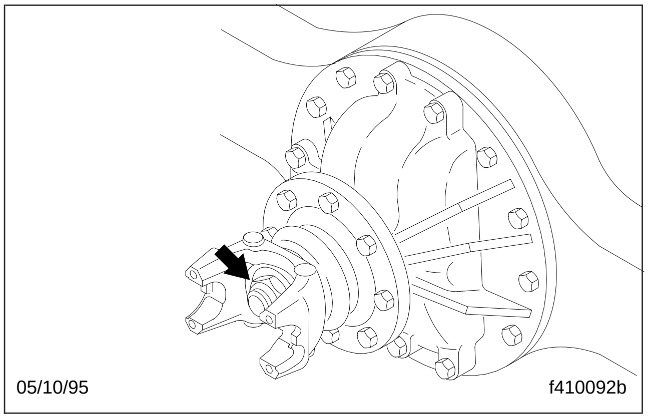
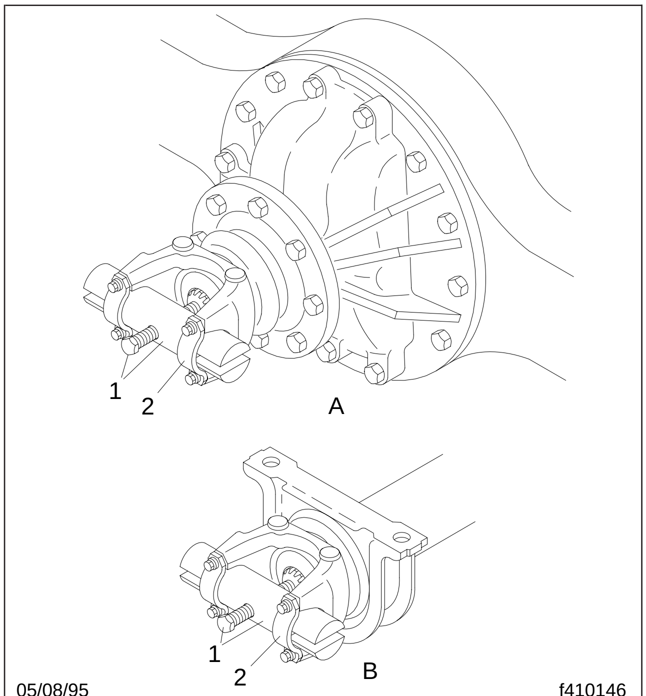
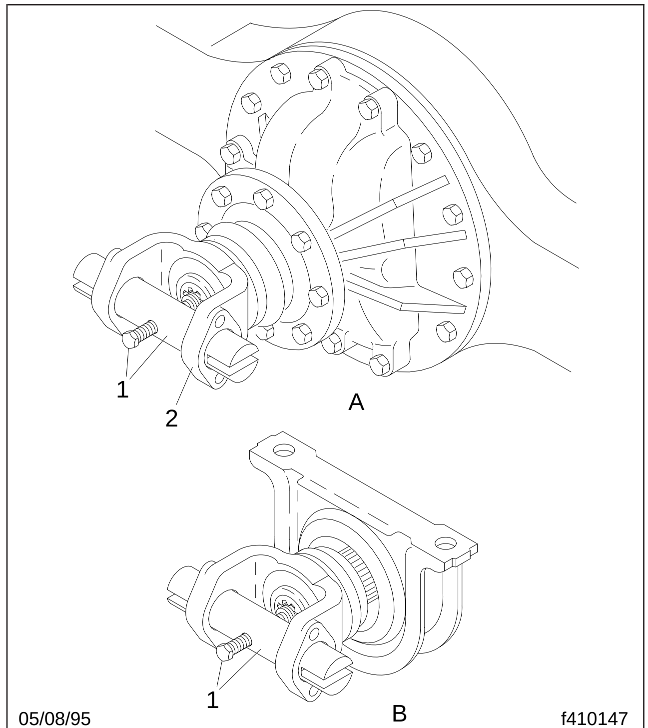


Fig. 7, Axle End-Yoke Locknut



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

Driveshaft Tube, Slip-Joint, Sleeve-Yoke, and Tube-Yoke Cleaning and Inspection

1. With the driveshaft removed, scrape or soak away any foreign material.
2. Examine the driveshaft tube for dents, bends, twists, splitting weld-seams, and signs of missing balance weights.

   Replace the driveshaft tube if damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), and Tube-Yoke Replacement." 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. 10**. Replace both the sleeve-yoke and the

Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly

splined shaft if the slip-joint is damaged; see "Slip-Joint Replacement or Assembly" and "Driveshaft Tube, Stub Shaft (Slip-Joint), and Tube-Yoke Replacement." Remove any burrs or rough spots using fine emery cloth.

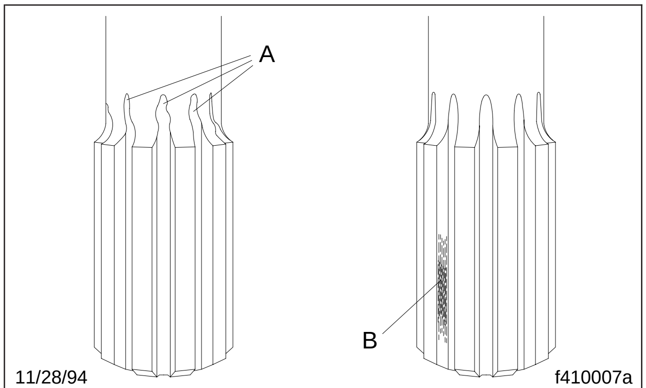


Fig. 10, Damaged Slip-Joint Splines

4. Check for a loose or missing sleeve-yoke plug. 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.
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.
7. Using fine emery cloth, smooth and clean the entire surface of all driveshaft yoke cross-holes.

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 the 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. 11**.

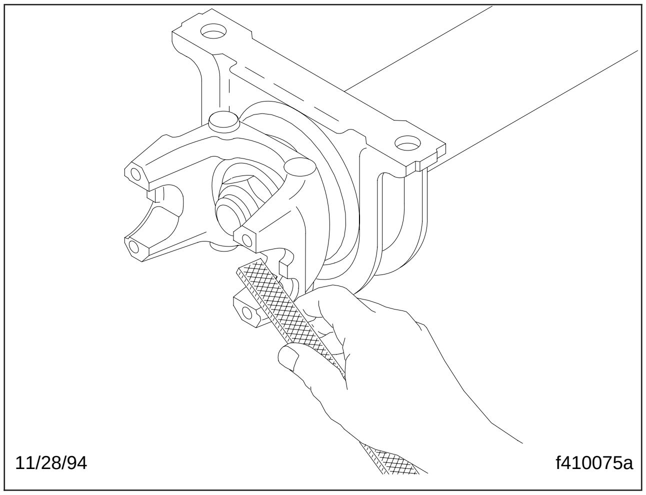


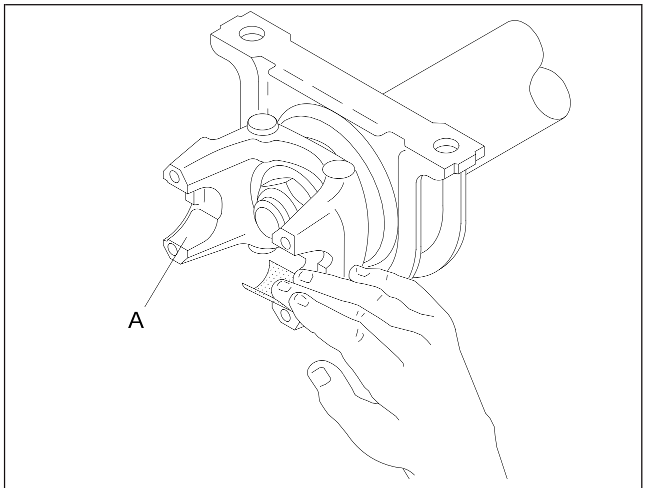
Fig. 11, Removing Burrs From a Half-Round End-Yoke Cross-Hole

3. Smooth and clean the entire surface of all end-yoke cross-holes, using fine emery cloth. See **Fig. 12**.

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. 13**. 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

Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly



A. Use fine emery cloth on this surface.

Fig. 12, Smoothing a Half-Round End-Yoke Cross-Hole

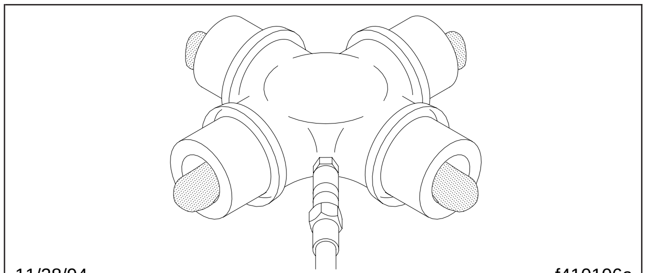
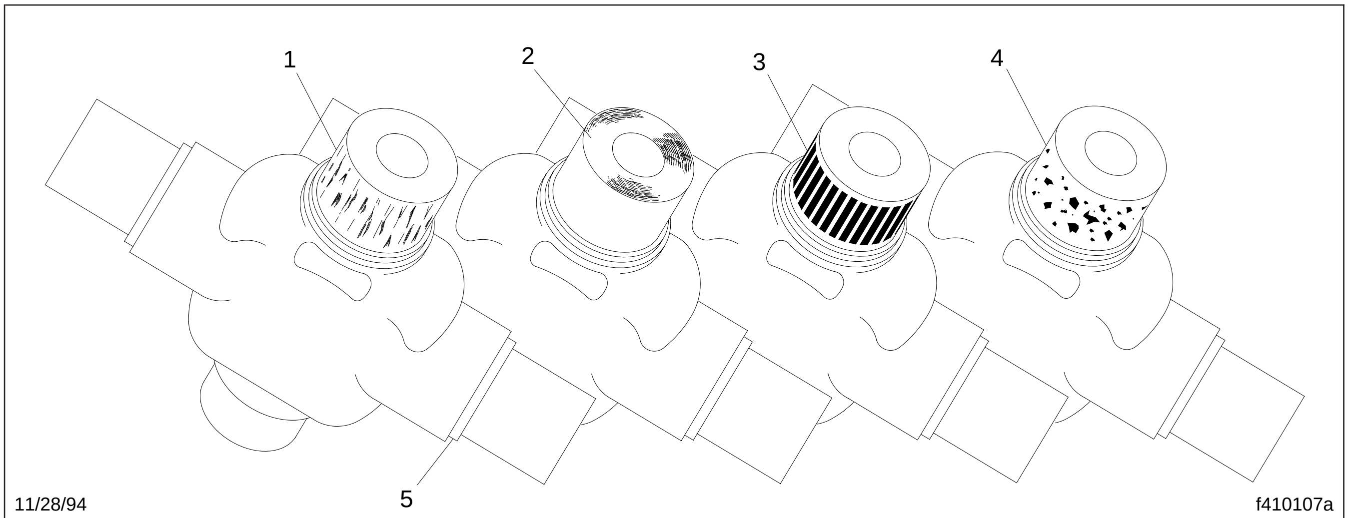


Fig. 14, Forcing Out Old Lubricant From a U-Joint Cross



1. Spalling
2. End Galling
3. Brinelling
4. Pitting
5. Slinger

Fig. 13, Damaged U-Joint Crosses

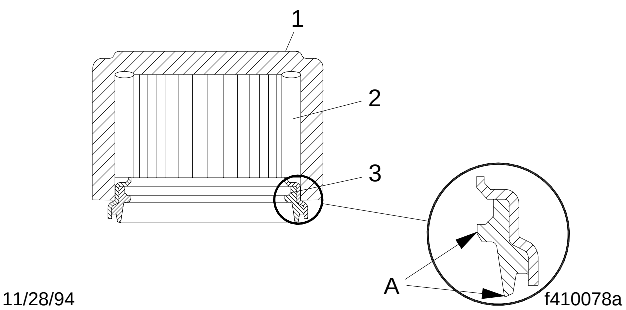
Fig. 14. Examine the old lubricant. If it appears rusty, gritty, or burnt, replace the U-joint assembly.

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. 15. 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.

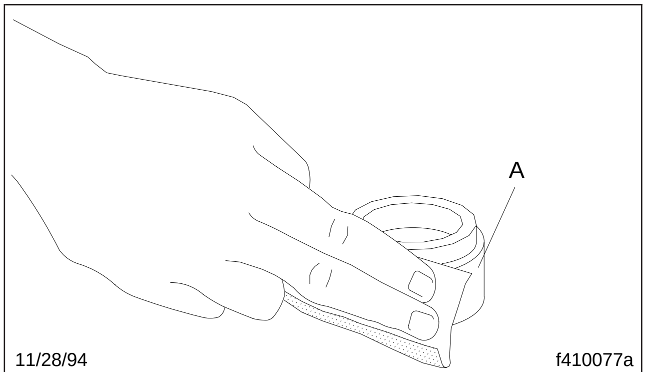
Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly



A. Lubricate seal lips here.
1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 15, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup

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.
7. Using fine emery cloth, smooth and clean the outside surfaces of all bearing cups. See **Fig. 16**.



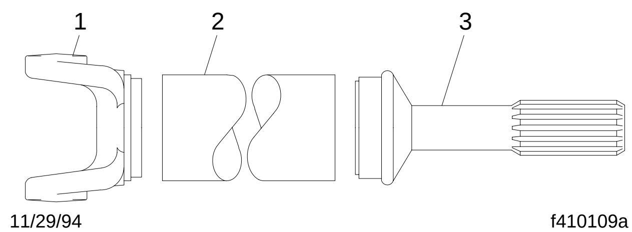
A. Use fine emery cloth on this surface.

Fig. 16, 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. 17**. Driveshaft rebuilding should be done by a machine shop that specializes in driveline repair.



1. Tube-Yoke
2. Driveshaft Tube
3. Stub Shaft

Fig. 17, Driveshaft Tube, Stub Shaft, and Tube-Yoke

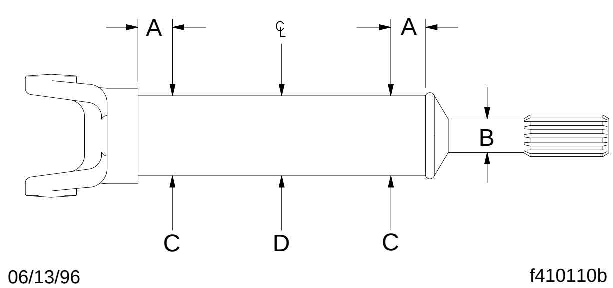
See **Fig. 18**. Runout limits for a new (rebuilt) driveshaft) are:

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.



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. 18, Driveshaft Runout Specifications

Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly

Slip-Joint 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 slip-joint dust cap, and (if so equipped) steel washer and cork seal, over the splined shaft. See **Fig. 6**.
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**.

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.

U-Joint Replacement or Installation

IMPORTANT: 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.

1. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. Make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase. See **Fig. 4** and **Fig. 5**.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

NOTE: Install the U-joint in the sleeve-yoke first. Next, align the alignment marks that were added to the sleeve-yoke and driveshaft tube, then connect the U-joint to the forward tube-yoke of the driveshaft.

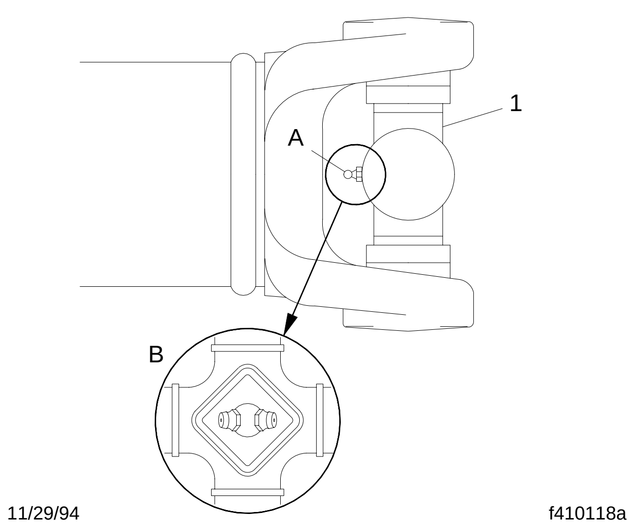
3. Lubricate the U-joint.
   - 3.1 Using a hand-type grease gun, or a high-pressure gun equipped with a low-pressure adapter, fill the lube passages in the cross with multipurpose chassis grease (lithium 12-hydroxy stearate, NLGI grade 1 or 2 with EP additives). See **Fig. 14**.
   - 3.2 Wipe a heavy coating of the same grease on the needles of each bearing cup, and pack each bearing cup about one-quarter full of grease. See **Fig. 15**.

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.

4. Install the U-joint cross and bearing assemblies in the yoke.
   - 4.1 Position the U-joint cross in the yoke with its lube fitting on the inboard side (toward the driveshaft) and pointing 90 degrees away from the driveshaft yoke lugs. See **Fig. 19**.
   - 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. Hold the trunnions in alignment with the cross-holes, while placing a bearing cup over the projected trunnion, and aligning it with the cross-hole.
   - 4.3 Using an arbor press, and holding the trunnion in alignment with the cross-hole,

Driveline Component Removal/Disassembly, Cleaning and Inspection, and Replacement or Installation/Assembly



A. Install U-joint cross with grease fitting toward the driveshaft, and pointing 90 degrees away from the yoke lugs.
B. Detail of Grease Fitting
1. U-Joint Cross

Fig. 19, U-Joint Grease Fitting Positioning

place a solid plug (with an outside diameter slightly smaller than the inside diameter of the cross-holes) on the upper bearing cup. See **Fig. 3**. Press the bearing cup into the cross-hole enough to install a snap ring.

4.4 Install the snap ring. See **Fig. 2**.

IMPORTANT: Be sure the snap ring is properly seated in its groove.

4.5 Turn the yoke over, and install the opposite bearing cup and snap ring.

If movement of the U-joint is stiff, strike the yoke ears with a soft hammer to seat the bearing needles.

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. 7**.
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.

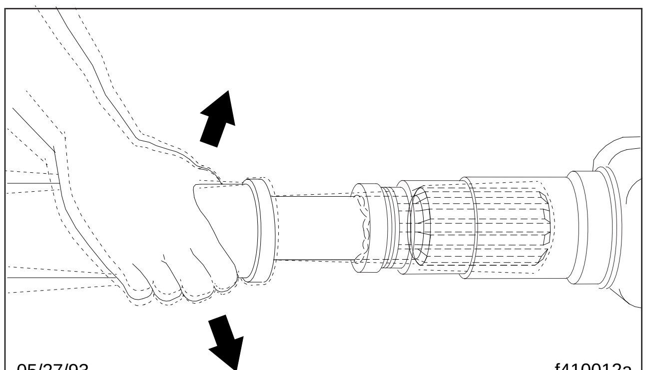
1. Check all tires for uneven wear and for out-of-roundness. Check for mismatched tires. Look for wheels and rims that are out of alignment. For instructions, see **Group 40**.
2. Check the rear suspension for loose or broken U-bolts; broken, shifted, or mismatched rear springs; or broken spring seats. If so equipped, check the air suspension for incorrect air spring height. Look for anything that could cause angular misalignment of the rear axle pinion(s). For instructions, see **Group 32**.
3. Check the frame rails and crossmembers for bends, twists, or breaks; for frame-alignment-checking and crossmember-replacement instructions, see **Group 31**.
4. Check the engine and transmission mounts; see **Group 01** (engine) and **Group 26** (transmission). Check the coupling shaft's midship bearing mounts. Replace mountings that are deteriorated or oil-soaked; tighten loose mounting bolts. Oil-soaked or deteriorated mountings, or loose mounting bolts, can cause driveline angular misalignment.
5. Check for loose U-joint bearing-cup-plate and bearing-strap capscrews, and for loose flange-yoke locknuts. Tighten any loose fastener to the applicable torque value in **Specifications, 400**. Then, on U-joint bearing-cup-plates equipped with lockplates, bend a lockplate tab upward until it is firmly against a flat side of the tightened capscrew head.

CAUTION

Do not overtighten the bearing-cup-plate or bearing-strap capscrews, or the flange-yoke locknuts. 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 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 120**.



Try to bend the sleeve-yoke and splined shaft up and down, and from side to side.

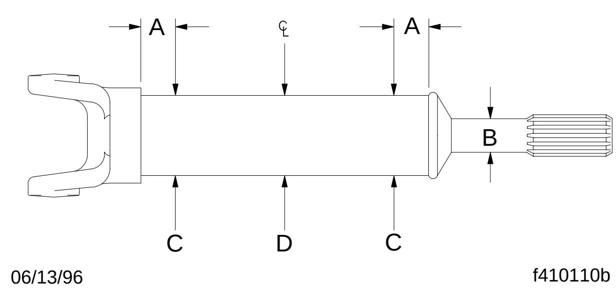
Fig. 1, Checking for Slip-Joint Spline Wear

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.

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 120** for runout specifications for a *new* (or rebuilt) driveshaft.

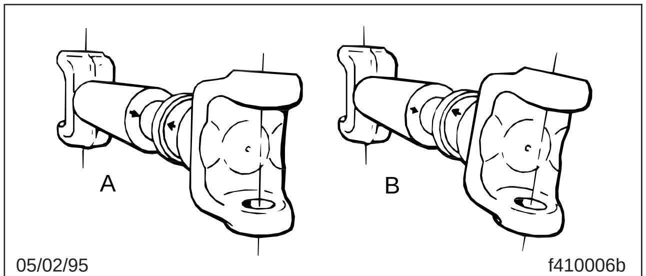


A. Measurement: 3" (76 mm)
B. Measurement: 0.015" (0.38 mm)
C. Measurement: 0.020" (0.51 mm)
D. Measurement: 0.025" (0.635 mm)

Fig. 2, Used Driveshaft Runout Specifications

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.

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 120**.

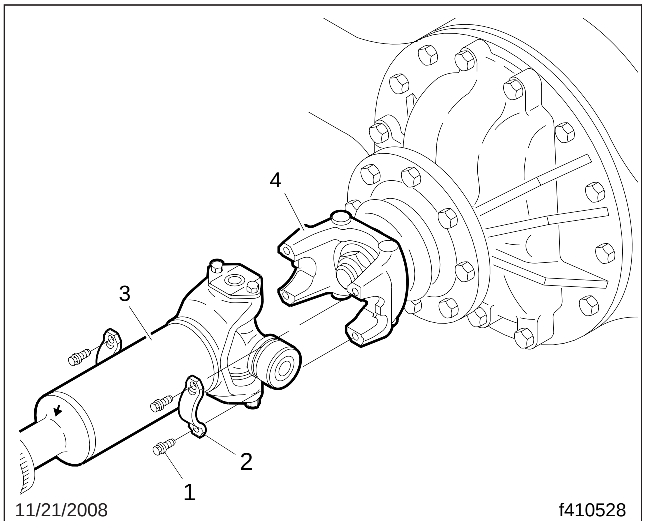
    If the yoke is not worn, tighten the yoke nut to its torque value.

11. Have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

Fastener Torques				
Description			**Size**	**Torque: lbf·ft (N·m)**
End-Yoke Nut				
Transmission Output Shaft	Allison	MD Series	2–16	600–800 (815–1085)
Single Axle Input Shaft	Meritor	RS-15-120, RS-15-210, RS-17-140, RS-17-220	M32 x 1.5	740–920 (1000–1250)
		RS-23-160	M45 x 1.5	1000–1230 (1355–1670)
		RS-23-240	M39 x 1.5	920–1130 (1250–1530)
U-Joint Capscrew				
Bearing Strap (for half-round end-yoke)	All Brands	—	3/8-inch	45–60 (61–81)
		—	1/2-inch	115–135 (156–183)
Flange-Yoke Locknut				
Flange-Yoke to Companion Flange	Spicer	1590, 1610, and 1710	3/8–24	40–48 (54–65)

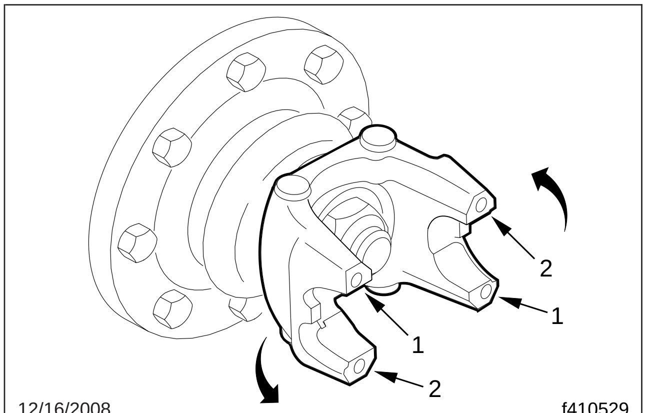
Table 1, Fastener Torques

NOTE: When installing a driveshaft with a half-round U-joint, as shown in **Fig. 1**, tighten the bearing-strap capscrews in increments of 20 lbf·ft (27 N·m), following the tightening sequence shown in **Fig. 2**.



1. Bearing-Strap Capscrew
2. Bearing Strap, Half-Round U-Joint
3. Driveshaft
4. Half-Round Yoke

Fig. 1, Half-Round U-Joint Installation



Tighten the capscrews in a counterclockwise sequence, starting with either number 1 position.

Fig. 2, Tightening Sequence

Special Tools

Journal Locator

(For installing Spicer 1610, 1710, 1760, and 1810 U-joints in full-round yokes)

To order, Contact your Dana Corporation Spicer Service Representative.

Specifications

U-Joint Removal Tool Kit

(For removing Spicer 1610, 1710, 1760 and 1810 U-joints and Meritor 17N, 17T, 176T and 18T 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 from transmission output shafts, coupling shafts, and rear-axle input and output shafts)

To order 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

To order Yoke and Flange Remover SP–450, contact:

G & W Tool Company
907 South Dewey
Wagoner, OK 74467

XC Model Air Plumbing Diagram, Chassis Built From July 1997

See **Fig. 1** for a full view of the chassis plumbing diagram. See **Fig. 2** and **Fig. 3** for a partial view.

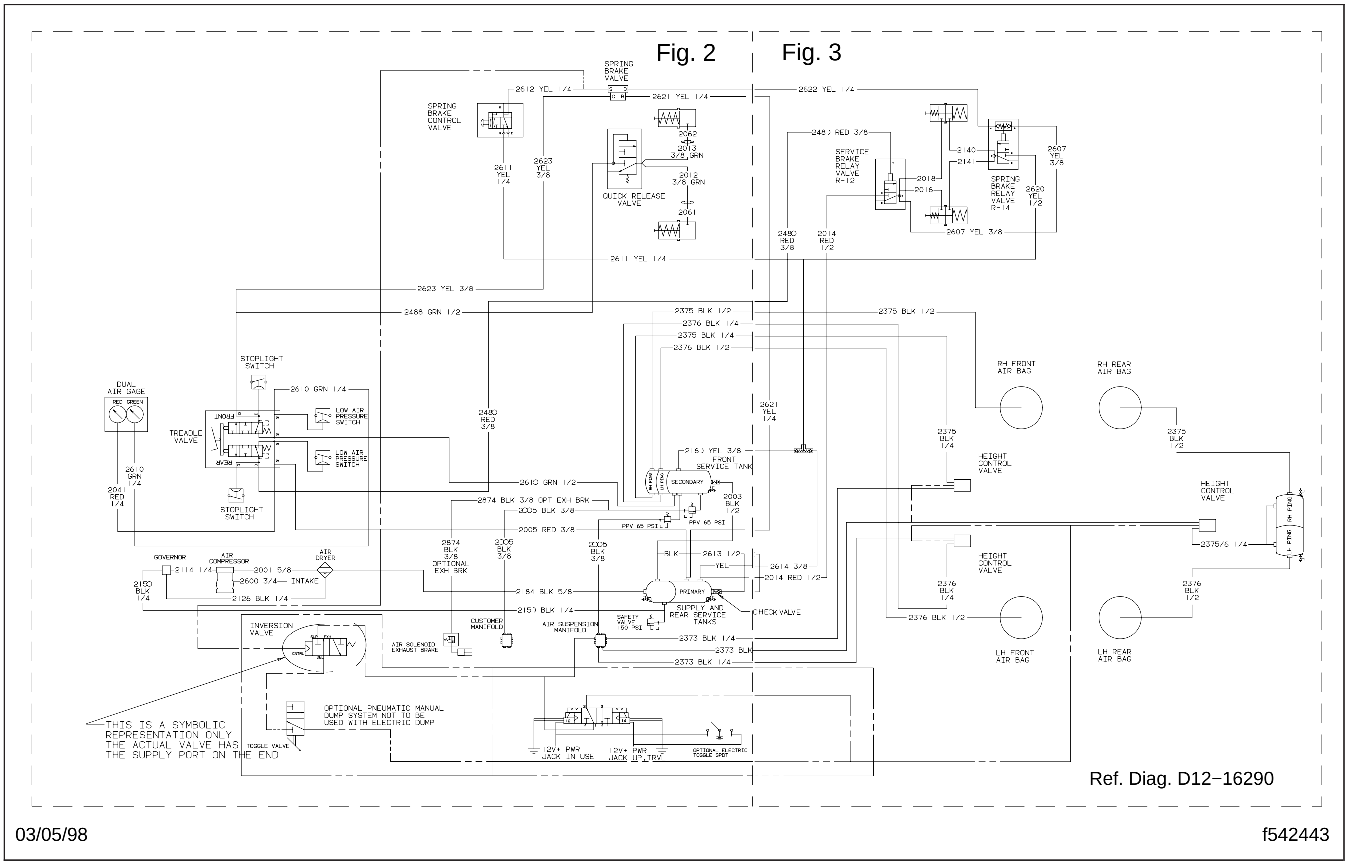


Fig. 1, Air Plumbing Diagram, Chassis Built From July 1997 (full view)

XC Model Air Plumbing Diagram, Chassis Built From July 1997

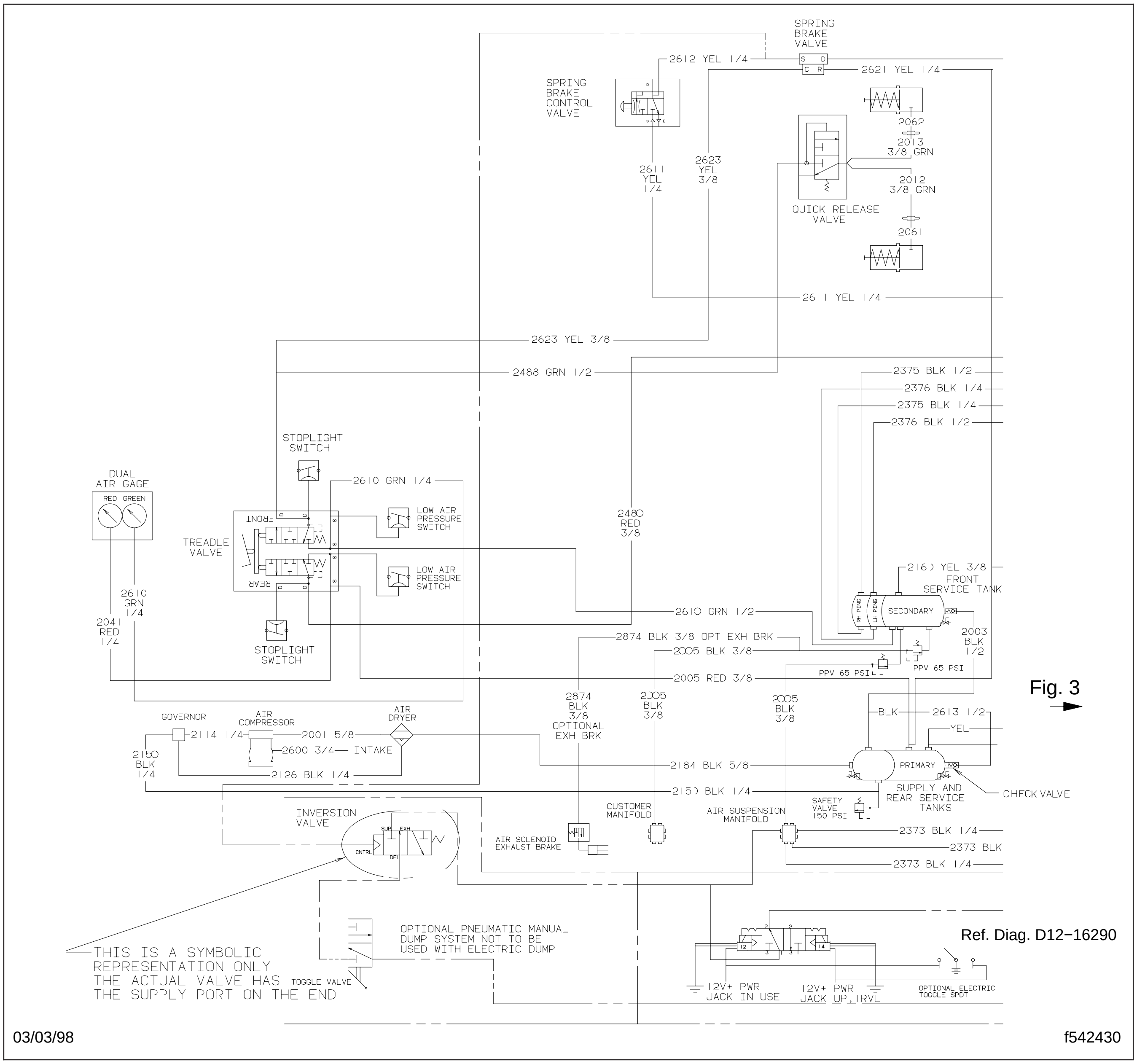


Fig. 2, Air Plumbing Diagram, Chassis Built From July 1997 (partial view)

XC Model Air Plumbing Diagram, Chassis Built From July 1997

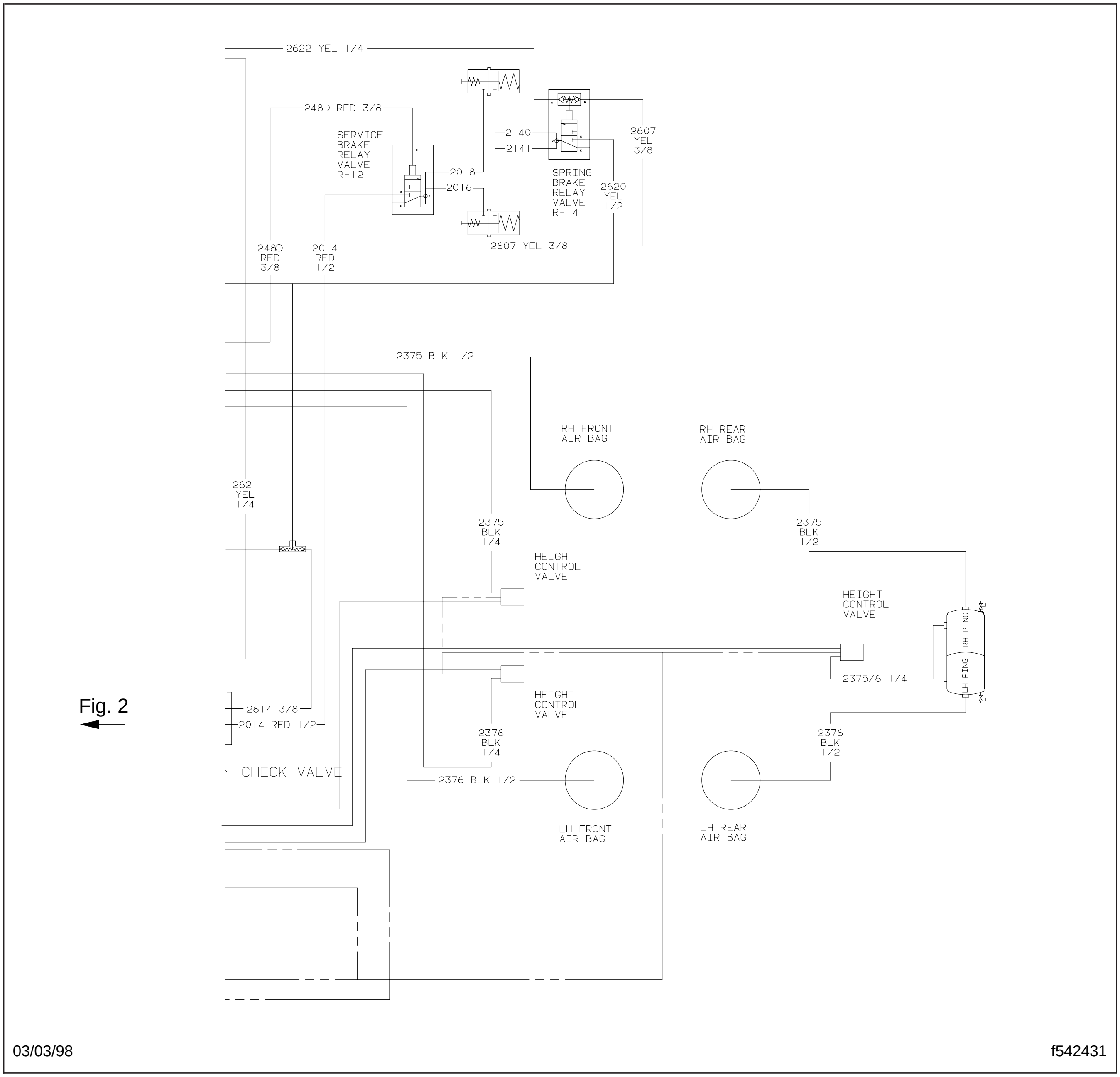


Fig. 3, Air Plumbing Diagram, Chassis Built From July 1997 (partial view)

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.

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 vehicle operator's manual.
2. Be sure that all relay valves are operating. For instructions, see Group 42 of the chassis maintenance manual.
3. Check the operation of the brake chambers as instructed in Group 42 of 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, see **Section 42.02** in this manual.
7. Examine leaking pipe connections for cracks or thread damage; replace as needed. If there is no damage, retighten the fitting. For instructions, see **Section 42.02** in this manual.

Safety Precautions

WARNING

Follow the manufacturer's procedures while working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion. Failure to take all necessary precautions during servicing of the air brake system can result in personal injury.

Compression and storage of air in the air brake system is comparable to the energy in a coiled spring: when released, it may be hazardous. 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 anyone: 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. This also applies to the service brake system.

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 line, 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.
The brake linings are worn or glazed.	Install new brake linings on the brake shoes on both sides of the axle.
The brakes need adjustment or lubrication.	Adjust or lubricate the brakes.
The automatic slack adjusters (if so equipped) 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. Replace the brake drums if needed.
Flat spots or dents on the roller surface were caused by skidding of the roller or incorrect handling of the rollers during installation.	Clean, then inspect the bearing rollers. Replace the rollers if damaged.
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.
The brake drums are glazed.	Turn the brake drums, if possible. If the maximum allowable diameter is exceeded, replace the drum. Do the same for both ends of the axle.

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 push rod may be incorrectly adjusted.	Readjust the push rod and/or pedal stop bracket.
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 not working.	Overhaul or replace the applicable 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 incorrect handling of the rollers during installation.	Clean, then inspect the rollers. Replace the rollers if damaged.

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 quick-release valve is not working.	Repair or replace the brake foot valve or quick-release 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.

Troubleshooting

Problem—Service Brakes Apply When the Parking Brakes Are Released With Air Pressure	
Possible Cause	**Remedy**
There is a leaking push rod seal between the parking brake and the service brake.	Replace the push rod seal.
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. Check the adjustment of the brake foot valve push rod.
The brake foot valve is not working.	Overhaul or replace the brake foot valve.
There is a 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**
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 not working.	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).

Troubleshooting

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
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, replace, or turn both brake drums. For instructions on turning drums, refer to the brake manufacturer's service manual. Find out what is causing the saturation and repair as needed.
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, replace, or turn both brake drums on that axle. For instructions on turning drums, refer to the brake manufacturer's service manual.
A brake shoe is distorted or broken.	Replace the brake shoe. Install a new, matched set of linings on both sets of brake shoes on that axle.
The pilot pads are damaged, allowing the brake drum to be installed out-of-round.	Replace the wheel hub.
A brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer's service manual.
One or more brake drums is scored or broken.	Replace both of the drums on that axle.

Problem—Uneven Service Brakes

Problem—Uneven Service Brakes	
Possible Cause	**Remedy**
The wrong brake linings were installed, or the linings were not replaced in pairs.	Replace the brake linings with the recommended size. Install new linings on both sets of axle brake shoes.
Grease has saturated the brake linings or the linings are glazed.	Install new linings on both axle brake shoes. Clean the brake drums. Find the cause of saturation, and repair as needed.
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 the brake drum(s), if possible. If the maximum allowable diameter of the brake drum(s) has been exceeded, replace the drum. Also, turn or replace the other drum on the axle. For turning the drum(s), refer to the brake manufacturer's service manual.
A service brake chamber diaphragm is leaking.	Tighten the clamp ring. If leaks persist, replace the service brake diaphragm.
The wheel bearings are out of adjustment.	Adjust the wheel bearings, or replace them if damaged. For instructions, see **Group 33** or **Group 35** 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. Find the cause of contamination and remedy it.

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.
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 brake foot valve push rod may be incorrectly adjusted.	Readjust the push rod and/or pedal stop bracket.

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.
A power spring is broken.	Replace the parking brake chamber.
A power spring in a parking brake is manually caged.	Uncage the power spring, using 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.
There is a broken return spring in the parking brake (double-diaphragm type brake chambers only).	Replace the parking brake chamber.

Troubleshooting

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 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 not working (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.

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.

Troubleshooting

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released	
Possible Cause	Remedy
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.
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.

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 service brake diaphragm or the parking brake chamber, as applicable.
The brake foot valve or quick-release valve is leaking.	Repair or replace the component(s) or assembly.
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.

Problem—Compressor Knocks (Continuously or Intermittently)

Problem—Compressor Knocks (Continuously or Intermittently)	
Possible Cause	Remedy
There is a loose drive pulley, belt, coupling, or gear (as indicated).	Tighten or replace the component. If applicable, inspect the pulley shaft for damage. Replace the shaft, if damaged.
Backlash is in the compressor drive gears on the drive coupling.	Repair or replace the compressor drive gears or drive coupling.
The air compressor bearings are damaged or worn.	Replace the bearings.
There are carbon deposits in the compressor cylinder head.	Remove the carbon deposits or replace the compressor.

Problem—Safety Valve Activates

Problem—Safety Valve Activates	
Possible Cause	Remedy
The safety valve is out of adjustment.	Adjust the safety valve, or install a new one.
There is too much air pressure in the brake system.	Refer to the problem "Air Pressure Rises Above Normal."

Troubleshooting

Problem—Safety Valve Activates	
Possible Cause	Remedy
The air reservoirs need to be drained 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.

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

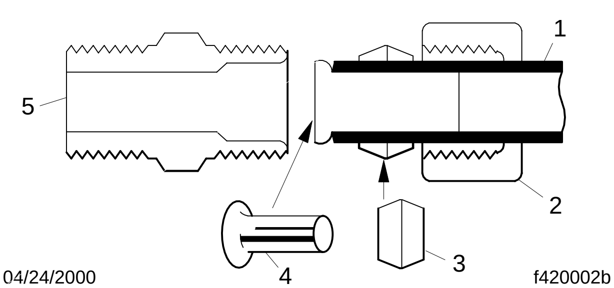
Before working on or around air brake systems and components, see Safety Precautions 100.

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. 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**.



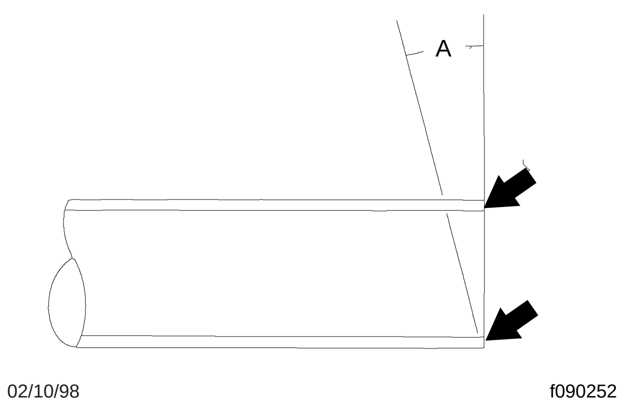
1. Nylon Air Line
2. Nut
3. Sleeve
4. Stainless Steel Insert
5. Body

Fig. 1, Nylon Air Line and Compression Fitting

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.

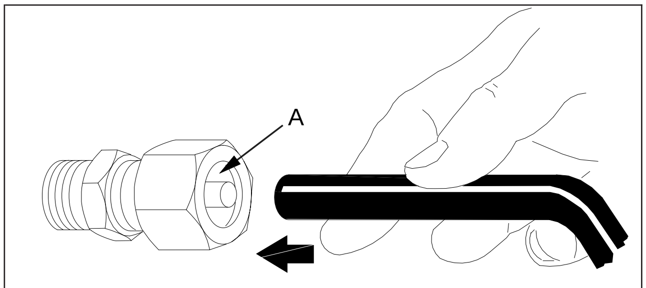
Fig. 2, Check Air Line End Angle

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.
12. Pull back on the air line to make sure it is fully seated.

Air Lines Replacement



A. Air line end must bottom before tightening the nut.

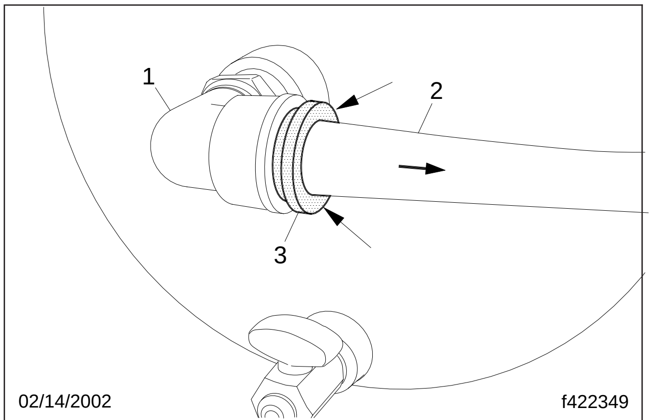
Fig. 3, Installing Nylon Air Line into Compression Fitting

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

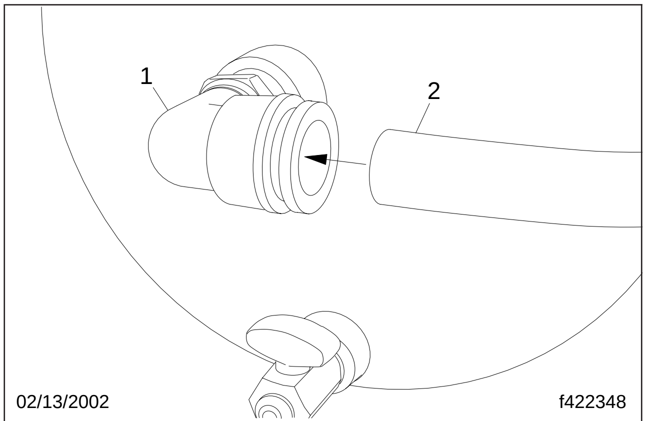
IMPORTANT: The use of a sharp air line cutter is highly recommended. This tool will insure a clean, perpendicular cut of the air line.

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.
11. Remove the chocks from the tires.



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

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.

Air Lines Replacement

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.

⚠ 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.

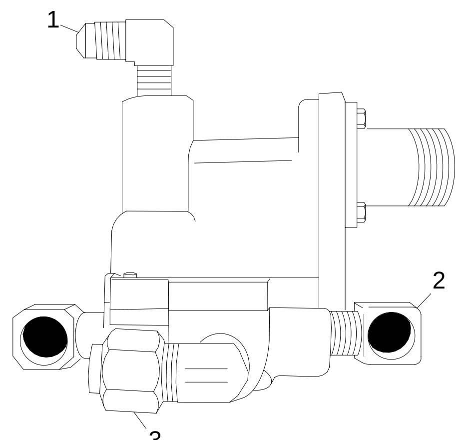
Never use diagonal pliers, a razor knife, saw or dull cutting tool to cut nylon air lines. The use of such tools leaves the air line with a sharp edge, burr or out-of-round condition which can damage the seal when the air line is inserted into the fitting. This reduces the sealing ability of the fitting. 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

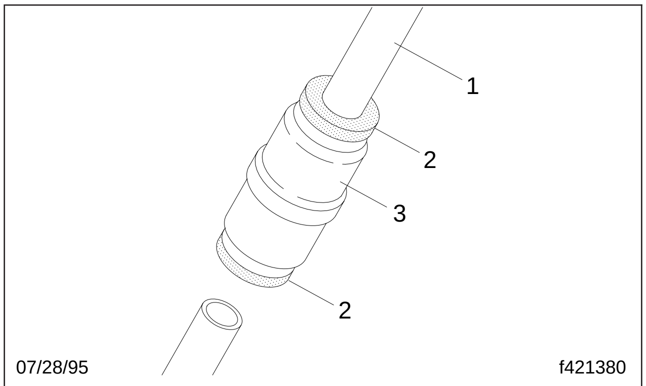
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Loosen the nut and remove the fitting.
5. Position the fitting.
6. Finger-tighten the 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**.

Fittings Replacement

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)

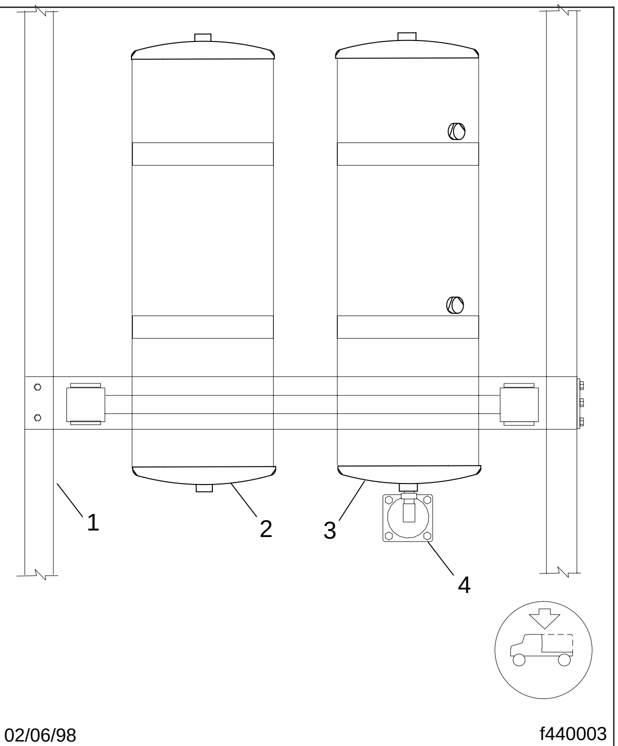
* Tighten to the lower torque value. If needed, turn the fittings to allow for the proper routing of the air lines.

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



1. Frame Rail
2. Secondary Air Reservoir
3. Primary/Supply Reservoir
4. Automatic Drain Valve

Fig. 1, Front Air Reservoirs (typical location)

Air reservoirs serve two main purposes:

1. They store compressed air used to apply the brakes and operate other air-powered devices, such as the engine brake and the air bags for the front and rear suspensions.
2. They provide a place where air, heated during compression, can cool and water vapor can condense into a liquid. Also, air reservoirs collect small amounts of oil passed by the compressor.

Each vehicle is equipped with two or three air reservoirs, depending upon the chassis configuration. The typical chassis has two reservoirs mounted at the front of the chassis above the front axle. See **Fig. 1**. If the vehicle has a rear air suspension, an additional air reservoir is mounted at the rear of the vehicle

Each reservoir and/or reservoir compartment is identified as one of three types: supply, primary, and secondary. the supply air and primary air compartments are located within the same reservoir. There may be up to three compartments in the secondary reservoir encompassing the secondary air and the air requirements of the front suspension.

The supply reservoir (or wet tank) receives compressed air directly from the compressor. It collects most of the water and oil condensate from the air, and feeds air to the other reservoir(s). At one of the outlet port of the supply compartment, there is a safety check valve, which protects the air system against excessive pressure.

The primary compartment is the air source for the brakes on the rear axle. At the inlet port of the primary compartment is an in-line check valve. The check valve allows air flow in one direction only, and prevents air flow in the reverse direction in case there is a drop in upstream air pressure.

The secondary reservoir is the air source for the front axle brakes. The secondary air reservoir or compartment is protected by a pressure protection valve. This valve prevents the complete loss of secondary air pressure if there is an air leak in any non-brake accessory.

If the vehicle has rear air suspension, the reservoir at the rear of the vehicle supplies air to the rear suspension airbags. The reservoir contains two compartments to direct air to the left and right rear airbags respectively.

Safety Precautions

When working on or around air reservoirs and components, the following precautions should be observed:

1. 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 released.
2. 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.

Tests

IMPORTANT: Before working on or around air reservoirs and components, review **Safety Precautions, 100**.

NOTE: If equipped with an automatic drain valve, see **Section 42.08** 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. See **Subject 110**.

If leaks occur on the surfaces of the air reservoir, replace the tank. See **Subject 120**.

Drain Valve Replacement and Leak Elimination

IMPORTANT: Before working on or around air reservoirs and components, review **Safety Precautions, 100**.

NOTE: If equipped with an automatic drain valve, see **Section 42.08**.

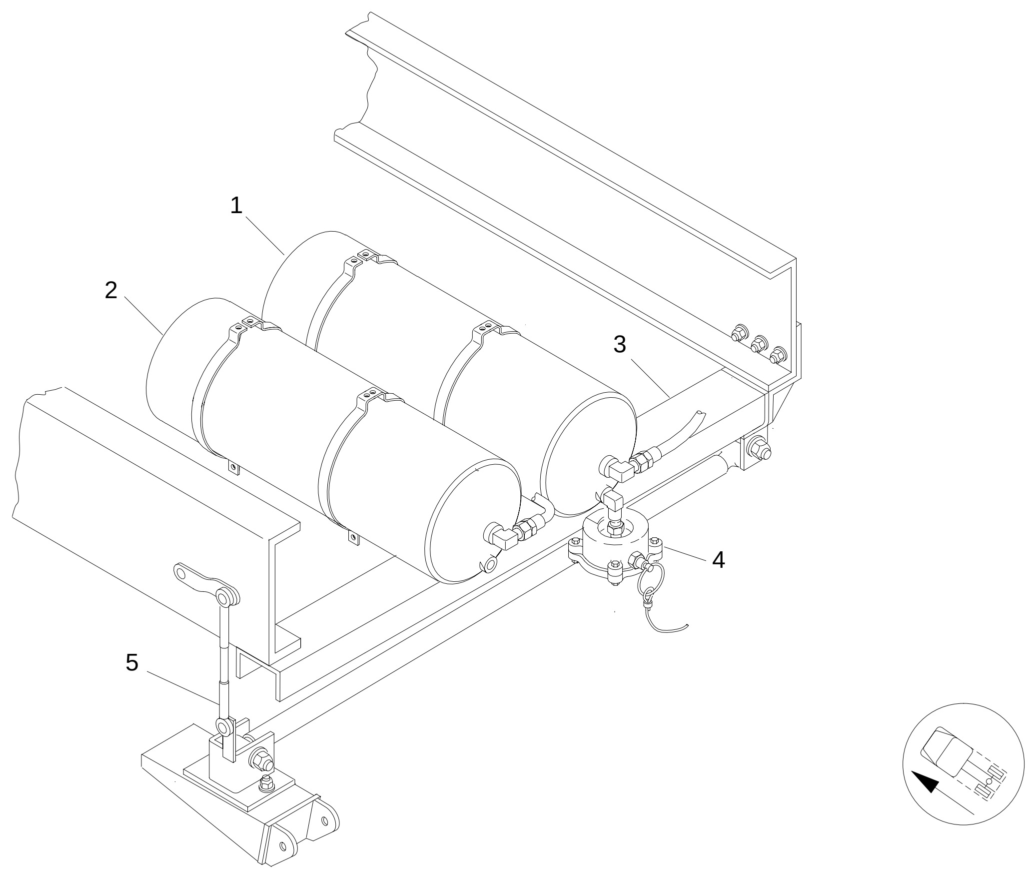
1. Park the vehicle on a level surface, shut down the engine, apply the brakes, and chock the tires.
2. Drain the air system, using the instructions in the chassis operator's manual.
3. If necessary, raise the front of the vehicle using the automatic leveling jack.
4. Using two wrenches (hold the coupler 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.
5. 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).
6. 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.
7. If the vehicle was raised using the automatic leveling jack, return the vehicle to the operating position.
8. Remove the chocks from the tires.

Replacement

IMPORTANT: Before working on or around air reservoirs and components, review **Safety Precautions, 100**.



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1. Primary/Supply Air Reservoir
2. Secondary Air Reservoir
3. Transverse Link Bracket
4. Automatic Drain Valve
5. Height Control Valve Linkage

Fig. 1, Air Reservoir Replacement

1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tires.
2. Drain the air system, using instructions in the vehicle operator's manual. See **Fig. 1**.
3. If necessary, raise the front of the vehicle using the automatic leveling jack.
4. Mark all reservoir air lines, couplers, and valves for later assembly. Carefully disconnect the parts. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove air lines after loosening the reservoir in the straps.

WARNING

The transverse link bracket is heavy and will fall after the last retaining bolt is loose. Lack of support underneath the bracket could result in personal injury.

Air Reservoir Replacement

5. Remove the transverse link bracket. Use at least one person to hold the bracket in place while performing the following substeps.
   5.1 On the drivers-side, remove the two retaining bolts that fasten the transverse link bracket to the frame rail.
   5.2 Remove the two bolts from the passengers-side of the bracket, which are attached to an additional bracket mounted on the frame rail.
   5.3 Lower the bracket.

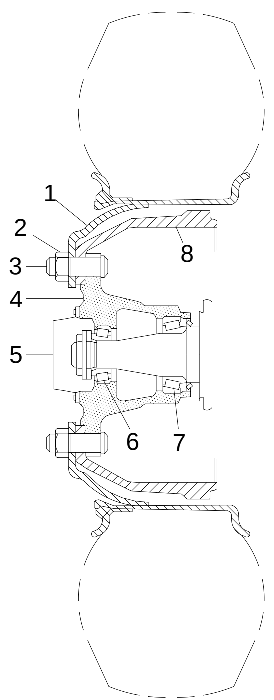
NOTE: The transverse link bracket will not be completely removed from the vehicle. Loosening the four fasteners will allow the bracket to be lowered away from the reservoir.

6. Remove fasteners from the reservoir strap fasteners.
7. Rotate the reservoir in the strap to access remove any remaining air lines.
8. Remove the reservoir.
9. Place a new reservoir in the straps, and connect any hard to reach air lines.
10. Install the strap mount nuts and tighten 20 to 25 lbf·ft (27 to 34 N·m).
11. As referenced earlier, connect all remaining air lines, couplers, and valves to the new reservoir, removing the caps as each part is installed.
12. Position the transverse link bracket. Install the bolts and tighten the nuts 128 lbf·ft (173 N·m).
13. If the vehicle was raised using the automatic leveling jack, return the vehicle to the operating position.
14. Remove the chocks from the tires.

General Description

The front and rear 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. See **Fig. 1** and **Fig. 2**.

The brake drum and lining work together as a mated friction pair, with the drum responsible for both heat absorption and dissipation. Lining performance and life largely depend on the condition of the drum and whether it can adequately absorb and dissipate heat generated by braking action.



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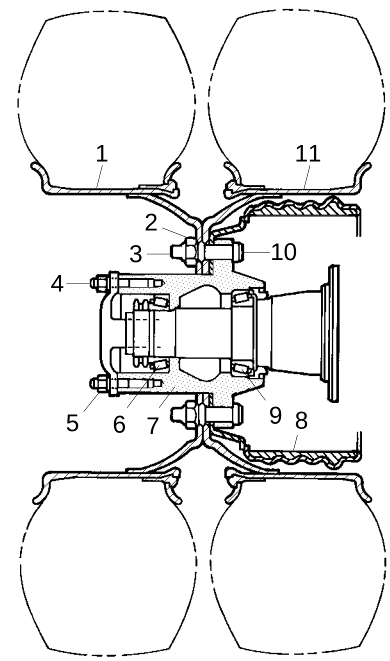
1. Disc Wheel
2. Wheel Nut
3. Wheel Stud
4. Hub
5. Hub Cap
6. Outer Wheel Bearing
7. Inner Wheel Bearing
8. Brake Drum

Fig. 1, Front Axle Disc Wheel Assembly (sectional view)



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1. Outer Wheel
2. Outer Wheel Nut
3. Wheel Stud
4. Drive Axle Stud
5. Drive Axle Stud Nut
6. Outer Wheel Bearing
7. Wheel Hub
8. Brake Drum
9. Inner Wheel Bearing
10. Wheel Stud
11. Inner Wheel

Fig. 2, Drive Axle Disc Wheel Assembly (sectional view)

Outboard-Mounted Drum Removal and Installation

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

Removal

1. Before working on the front axle, chock the rear tires and apply the parking brakes.

   Before working on the rear axle, chock the front tires and release the parking brakes.
2. Raise the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. Back off the slack adjuster to release the brake shoes. For instructions, see **Section 42.07** of this manual.

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. Unless exposure can be reduced below legal limits, wear an air purifying respirator approved by MSHA or NIOSH at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

To reduce asbestos exposure below legal limits, apply one of the following methods: (1) An enclosed-cylinder vacuum system equipped with a High Efficiency Particulate Air (HEPA) filter; (2) A solvent spray system that keeps the asbestos-contaminated parts wet until they can be placed in a sealed and labelled plastic bag.

4. Remove wheel and tire assemblies. For instructions, see **Group 40**.
5. Remove the brake drum. See **Fig. 1** and **Fig. 2**.

   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. Inspect the drum. See **Subject 120** for instructions.

Installation

1. Install the brake drum on the wheel hub.

   1.1 On hub-piloted drums, position the brake drum on the top step of the pilot pad. One of the hub’s pilot pads should be at the twelve o’clock (top center) position. See **Fig. 3**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are torqued.

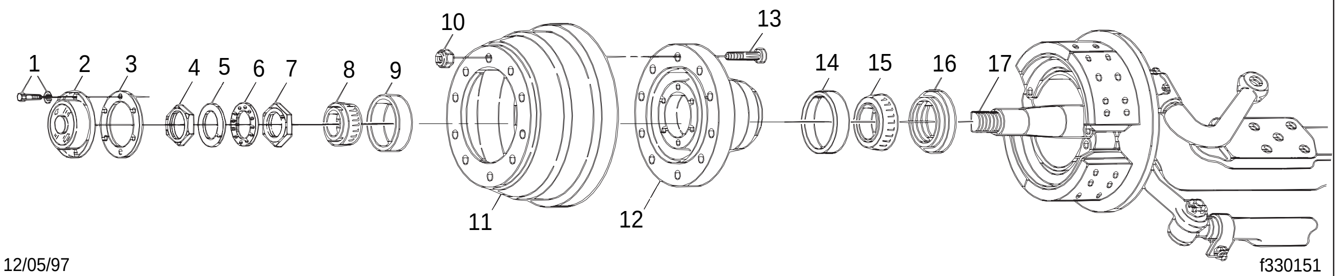
   1.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

   IMPORTANT: If damage to the pads prevents the drum from centering, replace the hub. If necessary, to hold the drum in position, adjust the brakes before installing the wheels.
2. Install the wheel and tire assemblies. See **Group 40** for instructions.

WARNING

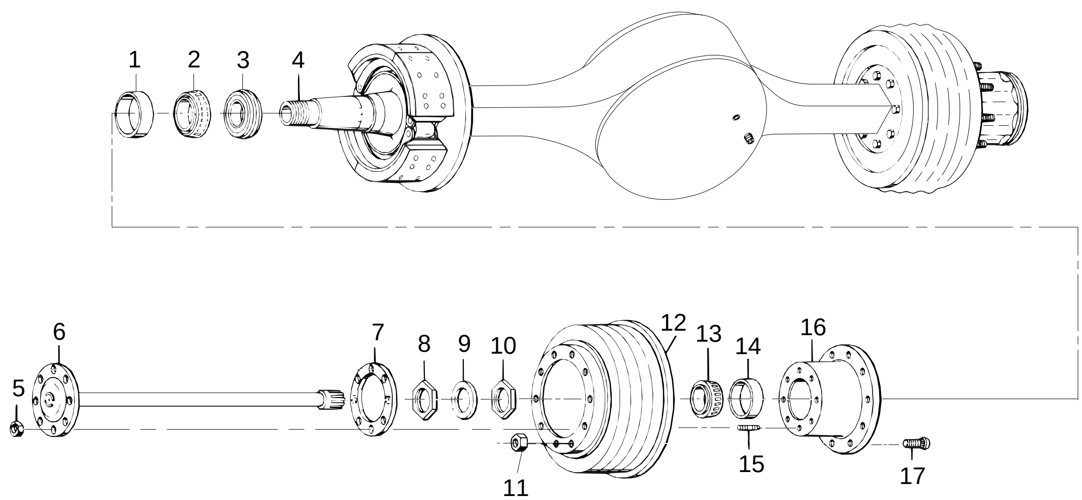
If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described

Outboard-Mounted Drum Removal and Installation



1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Hub Cap Gasket
4. Jam Nut
5. Lockwasher
6. Lockring
7. Wheel Bearing Adjusting Nut
8. Outer Wheel Bearing
9. Outer Wheel Bearing Cup
10. Wheel Nut
11. Brake Drum, Outboard-Mounted
12. Wheel Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Axle Spindle (Steering Knuckle)

Fig. 1, Typical Front Axle (exploded view)



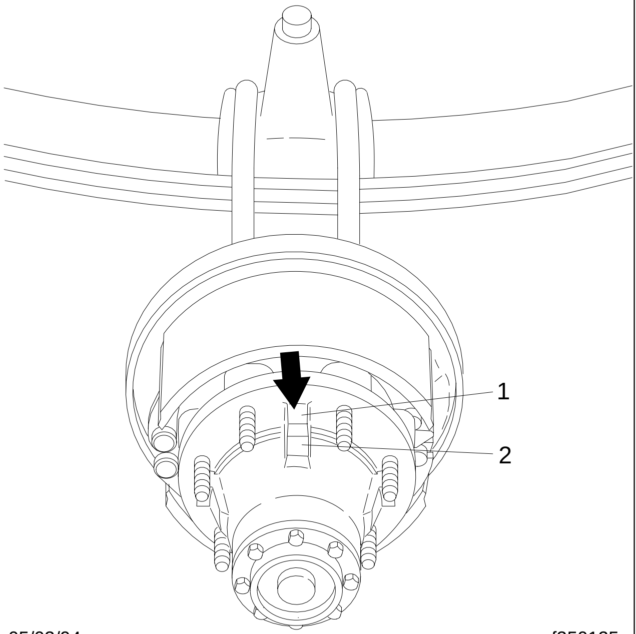
1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Brake Drum Nut
12. Brake Drum, Outboard-Mounted
13. Outer Wheel Bearing
14. Wheel Hub
15. Drive Axle Stud
16. Wheel Hub
17. Wheel Stud

Fig. 2, Typical Drive Axle (exploded view)

above exist, could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

3. Adjust the brakes at the slack adjusters. For instructions, see Group 42 in the chassis maintenance manual.
4. Remove the safety stands from under the axle; lower the vehicle.
5. Apply the parking brakes (if not already applied); then remove the chocks from the tires.

Outboard-Mounted Drum Removal and Installation



NOTE: Pilot pad at 12 o’clock position.
1. Drum Pilot
2. Wheel Pilot

Fig. 3, Front Axle Drum and Wheel Pilots (rear axle similar)

Inspection

New brake drums are purposely undersized to allow for turning, which may be needed if the drum is non-concentric when mounted on the hub. If a new drum is installed, the protective coating on the inner friction surface must first be removed with a solvent, and then rinsed with a hot water wash. Use a clean rag to remove any oily residue or metal chips from the friction surface.

If a drum must be turned or replaced, the other same-axle drum must be similarly turned or replaced to provide the same braking power on both wheels. Turned drums should not exceed the maximum allowable diameter, which is stamped on the outside surface of the drum. See **Fig. 1** for a typical location of this stamp.

NOTE: Drums that have been turned should then be cleaned by using fine emery cloth followed with a hot water wash. Drums that have been renewed using emery cloth should also be cleaned with a hot water wash.

WARNING

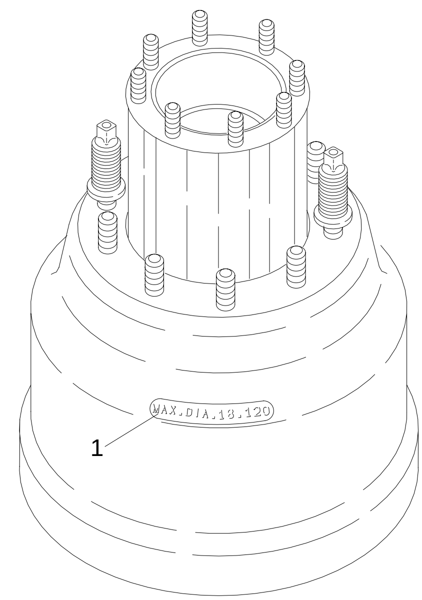
Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will cause drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimate drum breakage.

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.

If the drums are turned or replaced, replace the brake linings. For instructions, see **Section 42.10**.

1. Inspect the inner friction surface. If a veneered (highly glossed) or glazed surface exists, renew the drum by using 80-grit emery cloth or by turning the drums. See **Fig. 2**.



1. Maximum Diameter Stamp

Fig. 1, Stamp Location

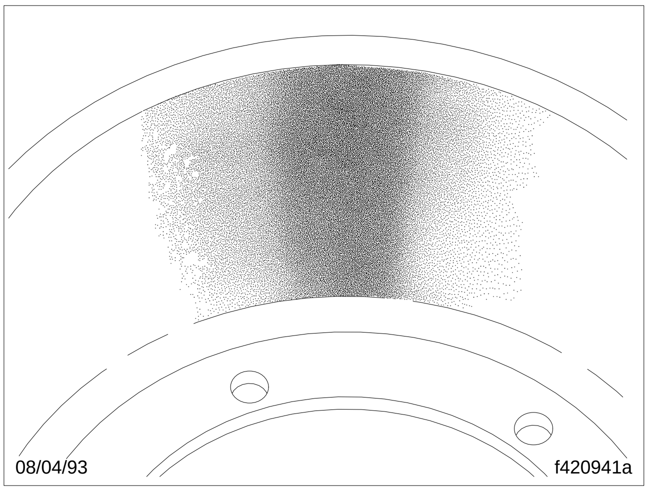


Fig. 2, Polished Drums

2. Inspect for heat checking, which is a form of buckling (cracking) resulting from a temperature

Inspection

differential in the drum wall between a relatively cool exterior and a hot friction surface. Heat checking is normal on all drums and may not reduce performance and lining life if the network of fine hairline cracks remains small. See **Fig. 3**. Examine heat checks of drums often to be sure the checks have not widened into drum weakening cracks (substantial cracks extending to the open edge of the drum). See **Fig. 4**.

Replace the same-axle drums if substantial cracks are present, or if widening of the fine hairline cracks occurs.

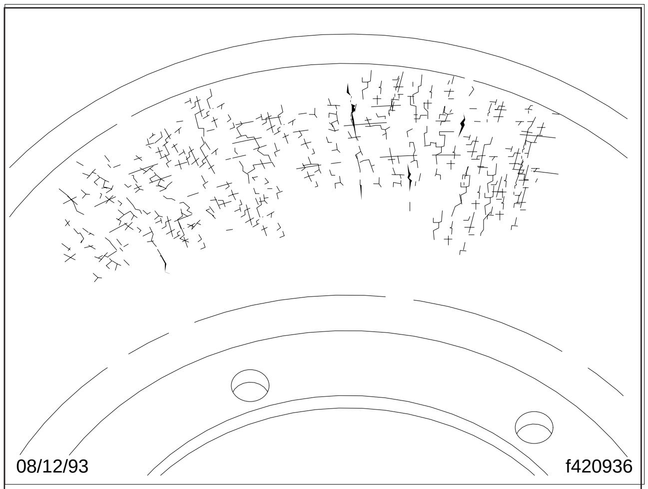


Fig. 3, Heat Checking

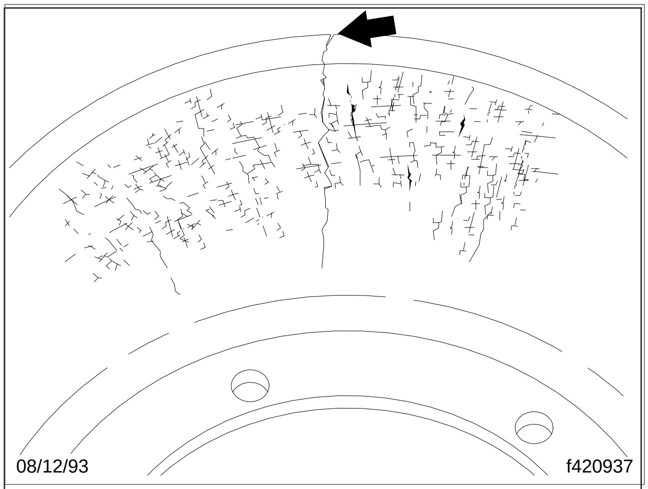


Fig. 4, Cracked Drums

NOTE: If there is normal heat checking as described above, inspect the drums at least every 12,000 miles (19 300 km) thereafter. If the vehicle is not equipped with brake dust shields, inspect the drums (using a flashlight from the inboard side of the wheels) every 6000 miles (9700 km). Inspect more often under adverse operating conditions.

3. Check for a contaminated inner friction surface. If fluids are present, such as oil or grease, remove them. Locate and correct the source of the contamination. If the brake drums are contaminated with fluids, the brake linings will also be affected. Since oil-or grease-saturated linings cannot be salvaged, they must be replaced. For instructions, see **Section 42.10**.

WARNING

Failure to replace fluid-contaminated brake linings could result in a partial loss of braking capacity. This could cause an accident resulting in personal injury or property damage.

4. Measure the inside diameter of the drum. If this measurement is greater than the maximum allowable diameter, replace the same-axle drums and linings. See **Fig. 5**

5. Check for a variation in gauge readings at different points on the radius of the drum's working surface. If the variation is more than 0.010 inch (0.25 mm) at any point, the drum is out-of-round to unacceptable limits. Remachine or replace the same-axle drums. See **Fig. 5**.

6. Inspect the outside surface of the drum. Remove any accumulation of mud, dirt, or rust; foreign matter acts as an insulator, trapping heat within the drum.

7. Check for hard, slightly raised, dark-colored spots on the inner friction surface or for a bluish cast on the brake parts, both of which are caused by high temperatures. See **Fig. 6** and **Fig. 7**. If the drums' maximum allowable diameters have not been exceeded, remachine both same-axle drums. If spots or discoloration cannot be removed, or if remachining is not possible, replace the drums. Also replace the brake shoe return springs. For instructions, see **Section 42.10**.

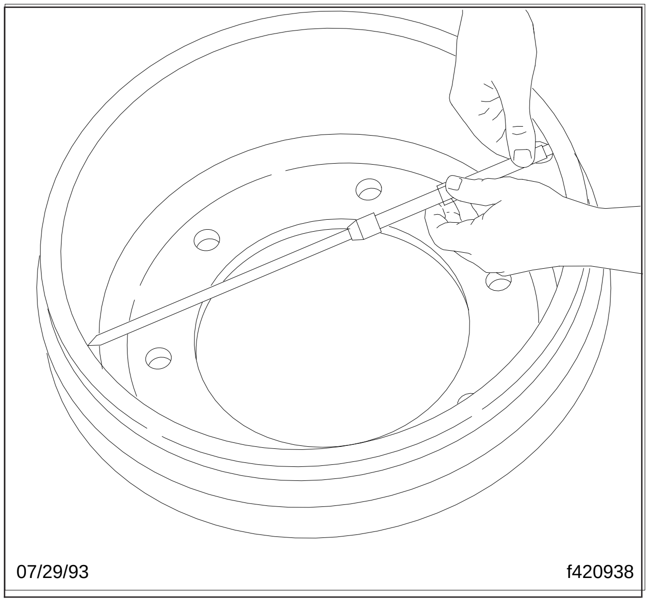


Fig. 5, Oversized Drums

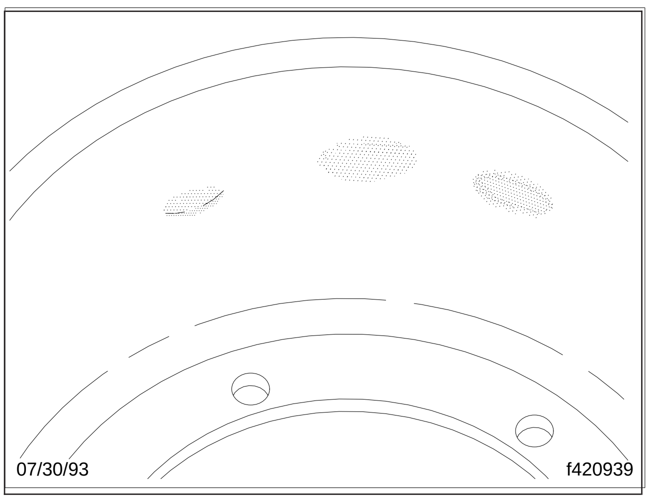


Fig. 6, Heat Spotted Drums

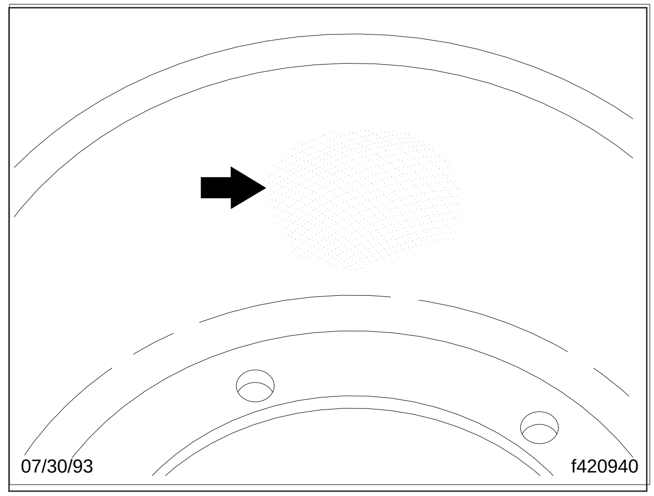


Fig. 7, Blue Drums

Specifications

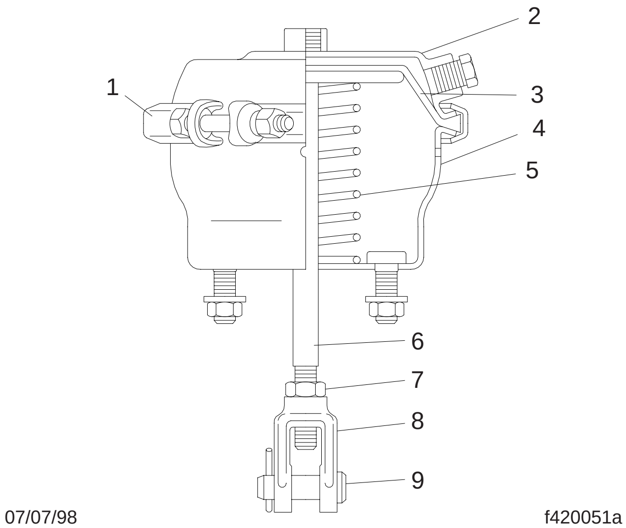
Fastener Torque Values			
Description	Grade	Size Inch (mm)	Torque lbf·ft (N·m)
Brake Drum Bolt	8	7/8 (20)	240 (325)

Table 1, Fastener 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. See **Fig. 1**.

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.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, 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.

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.

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. See Group 42 of the chassis 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

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, see **Specifications, 400**.
4. Using a soap solution, coat the area around the piston-rod hole. No leakage is permitted. If there is leakage, replace the diaphragm. For instructions, see **Subject 110**.

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

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, see **Section 42.07**. 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.

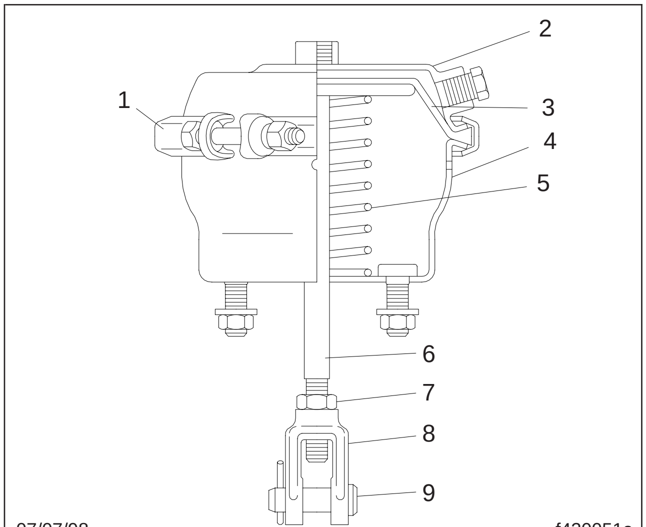
   5.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.

   5.2 Remove the cover assembly, and replace the diaphragm.

CAUTION

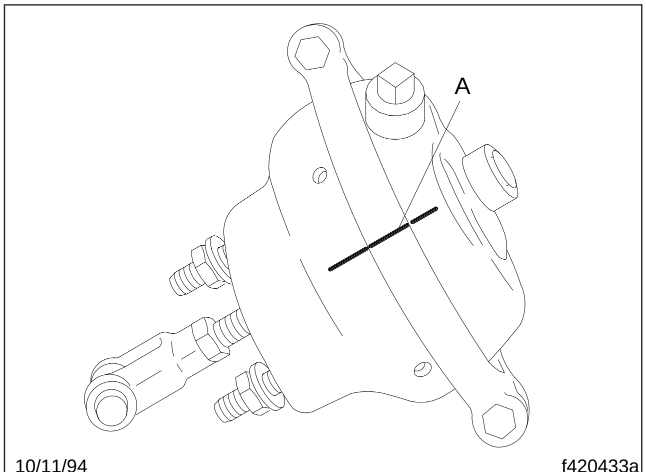
Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

   5.3 Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Sectional View



A. Reference Line

Fig. 2, Mark a Reference Line on the Chamber

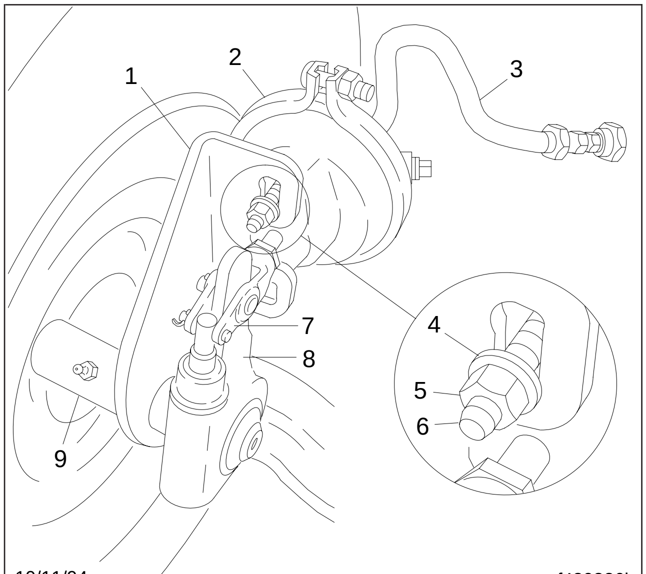
   Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications, 400**.

6. Release the clamp on the piston rod.
7. Do both of the tests in **Subject 100**.

Brake Chamber Diaphragm Replacement

8. Adjust the brakes at the slack adjuster. For instructions, see **Section 42.07**.
9. Remove the chocks from the tires.

Removal



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 Mounting

1. Chock the tires.

WARNING

Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. 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 airdevice 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**.
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: Gunite and Meritor 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.
2. Install the brake chamber. See **Fig. 1**.

   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.

Brake Chamber Removal and Installation

Mounting-Stud Locknut Torque Values		
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

2.3 Connect the clevis pin(s) to the slack adjuster.

NOTE: Gunite and Meritor 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, see **Section 42.10**.
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.

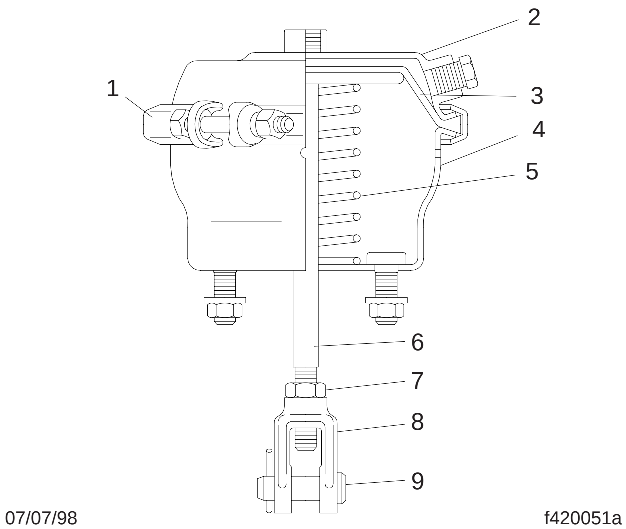
4.2 Before connecting the air line, make sure the fittings are clean and free of debris.

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



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, 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, see **Section 42.07**.

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**.

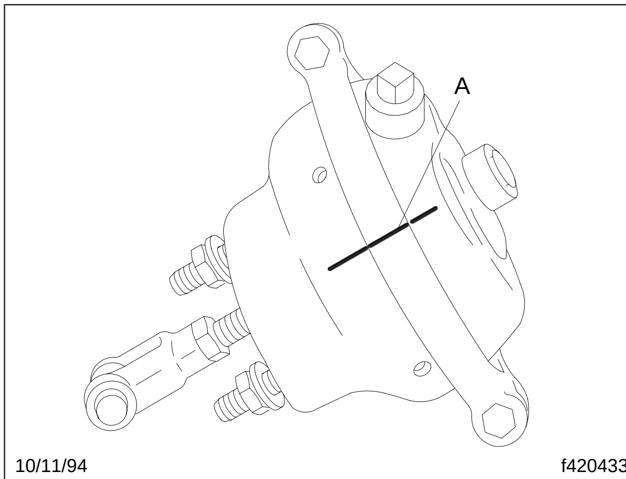
2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.

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 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.



A. Reference Line

Fig. 2, Mark a Reference Line on the Chamber

    3.4 Remove the piston rod assembly and spring.

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

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, see **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, see **Subject 120**.
5. Do both of the tests found in **Subject 100**.

Specifications

Mounting-Stud Locknut Torque Values		
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 (52–58)
	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

Clamp Ring Torque Values		
Description	**Chamber Size (in ^{2})**	**Torque lbf·ft (N·m)**
Clamp Ring Flange Nuts	12	17–21 (23–28)
	16	17–21 (23–28)
	20	9–19 (12–25)
	24	13–19 (17–25)

Table 2, Clamp Ring Torque Values

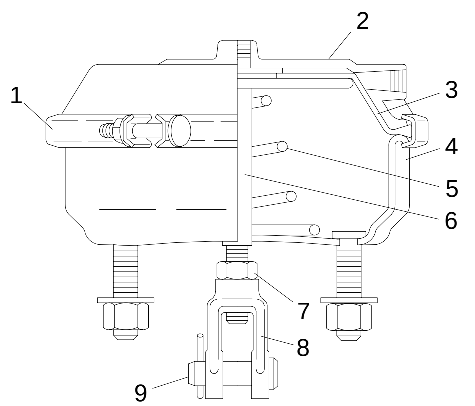
Piston Rod Nut Torque Values		
Description	**Chamber Size (in ^{2})**	**Torque lbf·ft (N·m)**
Piston Rod Nuts	12	20–30 (27–41)
	16 (7/16-inch Stud)	20–30 (27–41)
	16 (1/2-inch Stud)	20–30 (27–41)
	20	33–90 (45–122)
	24	33–90 (45–122)

Table 3, Piston Rod Nut Torque Values

General Information

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**.



02/28/95 f421326

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

Fig. 1, Brake Chamber (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

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, see **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

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.

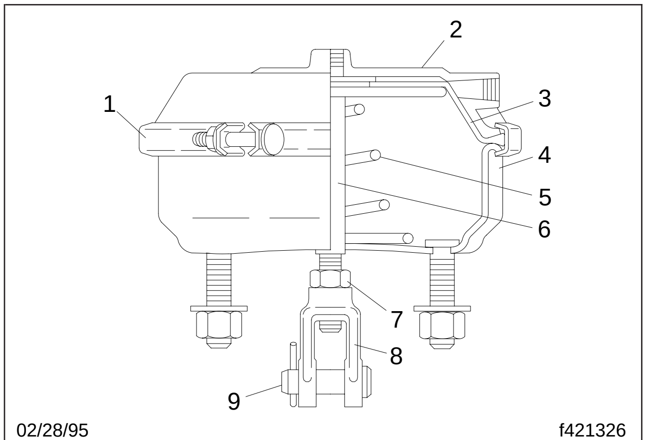
   5.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.

   5.2 Remove the pressure cap, and replace the diaphragm.

CAUTION

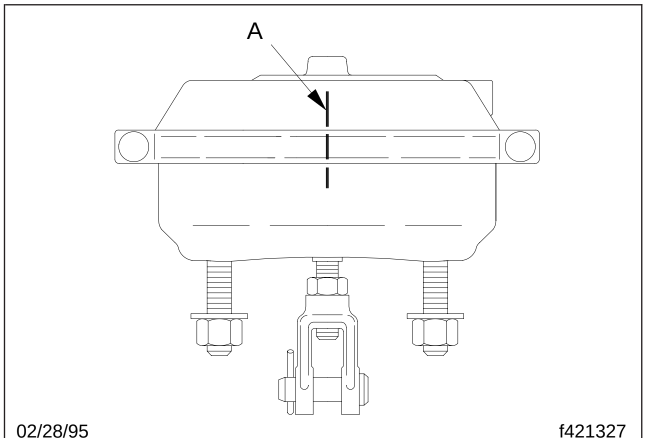
Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

   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.



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

Fig. 1, Brake Chamber (sectional view)



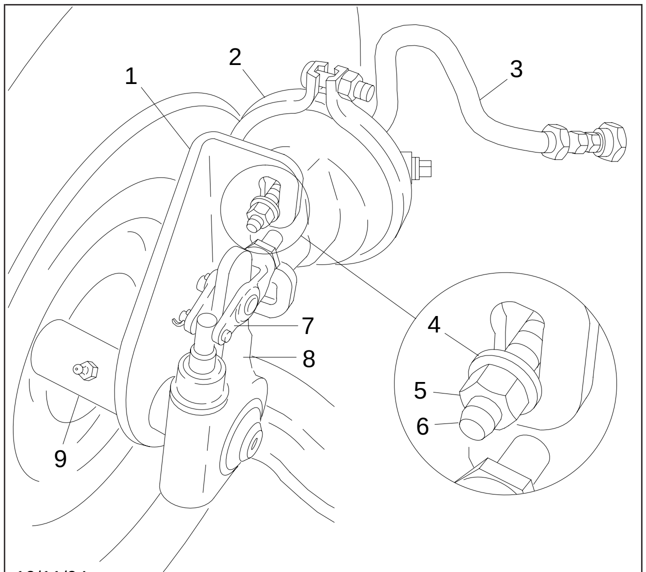
A. Reference Line

Fig. 2, Mark a Reference Line Along the Chamber

6. Release the clamp on the piston rod.
7. Do both of the tests in **Subject 100**.
8. Adjust the brakes at the slack adjuster. For instructions, see **Section 42.07**.
9. Remove the chocks from the tires.

Service Brake Chamber Removal and Installation

Removal



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, Service Brake Chamber

1. Chock the tires.

WARNING

Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. 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**.
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: Gunite and Meritor 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.
2. Install the brake chamber. See **Fig. 1**.
   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.

Mounting Stud Locknut Torque Values		
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).

   NOTE: Gunite and Meritor automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

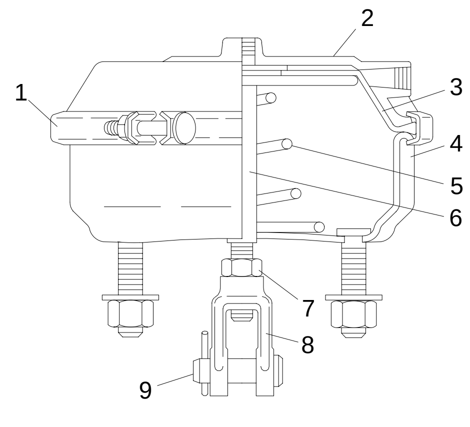
3. Adjust the brakes at the slack adjuster. For instructions, see **Section 42.07**.

Service Brake Chamber Removal and Installation

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

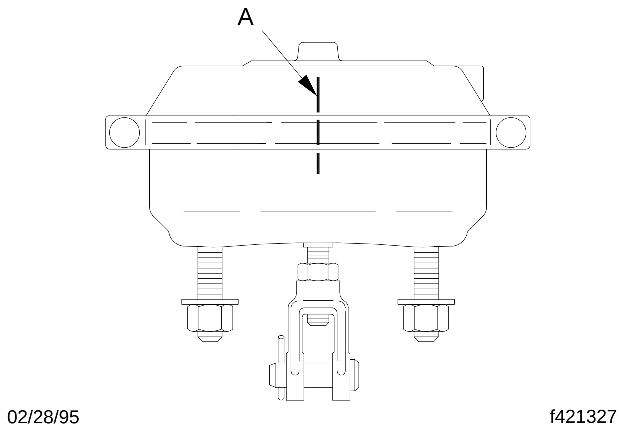


1. Clamp Ring
2. Pressure Cap
3. Diaphragm
4. Chamber Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Clevis Jam Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (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, see **Section 42.07** 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.



A. Reference Line

Fig. 2, Mark a Reference Line Along the Chamber

   - 3.4 Remove the piston rod assembly and spring.

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).
2. Assemble the brake chamber. See **Fig. 1**.
   - 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, until the chamber bottoms out on the flat surface. Clamp the rod at the chamber, making sure to protect the rod from dam-

Service Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

age. 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

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, see **Subject 120**.
5. Do both of the tests found in **Subject 100**.

Specifications

Mounting Stud Locknut Torque Values		
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

The Meritor 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 are adjusted only 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.

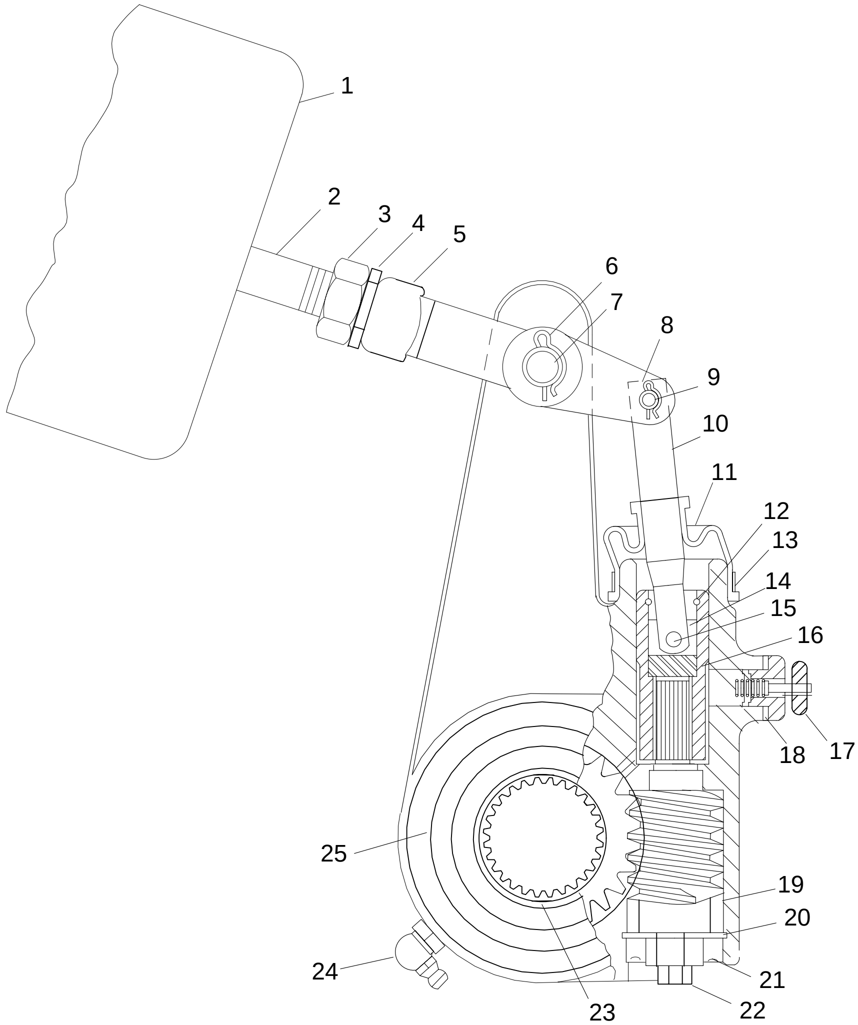
Principles of Operation

The externally splined end of the worm fits the internal splines on the actuator. 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. See **Fig. 1**.

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. 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 Information



1. Brake Air Chamber	10. Actuator Rod	18. Pawl Spring
2. Brake Chamber Push Rod	11. Boot	19. Worm
3. Clevis Jam Nut	12. Piston Retaining Ring	20. Worm Retaining Snap Ring
4. Collar	13. Boot Retaining Clamp	21. Worm Grease
5. Clevis	14. Actuator Piston	22. Manual (Worm) Adjusting Nut End
7. Clevis Pin (large)	15. Roller (Pin)	23. Gear
6. Cotter Pin (large)	16. Actuator (Adjusting Screw)	24. Grease Fitting
8. Cotter Pin (small)	17. Pressure Relief Capscrew	25. Gear Retainer/Seal
9. Clevis Pin (small)	18. Gasket	

Fig. 1, Automatic Slack Adjuster (sectional view)

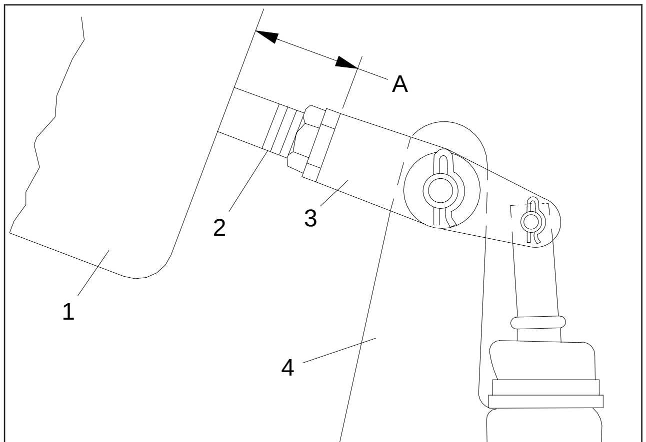
Removal

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

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 Clevis Position

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**. 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

Before turning the adjusting nut, remove the pressure relief capscrew, spring, and pull assembly. If equipped with a pull 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

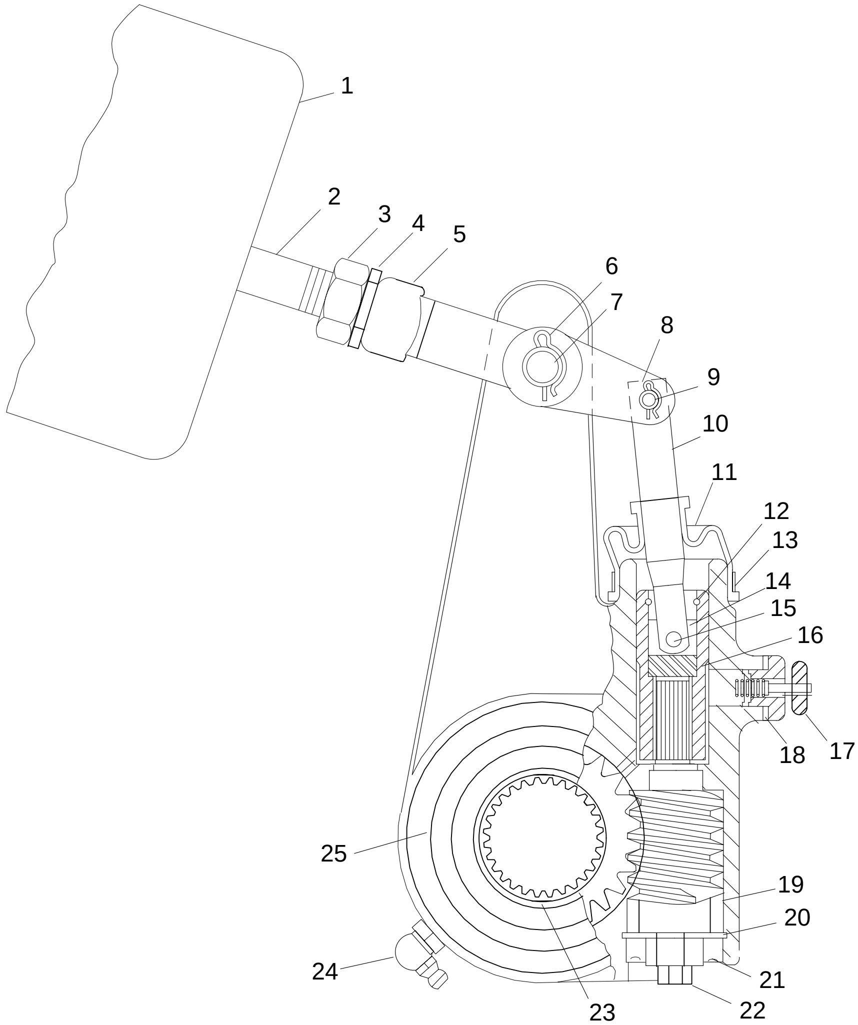
1. Inspect parts, and then prepare the slack adjuster for installation.
   - 1.1 Check the brake camshaft splines for wear or corrosion.
   - 1.2 Coat the camshaft splines and the splines of the slack adjuster gear with Meritor lubricant 0-637, Southwest SA 8249496, or an equivalent.

   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 measured during removal. Do not tighten the jam nut against the clevis.

Slack Adjuster Removal and Installation



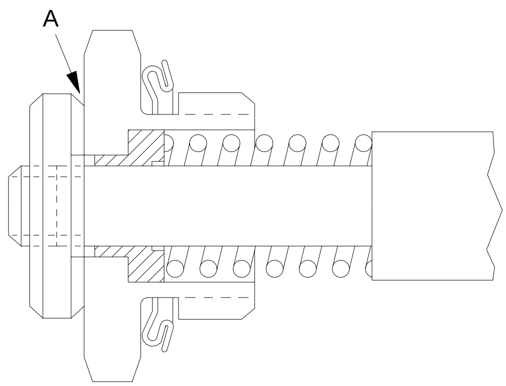
1. Brake Air Chamber
2. Brake Chamber Push Rod
3. Clevis Jam Nut
4. Collar
5. Clevis
7. Clevis Pin (large)
6. Cotter Pin (large)
8. Cotter Pin (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Screw)
17. Pressure Relief Capscrew
18. Gasket
18. Pawl Spring
19. Worm
20. Worm Retaining Snap Ring
21. Worm Grease
22. Manual (Worm) Adjusting Nut End
23. Gear
24. Grease Fitting
25. Gear Retainer/Seal

Fig. 2, Automatic Slack Adjuster (sectional view)

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.

   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 re-



A. Insert screwdriver here.

Fig. 3, Pull-Pawl Assembly (sectional view)

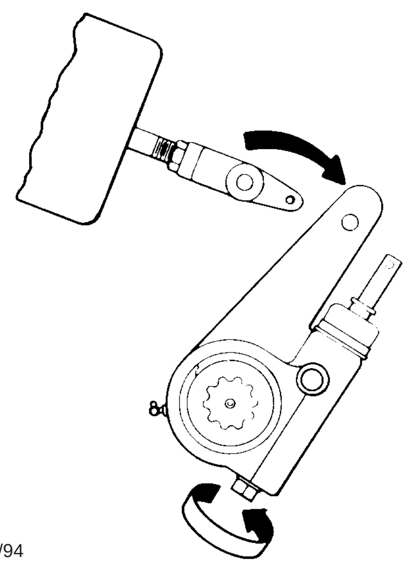
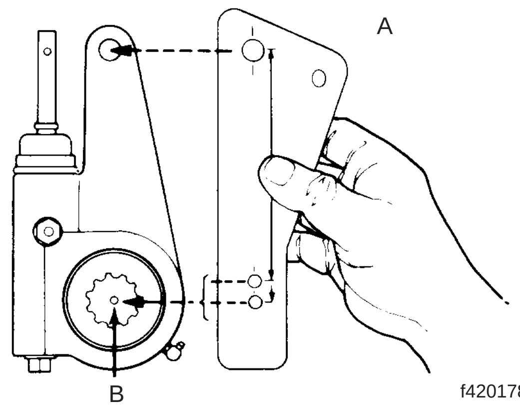


Fig. 4, Move the Slack Adjuster Away from the Clevis

moved. See **Fig. 5**. See **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, several types of installation templates are used. They can be made using the measurements provided in **Fig. 6**. Or, they can be ordered from:

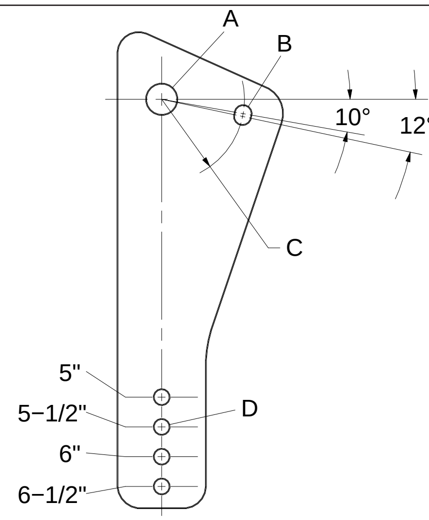


A. Measure slack adjuster arm length.
B. Camshaft Center

Fig. 5, Measure the New Slack Adjuster

Attn: Literature Distribution Meritor International 2135 W. Maple Road Troy, Michigan 48084

3.2 Position the slack adjuster on the camshaft.



A. 0.50" (12.7 mm) Diameter Hole
B. 0.12" (3.0 mm) Radius
C. 1.38" (35 mm) Radius
D. 0.250" (6.4 mm) Diameter Hole (4 qty.)

Fig. 6, Installation Template Specifications

Slack Adjuster Removal and Installation

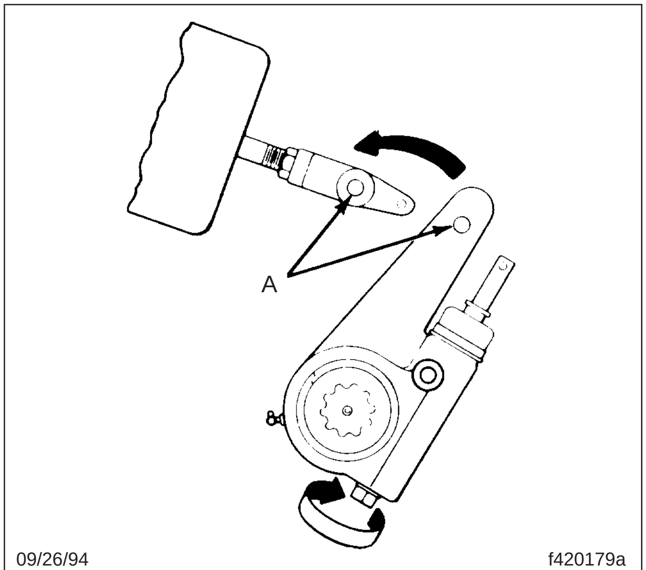
3.3 Install the spacing washers and the snap ring that attach the slack adjuster to the camshaft. Add enough washers to limit the camshaft end play to 0.060 inch (1.5 mm). Check the end play using the instructions in the applicable brake chamber section in this manual.

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

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.

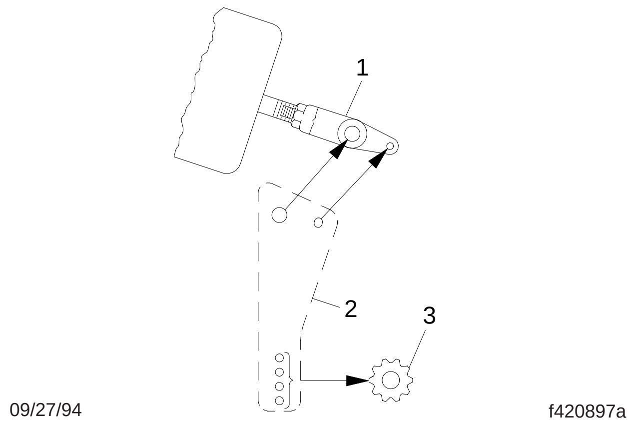
3.5 Using a wrench, turn the manual adjusting nut to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 7**. Insert the large clevis pin.



A. Align holes.

Fig. 7, Aligning the Holes

3.6 With the brakes fully released, place the applicable installation template over the clevis and camshaft end. See **Fig. 8**.



1. Clevis
2. Template
3. Camshaft End

Fig. 8, Position the Installation Template

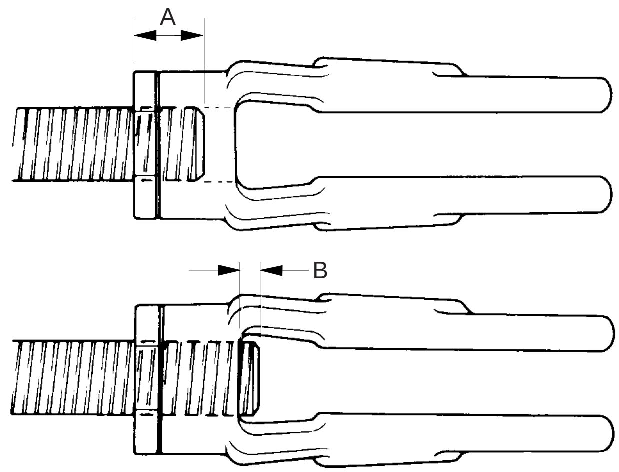
3.7 Temporarily insert the large clevis pin through the large holes in the template and the clevis.

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. Temporarily place the small clevis pin through the template and clevis to make sure the alignment is correct. Remove both pins and the template. Insert both clevis pins with the pin head on the inboard side of the slack adjuster. Be sure the small clevis pin is inserted 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).



A. Minimum 1/2" (13 mm)
B. Maximum 1/8" (3.2 mm)

Fig. 9, Check Push Rod Engagement

4. Set the free-stroke.

4.1 Turn the manual adjusting nut counter-clockwise 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 thelarge clevis pin. See **Fig. 10**.

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**.

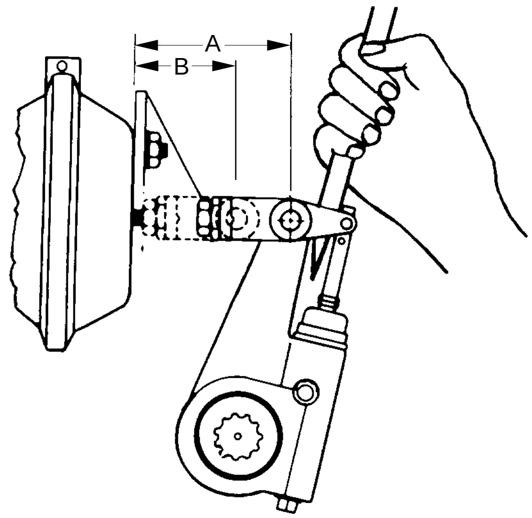
The difference between the two measurements is the initial free-stroke, and sets the clearance between the linings and the drum.

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.



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).

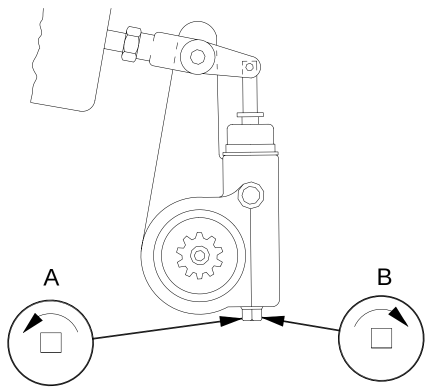
Fig. 10, Measuring Free-Stroke

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**.

5.2 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. 12**.

Slack Adjuster Removal and Installation



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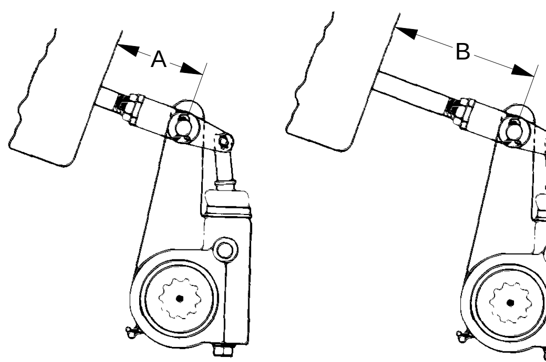
A. Shorten stroke.
B. Lengthen stroke.

Fig. 11, Turn the Adjusting Nut



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NOTE: Measure distance *A* with the brakes released; measure distance *B* with the brakes applied.

Fig. 12, Measuring Adjusted Brake Chamber Stroke

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 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, see 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. 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, see **Section 42.06** in this manual.
9. Remove the chocks from the tires.

Specifications

Lubricant Specifications	
Lubricant Type	**Temperature**
Amoco Super Permalube No. 2 Aralub 3837 Citco Premium Lithium EP No. 2 Exxon Ronex MP No. 2 Kendall L-427 Super Blu No. 2 Mobilith AW No. 1 Meritor 0-616-A Meritor 0-692 Shell Darina No. 1 Sohio Factran EP No. 2 Texaco Hytherm EP No. 1 Texaco Thermotex EP No. 1 Tribolube 12, Grade 1	–40°F (–40°C) or Above
Mobil 28 Meritor 0-645	Below –40°F (–40°C)

Table 1, Lubricant Specifications

Slack Adjuster Arm Lengths	
Arm Length	**Chamber Size**
5 inches (127 mm)	9, 12, 16, 20, 24, 30
5-1/2 inches (140 mm)	9, 12, 16, 20, 24, 30
6 inches (152 mm)	24, 30
6-1/2 inches (165 mm)	30

Table 2, Slack Adjuster Arm Lengths

Brake Chamber Strokes	
Chamber Size	**Maximum Chamber Stroke for Cam Brake**
9	Less than 1-1/2 inches (38 mm)
12	Less than 1-1/2 inches (38 mm)
16	Less than 1-3/4 inches (44 mm)
20	Less than 1-3/4 inches (44 mm)
24	Less than 1-7/8 inches (48 mm)
24 *	Less than 2 inches (51 mm)
30	Less than 2 inches (51 mm)

* Long stroke.

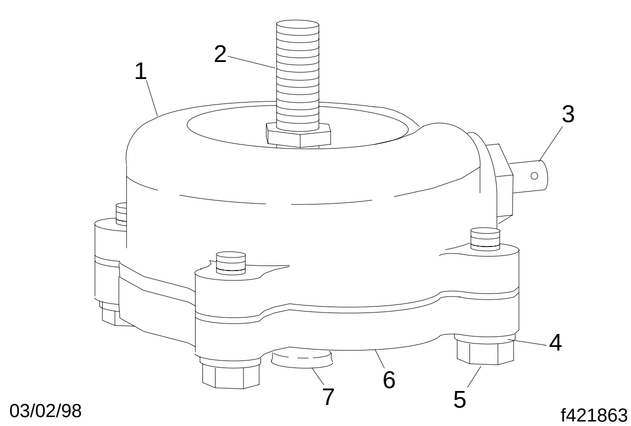
Table 3, Brake Chamber Strokes

General Description

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 foot valve is protected by a check valve between the wet-and dry-air tanks, any leak or sticking valve will not reduce the supply of air that is in the dry part of the system.

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 about 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 enough to close the exhaust valve. See **Fig. 5**.



1. Valve Body
2. Top Reservoir Port
3. Drain Port
4. Lockwasher
5. Capscrew
6. Valve Cover
7. Exhaust Port

Fig. 1, DV-2 Valve

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.

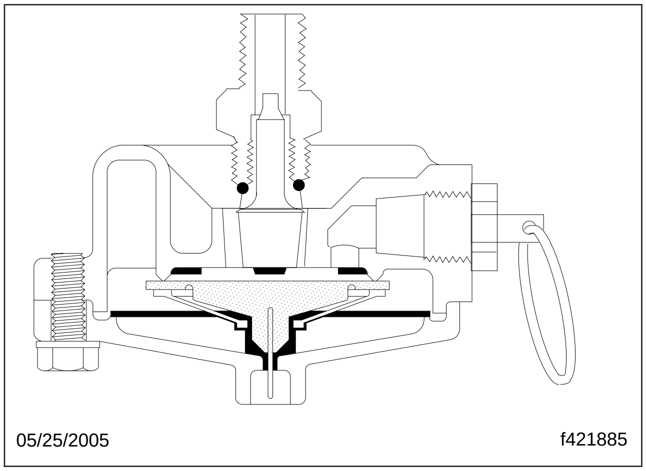


Fig. 2, No System Pressure

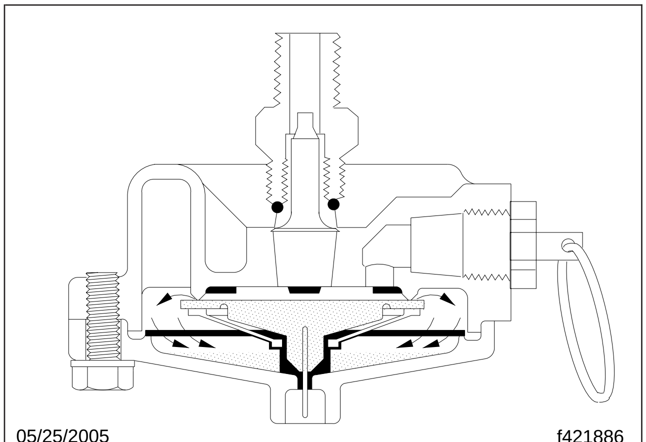


Fig. 3, Start of System Pressure Charging

General Information

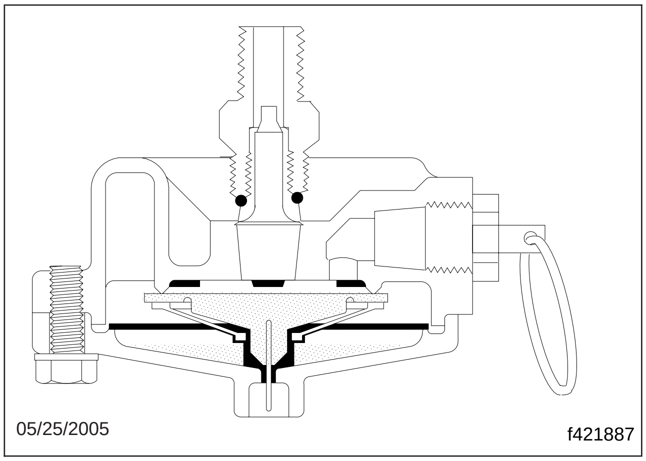


Fig. 4, System Pressure Rising

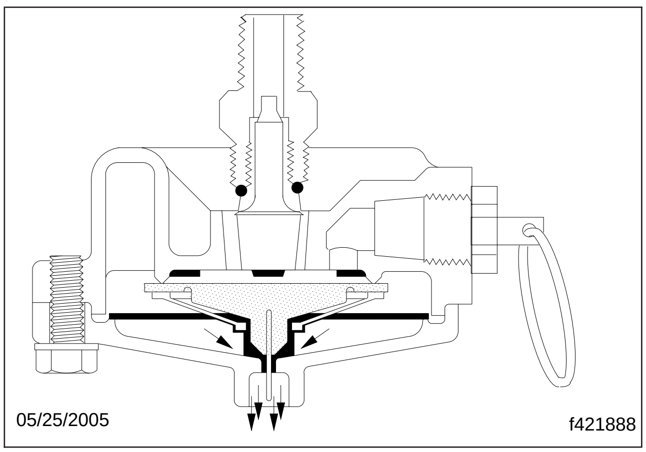


Fig. 5, Exhaust Cycle

Safety Precautions

When working on or around air brake systems and components, the following precautions should be observed.

1. Always chock the vehicle's wheels and stop the engine when working under a vehicle. 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 released.
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 the correct tools and observe all precautions pertaining to use of those tools.

Operating Test

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

Do the following test after repairing or replacing the DV–2 valve to ensure that the valve is functioning correctly.

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 correctly, 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 correctly.

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, see **Safety Precautions, 100**.

1. Chock the tires, and drain the reservoirs.
2. Remove the drain valve assembly from the end of the wet tank reservoir.

Installation

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

1. Using an approved cleaning solvent, flush and clean the wet tank reservoir to avoid early fouling at the drain valve. Aerate the wet tank completely 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

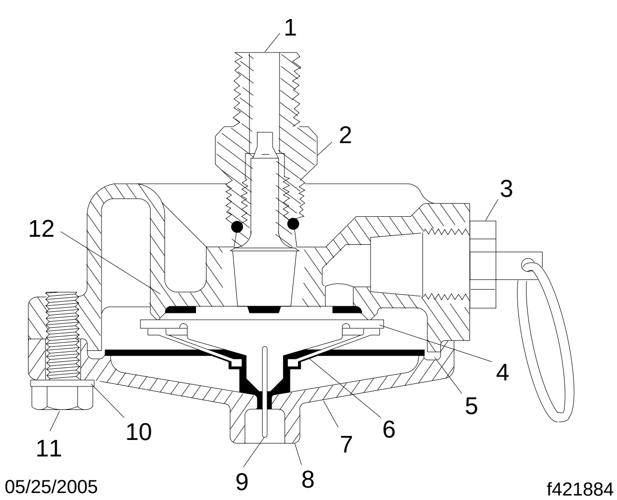
Disassembly

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

1. Remove the drain valve following the instructions in **Subject 120**. See **Fig. 1**.
2. Remove the four capscrews that hold the valve cover to the valve body.
3. Remove the valve cover and sealing ring.
4. Remove the valve guide and the inlet and exhaust valve from the valve body.
5. Remove the hexhead nipple from the valve body.

Cleaning and Inspection

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.



1. Top Reservoir Port
2. Hexhead Nipple
3. Drain Port Capscrew
4. Inlet and Exhaust Valve
5. Valve Sealing Ring
6. Valve Guide
7. Valve Cover
8. Exhaust Port
9. Wire Stem
10. Lockwasher
11. Capscrew
12. Inlet Valve Seat

Fig. 1, DV-2 Valve (cutaway view)

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. If any rubber parts are worn, cracked, torn or otherwise deteriorated, replace them with new parts.
3. Examine all metal parts. 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

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, see **Safety Precautions, 100**.

Before assembling the drain valve, apply a light film of grease on the inlet valve seat.

IMPORTANT: Do not apply oil to the inlet and exhaust valve.

1. Install the valve sealing ring into its groove in the valve cover. 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).
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 under **Subject 120**.

Specifications

Torque Values	
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 Information

The R–12 and R–14 relay valves are control relay stations in the air brake system to speed the application and release of the brakes. See **Fig. 1** and **Fig. 2**. Mounted at the rear of the vehicle, they are operated by remote control and give the same amount of air pressure to the brake chambers as they receive from the service brake foot valve or other source.

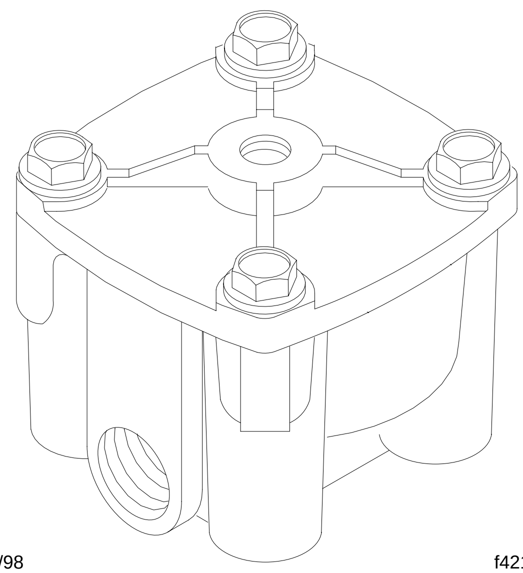


Fig. 1, R-12 Relay Valve

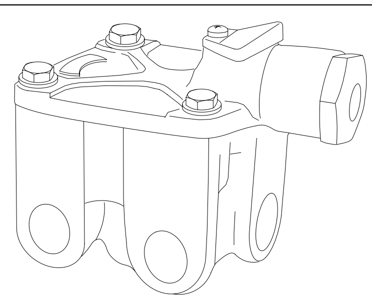


Fig. 2, R-14 Relay Valve

The valves are piston operated and have an insert-type inlet and exhaust valve that can be serviced without removing the lines from the valve body.

Principles of Operation

APPLICATION

Air pressure delivered to the service port enters the small cavity above the piston and moves the piston down. The exhaust seat moves down with the piston and seats on the inner or exhaust portion of the inlet/exhaust valve, sealing off the exhaust passage. At the same time, the outer or inlet portion of the inlet/exhaust valve moves off its seat, permitting supply air to flow from the reservoir, past the open inlet valve and into the brake chambers. See **Fig. 3**.

BALANCE

The air pressure being delivered by the open inlet valve also is effective on the bottom area of the relay piston. When air pressure beneath the piston equals the service air pressure above, the piston lifts slightly and the inlet spring returns the inlet valve to its seal. The exhaust remains closed as the service line pressure balances the delivery pressure. As delivered air pressure is changed, the valve reacts instantly to the change holding the brake application at the level.

EXHAUST OR RELEASE

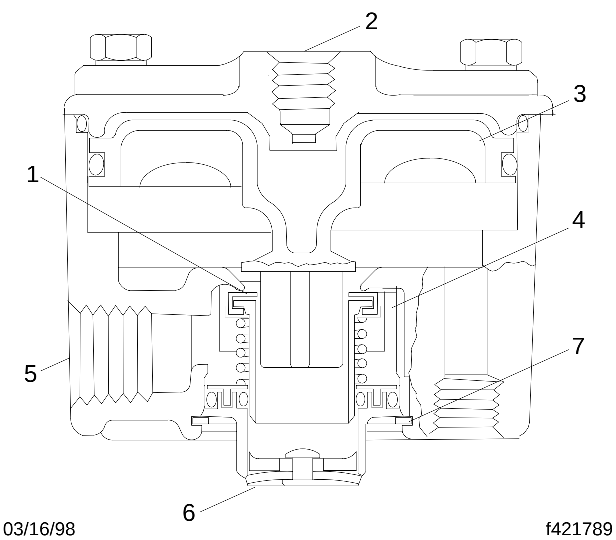
When air pressure is released from the service port and air pressure in the cavity above the relay piston is exhausted, air pressure beneath piston lifts the relay piston and the exhaust seat moves away from the exhaust valve, opening the exhaust passage. With the exhaust passage open, the air pressure in the brake chambers is then permitted to exhaust through the exhaust port, releasing the brakes.

ANTI-COMPOUNDING (SIMULTANEOUS SERVICE AND PARK APPLICATION), R–14 VALVE

An "anti-compound" feature allows the R–14 valve to be used as either a service or spring brake relay valve. An exhaust cover is installed that protects the 1/8-inch balance port when the R–14 anti-compound feature is not in use. See **Fig. 4**.

In applications where the R–14 is used to control spring brake chambers, the anti-compound feature may be utilized. To utilize, the exhaust cover of the

General Information

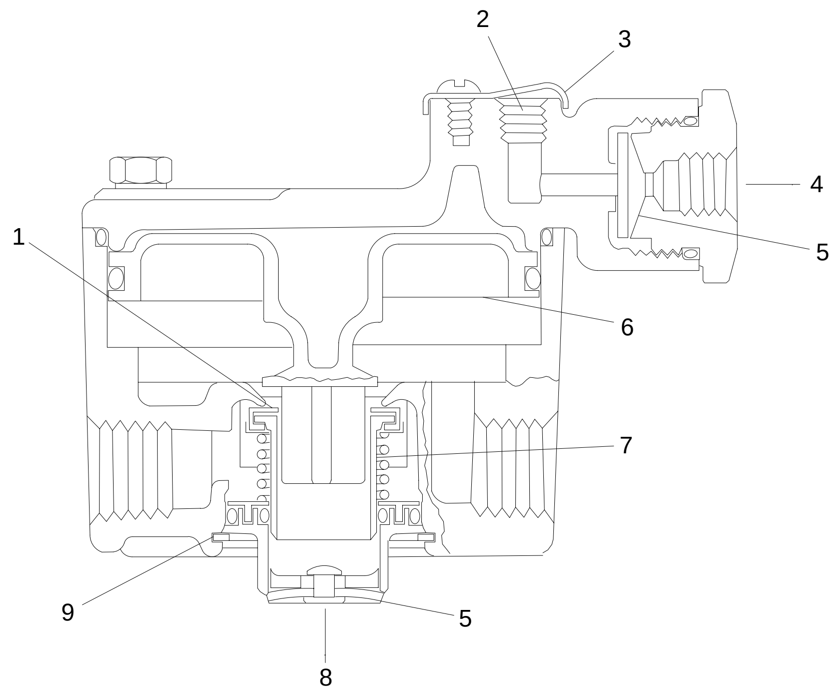


1. Exhaust Seat
2. Service Port
3. Relay Piston
4. Inlet/Exhaust Assembly
5. Supply Port
6. Exhaust Port
7. Retaining Ring

Fig. 3, R-12 Relay Valve (sectional view)

quick release portion of the R–14 is removed and a line is installed, which is connected to the delivery of the service brake valve or relay valve. With no compressed air at the service port of the R–14, the parking brakes apply. When a service brake application is made, air from the service brake valve enters the exhaust port of the quick release of the R–14 and moves the diaphragm, blocking the service port. Air then proceeds into the cavity above the relay piston, forces the piston down, closing the exhaust and opening the inlet to deliver air to the spring brake cavity.

General Information



1. Exhaust Seat
2. Balance/Quick Exhaust (Anti-Compound)
3. Exhaust Cover
4. Service Port
5. Diaphragm
6. Relay Piston
7. Inlet/Exhaust Valve
8. Exhaust Port
9. Retaining Ring

Fig. 4, R-14 Relay Valve (sectional view)

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

A. Chock the tires and stop the engine before working under the vehicle. Releasing air from the system may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters; they will apply as air pressure drops.

B. 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.

C. 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.

D. Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs and injury can result if not correctly disassembled. Use only correct tools and observe all precautions regarding use of those tools.

Relay Valve Operation and Leakage Tests

Operation Test

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

1. Start the vehicle and build the brake system to cut-out pressure, 120 psi (827 kPa).
2. Make several service brake applications and check for prompt application and release of the brakes.
3. If brake response is slow, troubleshoot the brake system. For instructions, see **Section 42.01** in this group. If the valve is malfunctioning, repair or replace it.

Leakage Test

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

1. Start the vehicle and build the brake system to cut-out pressure, 120 psi (827 kPa).
2. Check for inlet valve and O-ring leakage.
   - 2.1 Make this check with the service brakes released when the R–12 or R–14 is used to control the service brakes.
   - 2.2 Make the check with the spring brakes (parking brakes) applied when the R–14 is used to control the spring brakes.
3. While holding a full service brake application, apply a soap solution to the exhaust port. Leakage at the exhaust port should not exceed a 1-inch (2.5-cm) bubble in three seconds.

NOTE: If the anti-compound feature is in use, the line attached to the balance port must be disconnected to perform this test.

4. Coat the outside of the valve where the cover joins the body to check for seal ring leakage; no leakage is permitted.
5. If the R–14 is used to control the spring brakes, release the park control, apply a soap solution to the balance port. Leakage at the balance port should not exceed a 1-inch (2.5-cm) bubble in three seconds.

IMPORTANT: If the valves do not function as described in the above test, or if leakage is excessive, replace it. For instructions, see **Subject 120**.

Removal

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

1. Chock the tires, and drain the air system.
2. Remove all air hoses from the valve. Cap the hoses and mark them for reassembly.
3. Remove the valve mounting bolts. Remove the valve.

Installation

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

1. Attach the valve to the vehicle, using the bolts, washers, and nuts. Tighten the nuts 132 to 180 lbf·in (1500 to 2040 N·cm).
2. Remove the caps from the air lines, then depending on the type of air hose, do one of the following.

   Nylon Tubing: Connect the hose fittings to the valve ports, and tighten the nuts finger-tight. Using a wrench, tighten the nuts at least two turns, or until no threads show on the fittings.

   Wire Braid Hoses: Connect the hose fittings to the valve ports, and hand-tighten the nuts. Using a wrench, tighten the nuts until resistance is felt. Tighten one-sixth turn more. Do not overtighten.
3. Close the air reservoir drain cocks. Start the vehicle engine to pressurize the air system.
4. Test the valve following the instructions in **Subject 110**.

Relay Valve Disassembly, Cleaning and Inspection, and Assembly

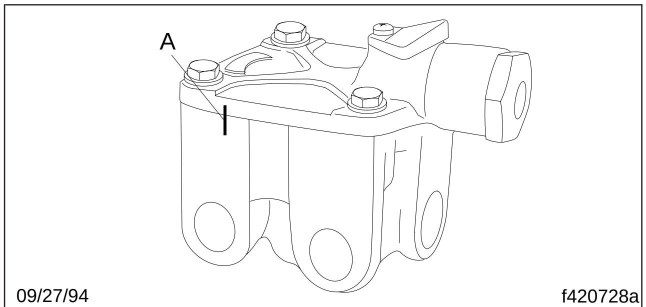
Disassembly

IMPORTANT: Before working on or around air brake systems and components, refer to **Safety Precautions, 100**.

1. Remove the valve from the vehicle. For instructions, see **Subject 120**.

NOTE: Prior to disassembly, draw an alignment mark across the valve cover and body, for reassembly alignment. See **Fig. 1**.

2. Disassemble the valve.
   - 2.1 Referring to **Fig. 2**, remove the four cover capscrews and lockwashers.



A. Mark the valve housing for reassembly alignment.

Fig. 1, Valve Marked for Reassembly (R-14 valve shown)

   - 2.2 Remove the valve cover and O-ring.
   - 2.3 Remove the relay piston, and the O-ring.
   - 2.4 While depressing the exhaust cover, remove the retainer ring; slowly remove the exhaust cover and the valve spring. Remove the O-rings from the exhaust cover.
   - 2.5 Remove the inlet/exhaust valve. Remove the valve retainer from the inlet/exhaust valve.
3. On the R–14 valves, remove the Phillips head screw and the exhaust cover. Then, remove the service port cap nut, the O-ring, and the diaphragm located inside the service port.

Cleaning and Inspection

WARNING

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

IMPORTANT: Before working on or around air brake systems and components, see **Safety Precautions, 100**.

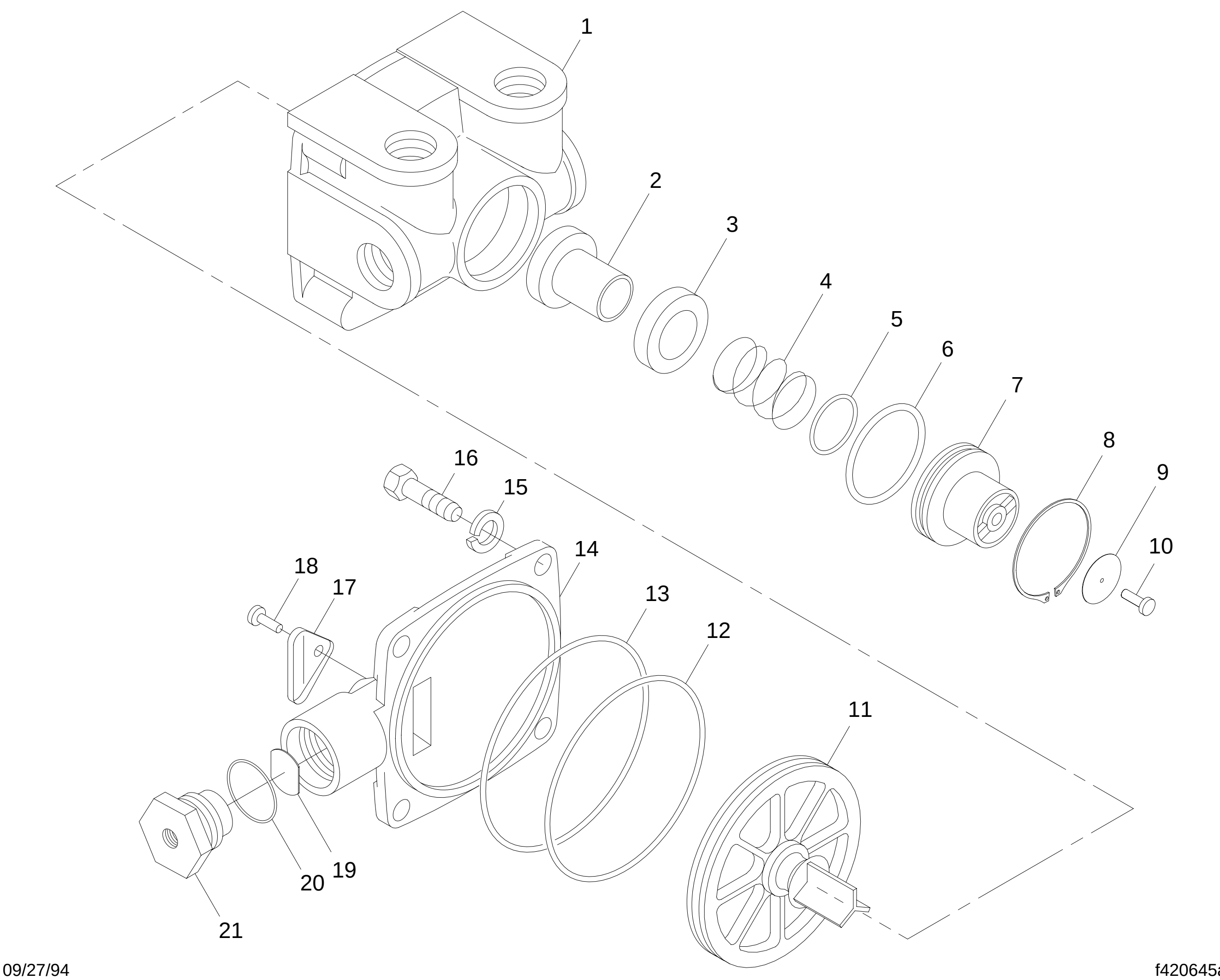
1. Wash all metal parts of the valve in cleaning solvent. Dry the metal parts of the disassembled valve with compressed air.
2. Wipe all rubber parts clean with a clean cloth. Examine all rubber parts for cracks, tears, or other deterioration. If any rubber parts are worn, cracked, torn or otherwise damaged, 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. Check the springs for distortion and corrosion. If the springs are distorted or corroded, replace them.
5. Inspect the exhaust seat of the quick release diaphragm in the R–14 cover and make sure all internal air passages in the area are open and clean and free of nicks and scratches.

Assembly

IMPORTANT: Before working on or around air brake systems and components, refer to **Safety Precautions, 100**.

1. Lubricate the O-rings and all sliding parts with Dow Corning 55-M pneumatic grease or equivalent. Assemble the valve. See **Fig. 2**.
   - 1.1 Install the O-ring on the relay piston.
   - 1.2 Install the inner and outer O-rings on the exhaust cover.
   - 1.3 Install O-ring on the valve cover.
   - 1.4 Install the relay piston in the body, taking care not to damage the piston O-ring.

Relay Valve Disassembly, Cleaning and Inspection, and Assembly



1. Body
2. Inlet/Exhaust Valve
3. Valve Retainer
4. Valve Spring
5. O-Ring
6. O-Ring
7. Exhaust Cover
8. Retainer Ring
9. Diaphragm
10. Rivet
11. Relay Piston
12. O-Ring
13. O-Ring
14. Valve Cover
15. Lockwasher (4 qty)
16. Capscrew (4 qty)
17. Exhaust Cover
18. Screw, Phillips #10–24
19. Diaphragm
20. O-Ring
21. Cap Nut

Fig. 2, R-14 Valve (R-12 similar)

1.5 Noting the reference mark made during disassembly, secure the valve cover with four capscrews and lockwashers. Torque the capscrews 80 to 120 lbf·in (900 to 1360 N·cm).

1.6 Install the valve retainer on the inlet/exhaust valve assembly. Install the inlet/exhaust valve assembly in the body.

1.7 Install the exhaust cover. While depressing the exhaust cover, install the retaining

Relay Valve Disassembly, Cleaning and Inspection, and Assembly

ring, making sure the retaining ring is completely seated in the groove.

1.8 On R–14 valves, place the diaphragm in the service port making sure it is positioned between the guide ribs. Install the service port cap nut and O-ring, then tighten to 150 lbf·in (1700 N·cm).

1.9 Position the exhaust cover, then install the Phillips head screw. Tighten the screw 25 lbf·in (280 N·cm).

2. Install the relay valve on the vehicle following the instructions in **Subject 120**.
3. Test the valve following the instructions in **Subject 110**.

Specifications

Torque Values	
Description	**Torque: lbf·in (N·cm)**
Valve Cover Capscrews	80–120 (900–1360)
Valve Mounting Capscrews	132–180 (1500–2040)
Service Port Cap nut	150 (1700)
Phillips Screw, no. 10–24	25 (280)

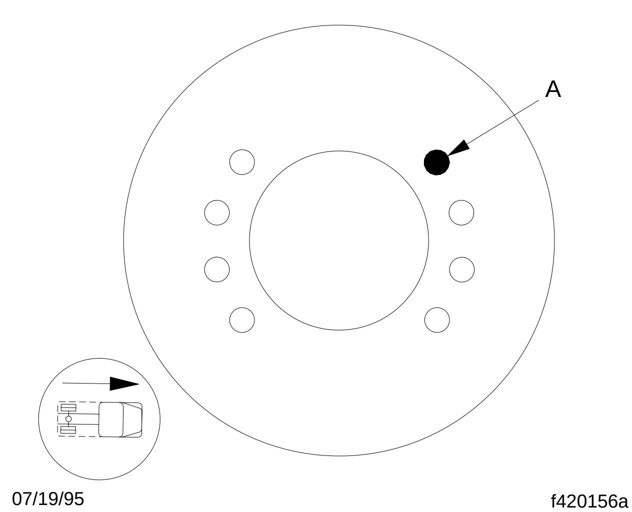
Table 1, Torque Values

General Information

Meritor (formally Rockwell) "Q" and "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.

Meritor 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, Open Hole Location

Meritor attaches an identifying label on 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 Meritor lining designation. The new lining edge code will show the supplier lining designation and the corresponding Meritor designation. See **Table 1**.

Edge Codes		
Vendor Code		**Design.**
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 Meritor aftermarket lining material designation. See "Meritor 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 Information

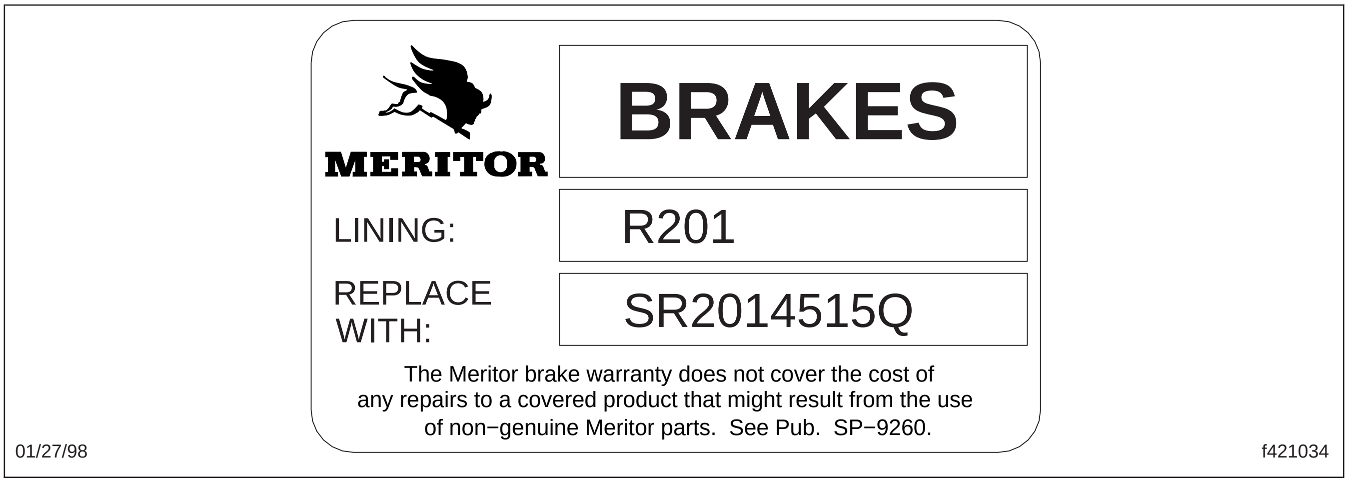


Fig. 2, Meritor Brake Shoe Lable, Example

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 brake. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (NIOSH).

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator

Safety Precautions

and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

WARNING

Before starting the procedure below, read the 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, see **Group 33** or **Group 35** in this manual.

CAUTION

Before you back off automatic slack adjusters, see Section 42.07 or the manufacturer's service information for instructions. Failure to do so could damage the slack adjusters.

4. Back off the slack adjusters. For instructions, see **Section 42.07** in this manual.
5. If equipped with 15-inch "Q" Series brakes, go to the next step.

   If equipped with "Q" Plus Series brakes, or 16-1/2 inch "Q" 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**.

   5.4 Rotate the bottom shoe to release tension on the two retaining springs. Remove the springs and the brake shoes. See **Fig. 3**.

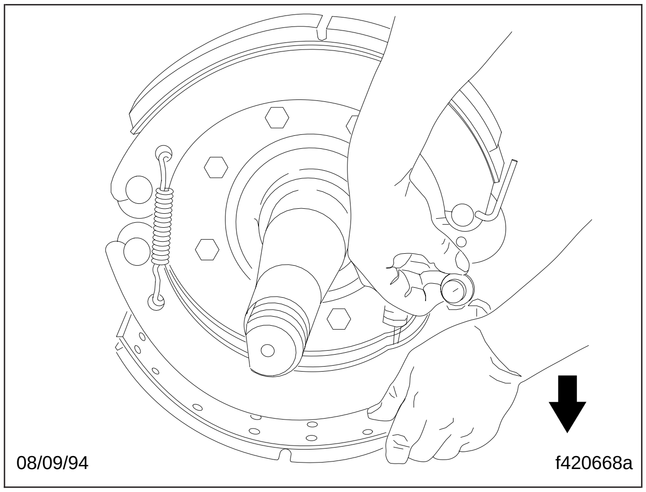


Fig. 1, Remove the Bottom Cam Roller

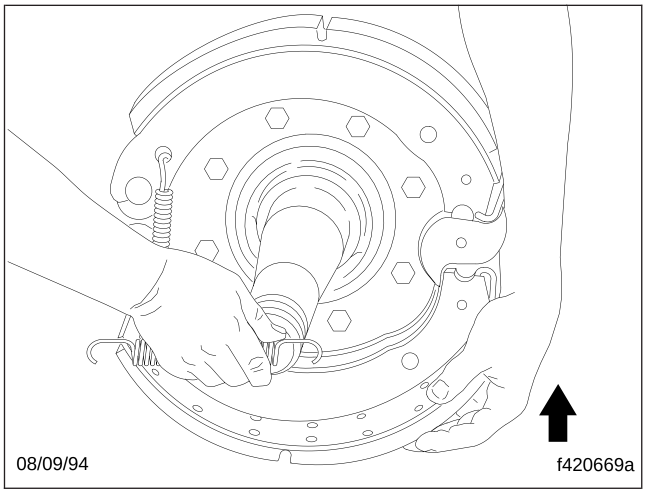


Fig. 2, Remove the Spring

6. If equipped with 15-inch "Q" Series 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.

   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. See **Subject 120**.

Brake Shoe Removal and Installation

Installation

IMPORTANT: For best brake performance, don't mix "Q" and "Q" Plus Series brakes. Use the same brake series on the entire vehicle.

1. Apply a thin film of a temperature resistant grease (Meritor 0-616, or an equivalent) on the anchor pins where they touch the brake shoes. Also, apply a multipurpose chassis grease (Meritor 0-617-A or 0-617-B, or an equivalent) on the retainer clips, spider, and shoe rollers where they touch the brake shoes.

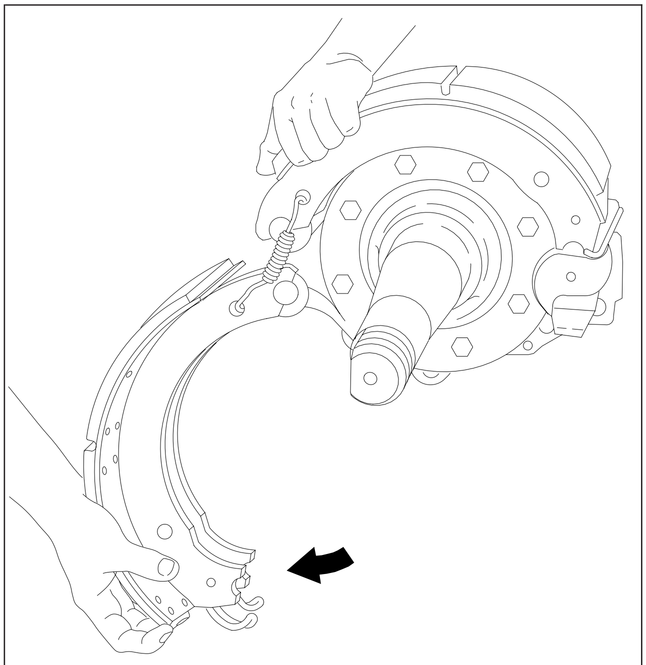


Fig. 3, Remove the Springs and Brake Shoes

IMPORTANT: Don't apply any grease on the outer diameter of the roller that touches the cam head.

2. Go to the step for installing the brake shoes on 15-inch "Q" Series brakes, if so equipped.

   If equipped with "Q" Plus Series brakes, or 16-1/2 inch "Q" Series brakes, install the brake shoes.

   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**.

   2.2 Turn the lower brake shoe forward and attach a new brake shoe return spring. See **Fig. 5**.

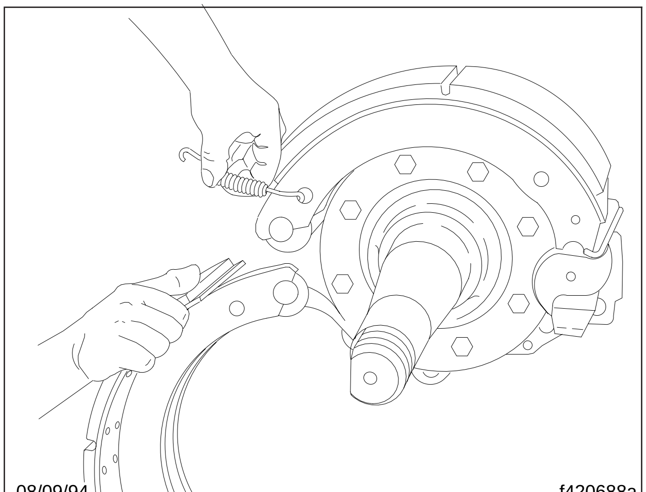
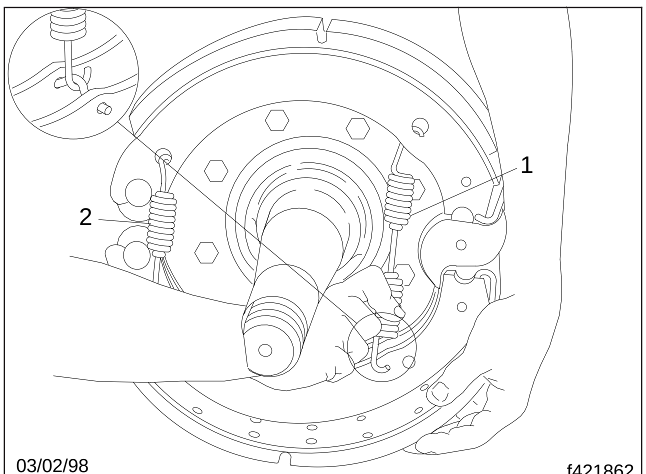


Fig. 4, Attach the New Springs

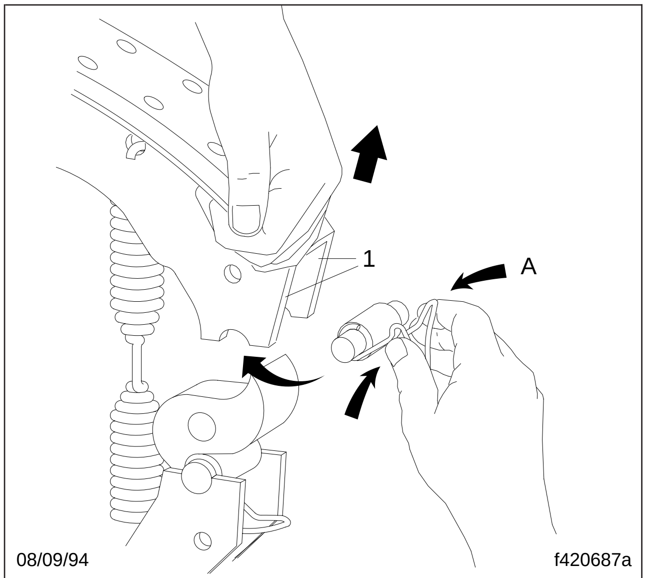


1. Return Spring
2. Retainer Spring

Fig. 5, Attach the 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. Press the ears of the retainer together to permit the retainer to fit between the brake shoe webs. See **Fig. 6**.

2.4 Push the retainer into the brake shoe until the ears lock in the holes in the shoe webs. See **Fig. 7**.



A. Squeeze
1. Web

Fig. 6, Install the Cam Rollers and Retainers

3. If equipped with 15-inch "Q" Series brakes, install the brake shoes.

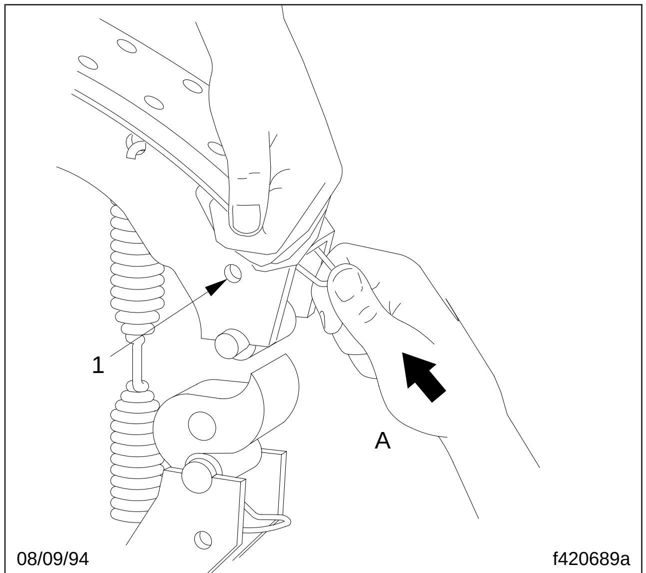
   3.1 Install the retainer spring on the shoes and install the shoes on the anchor pins. See **Fig. 5**. Hold the bottom shoe in position and install the return spring.

   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, see **Group 33** or **Group 35** in this manual.

5. Adjust the brakes at the slack adjusters. For instructions, see **Subject 130**.

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

WARNING

Don't operate the vehicle until you have adjusted the brakes and checked for their proper operation. Failure to do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

7. Check for proper brake operation.

   7.1 To ensure that the braking system is working correctly, make ten 40 to 20 mph (60 to 30 km/h) snubs to seat the linings.

   7.2 Make ten stops from 20 mph (30 km/h) at 50 percent air pressure.

   7.3 Make a full-pressure stop from 20 mph (30 km/h).

   7.4 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others shows a lack of braking effort on those wheels.

Brake Shoe and Lining Inspection

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.

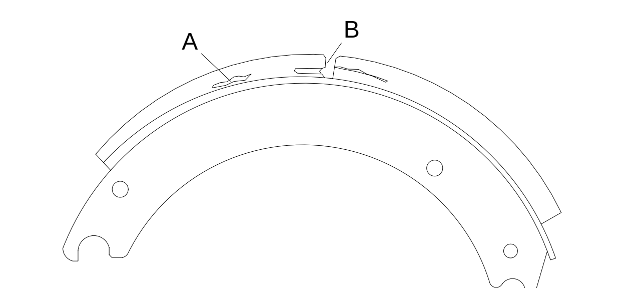
   2.2 Replace the linings if the lining surface is closer than 1/32 inch (0.8 mm) to any rivet head.

   2.3 The lining is considered worn-out and the vehicle should not be driven if:

   - Cracks on the lining surface exceed 1/16 inch (1.6 mm);
   - The lining edge shows cracks or voids over 1/16 inch (1.6 mm) in width and 1-1/2 inches (38 mm) in length. See **Fig. 1**;
   - Portions of the lining are missing exposing a rivet when viewed from the edge. See **Fig. 2**;
   - Cracks extend across the lining face and through the lining edge, or the lining is loose on the shoe. See **Fig. 3**.

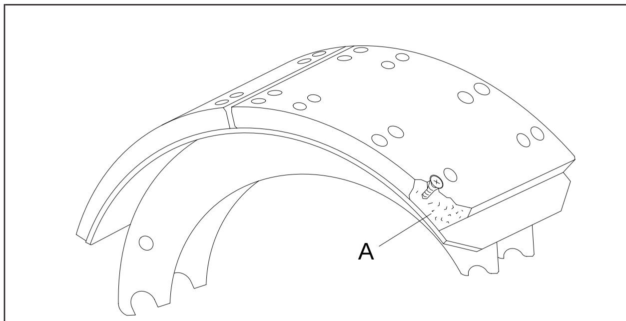
   2.4 The vehicle is still operational but linings should be replaced as soon as possible if:

   - Horizontal or vertical cracks in the lining edge exhibit no loss of material and do not exceed 1/16 inch (1.6 mm) in width or 1-1/2 inch (38 mm) in length. See **Fig. 4**;
   - Corner portions of the lining are missing with no fastener exposed. See **Fig. 5**;
   - Surface cracks extend from hole to hole or if there is scoring and contamination from road debris. See **Fig. 6**.



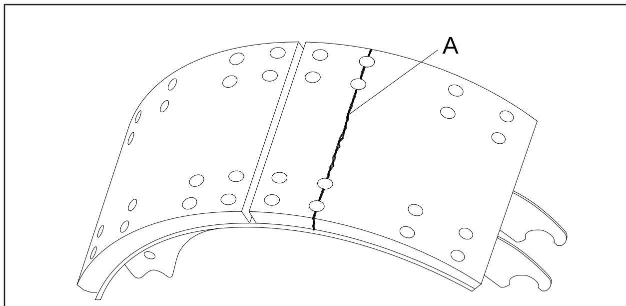
A. Cracks exceeding 1-1/2 inches (38 mm) in length.
B. Cracks or voids exceeding 1/16 inch (1.6 mm) in width.

Fig. 1, Cracks and Voids



A. Exposed fastening device.

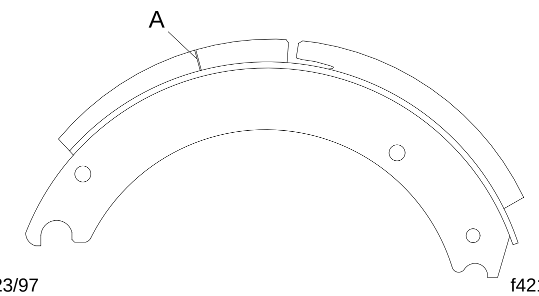
Fig. 2, Portions of the Brake Lining Missing



A. Cracks extending through the lining edge.

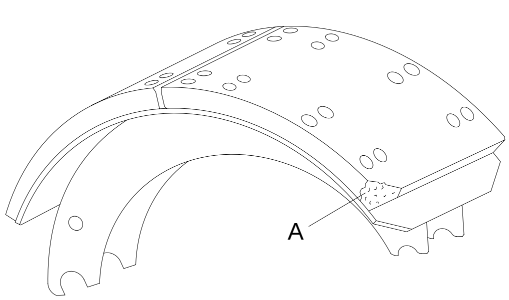
Fig. 3, Cracks in the Brake Lining

Brake Shoe and Lining Inspection



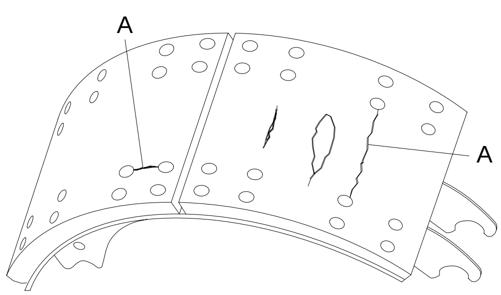
A. Cracks not exceeding 1-1/2 inches (38 mm) in length or 1/16 Inch (1.6 mm) in width.

Fig. 4, Cracks and Voids



A. Corner segment missing with no fastener exposed.

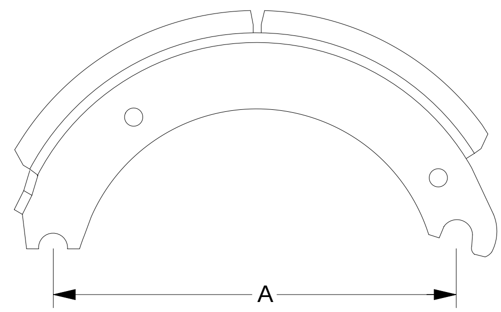
Fig. 5, Portions of the Brake Lining Missing



A. Cracks extending from hole to hole.

Fig. 6, Cracks in the Brake Lining

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 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. 7**.



A. 12-7/8 inches (327 mm)

Fig. 7, Measuring the Shoe Span

Adjustment

MERITOR AUTOMATIC SLACK ADJUSTER

1. Check the free-stroke.

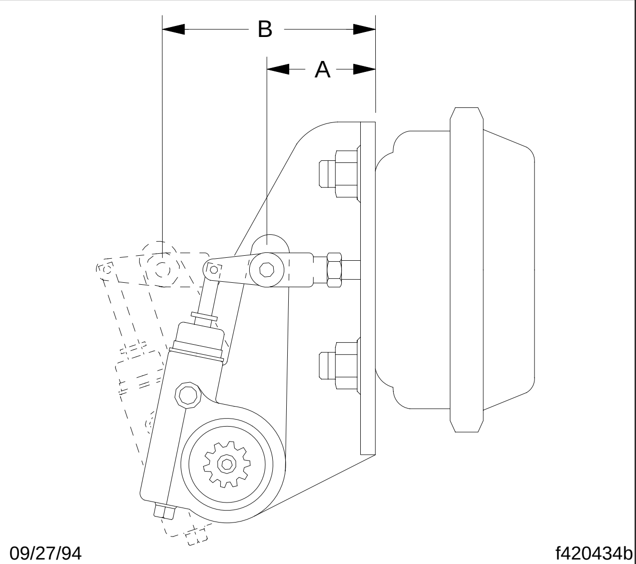
    1.1 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.

    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.



A. Brakes Released
B. Brakes Applied

Fig. 1, Measure the Distance Between A and B

    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

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**.

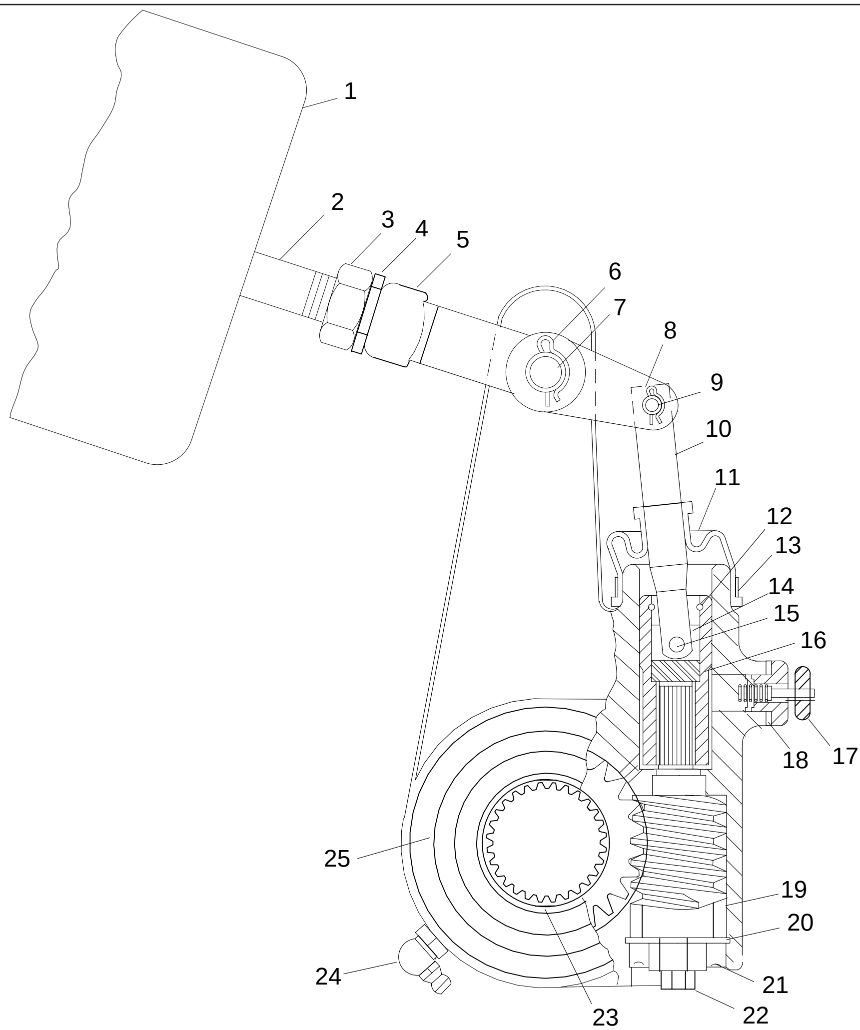
    2.2 Build air pressure to 100 psi (689 kPa). Shut down the engine. Fully apply the brakes, then measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**. The difference between the measurements is the brake chamber stroke.

    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

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



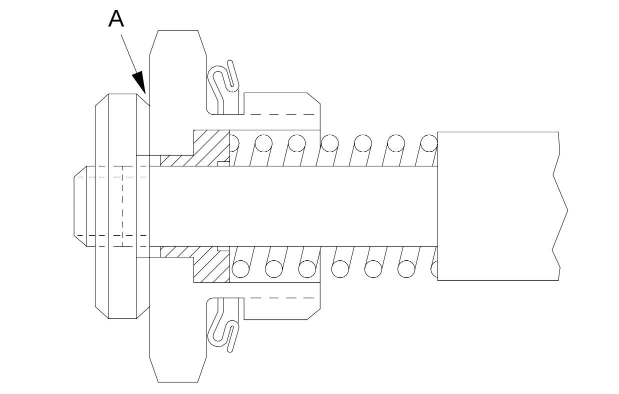
1. Brake Air Chamber	10. Actuator Rod	19. Worm
2. Brake Chamber Push Rod	11. Boot	20. Worm Retaining Snap Ring
3. Clevis Jam Nut	12. Piston Retaining Ring	21. Worm Grease
4. Collar	13. Boot Retaining Clamp	22. Manual (Worm) Adjusting Nut End
5. Clevis	14. Actuator Piston	23. Gear
7. Clevis Pin (large)	15. Roller (Pin)	24. Grease Fitting
6. Cotter Pin (large)	16. Actuator (Adjusting Screw)	25. Gear Retainer/Seal
8. Cotter Pin (small)	17. Pull-Pawl Assembly	
9. Clevis Pin (small)	18. Gasket	

Fig. 2, Automatic Slack Adjuster (sectional view)

2.4 Turn the adjusting nut 1/8 turn, as shown in **Fig. 4**. Measure the stroke again, and adjust until correct.

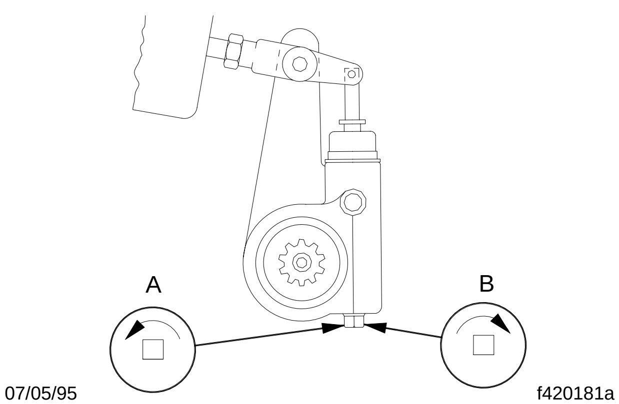
CAUTION

Don’t make the adjusted chamber stroke too short. The free-stroke must not be less than 5/8



A. Insert screw driver here.

Fig. 3, Pull-Pawl Assembly (sectional view)



A. Shorten the stroke.
B. Lengthen the stroke.

Fig. 4, Turn the Adjusting Nut

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 150.

2.5 If necessary, replace the slack adjuster. For instructions, see Section 42.07.

2.6 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).

HALDEX AUTOMATIC SLACK ADJUSTER

1. Turn the adjusting hexnut clockwise until the brake lining meets the brake drum, then back off counterclockwise 3/4 turn. See Fig. 5. There will be a ratcheting sound.

2. Measure the distance from the bottom of the air chamber to the far side of the clevis-pin hole. See Fig. 6. Record the exact distance as measurement A. Apply and hold a 80 psi (551 kPa) brake application. Measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. See Fig. 6. Record the exact distance as measurement B. Subtract measurement A from measurement B to determine the applied stroke. Compare this value to the value in Table 2.

   If the stroke varies or remains greater than the specified range, check the brake components. For instructions, see Subject 150. If necessary, replace the slack adjuster. For instructions, see Section 42.07.

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 *, 30	Less than 2 (51)
36	Less than 2-1/4 (57)

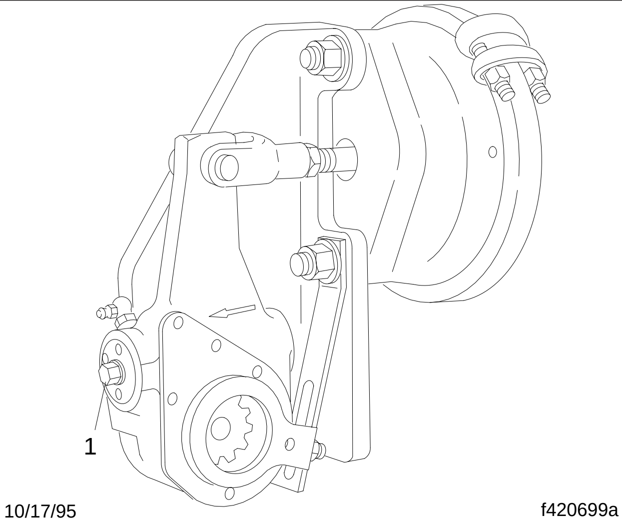
* Long Stroke

Table 1, Maximum Adjusted Brake Chamber Stroke

Maximum Adjusted Brake Chamber Strokes With Haldex Automatic Slack Adjusters	
Chamber Size	**Stroke inch (mm)**
16	3/4 to 1-3/4 (19 to 44)
20	1 to 1-/34 (25 to 44)
24	1 to 1-7/8 (25 to 48)
30	1-1/2 to 2 (38 to 51)

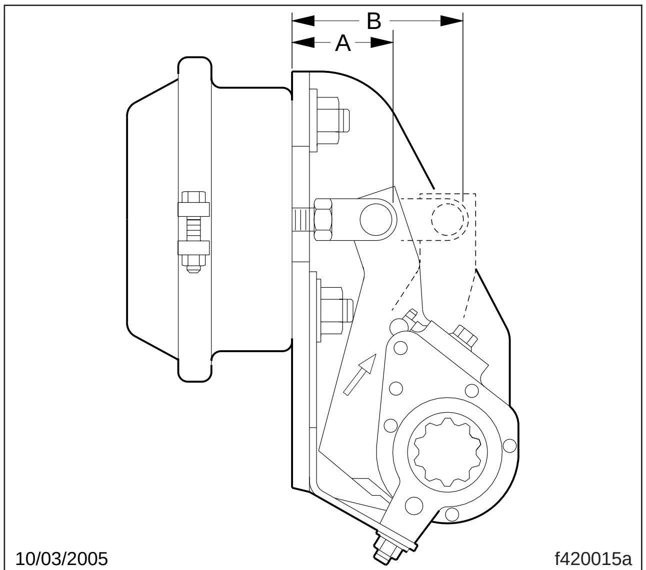
Table 2, Maximum Adjusted Brake Chamber Strokes With Haldex Automatic Slack Adjusters

Brake Adjustment



1. Adjusting Hexnut

Fig. 5, Turn the Adjusting Hexnut Clockwise



A. Air Chamber to Clevis Pin Hole (brakes released)
B. Air Chamber to Clevis Pin Hole (brakes applied)

Fig. 6, Brake Stroke Check, Haldex (SAB) Automatic Slack Adjuster

⚠ WARNING

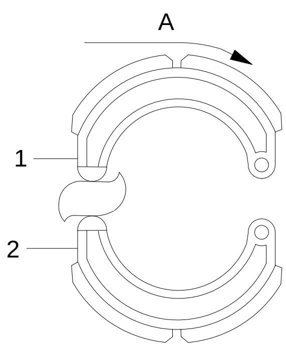
Before starting the procedure below, read the information in Safety Precautions, 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

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**.



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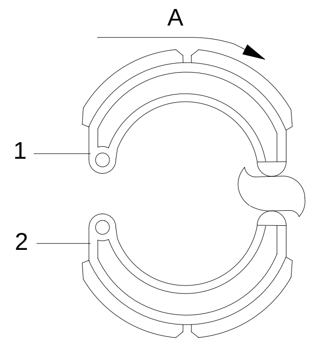
A. Right wheel rotation
1. Primary Shoe
2. Secondary Shoe

Fig. 1, Camshaft Behind Axle



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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

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, see **Subject 150**.
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**.

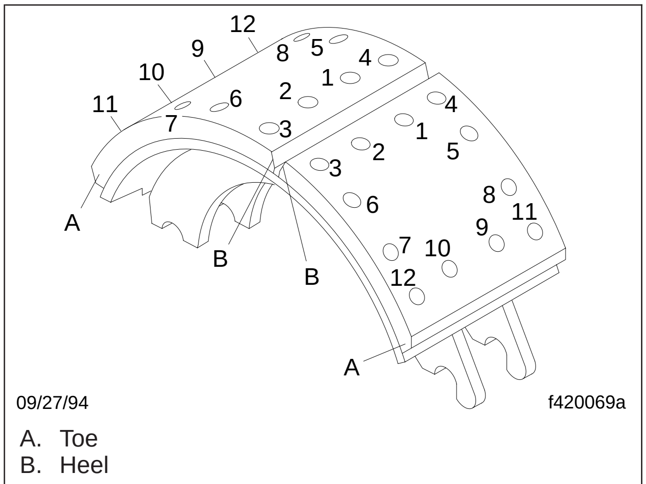


Fig. 3, Rivet or Bolt Attachment Sequence

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.

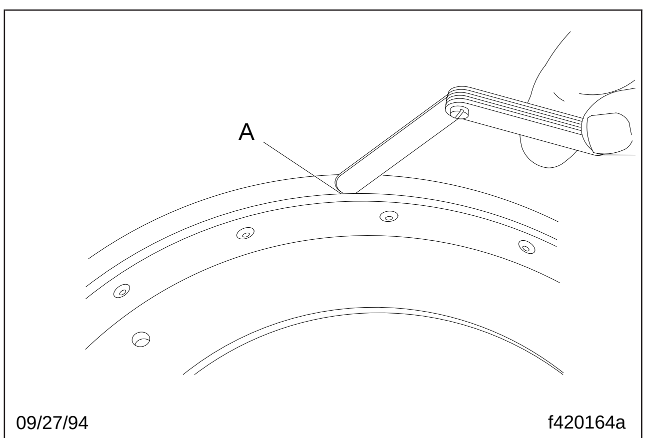


Fig. 4, Insert the Feeler Gauge between the Lining and Shoe Table

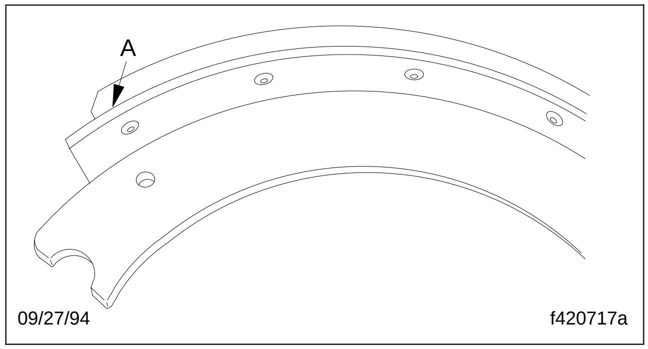


Fig. 5, Area of Feeler Gauge Clearance

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.

REPLACEMENT USING BOLTS

1. Clean the shoe table. For instructions, see **Subject 150**.
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

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, see **Group 33** or **Group 35** in this manual.
2. Disconnect the slack adjuster from the push rod clevis. For instructions, see **Section 42.07**, or 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, see **Section 42.07** in this manual.

CAUTION

Don't hammer on the slack adjuster to remove it. Damage to the adjuster or camshaft spline may result.

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, see **Section 42.07**.

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 conditionsexist.
12. Remove and inspect the old bushing and the grease seal.

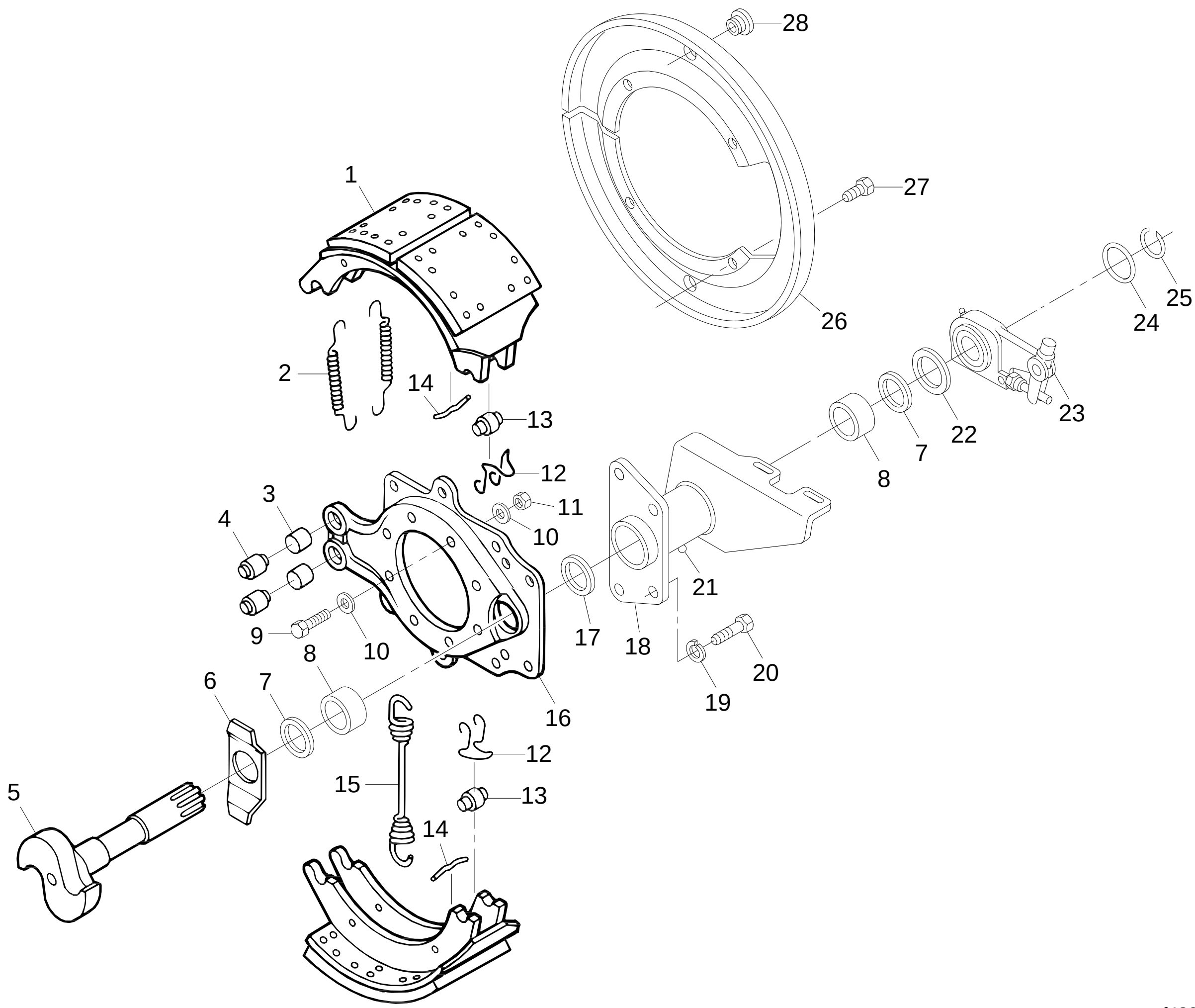
    12.1 Check the camshaft bushing for wear. The inner surface must be smooth; if rough or abrasive, replace the bushing.

    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.

Brake Components Disassembly and Inspection, Cleaning, and Assembly



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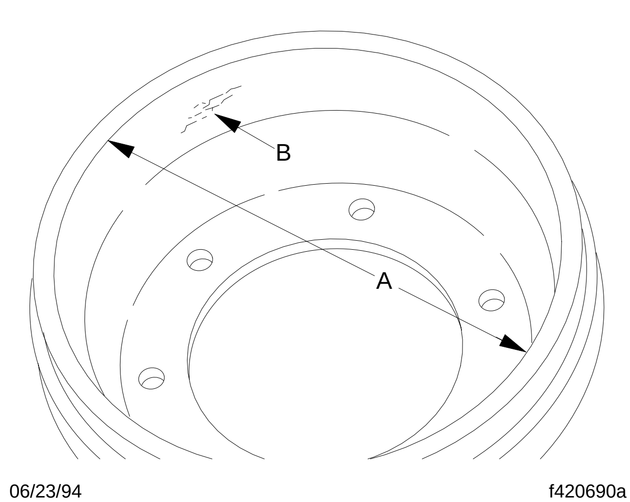
NOTE: 16–1/2 inch "Q" series and all "Q" Plus series shown.

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 Washers
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 Series Brakes

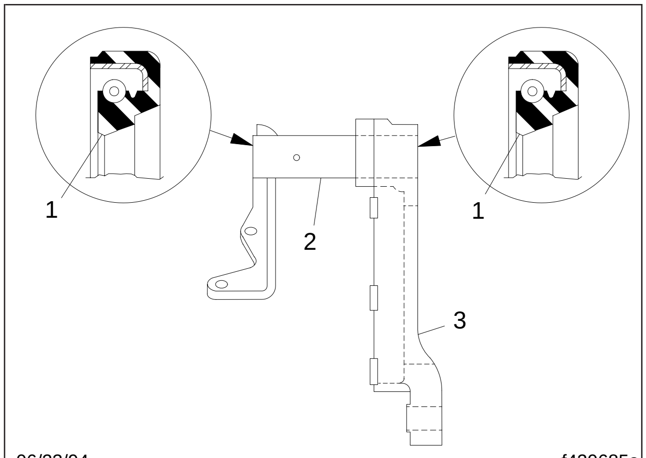
Brake Components Disassembly and Inspection, Cleaning, and Assembly



A. Check for diameter and for out-of-round.
B. Check for cracks, heat checks, glazing, and grooves.

Fig. 2, Check the Drums

15. If equipped, remove the four capscrews that attach the dust shield to the spider; remove the dust shield.



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. Inspect the spider and parts for damage; replace as needed.
    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

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

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 accumula-

Brake Components Disassembly and Inspection, Cleaning, and Assembly

tion. Wipe the interior of the drums with a greaseless solvent to remove lining dust.

3. Thoroughly clean all remaining brake parts with a suitable shop solvent. Wipe dry with a clean, lint-free cloth, or use low-pressure, filtered and compressed air.

Assembly

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 to the torque provided in **Specifications, 400**.

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 to the torque provided in **Specifications, 400**.

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 and locknuts. Tighten the nuts to the torque provided in **Specifications, 400**.

   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 to the torque provided in **Specifications, 400**.

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 (Meritor 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. Adjust the slack adjuster. For instructions, see **Section 42.07** or the manufacturer’s service information.

8. Install the brake shoes. For instructions, see **Subject 110**.

Specifications

Torque Values				
Description	Grade	Size	Torque	
			lbf·in (N·cm)	lbf·ft (N·m)
Brake Shoe Lining Nuts	—	3/8	—	24–31 (18–23)
		1/4	80–100 (900–1120)	—
Dust Shield Capscrews	5	3/8–16	—	25–35 (34–47)
	8			35–50 (47–68)
Spider Mounting Bolts: Customary Thread Capscrew	8	1/2–13	—	60–80 (81–108)
Hexhead Capscrew		5/8–11		130–160 (176–217)
Flanged Hexhead Capscrew		5/8–11		160–200 (217–271)
Midland Brake Chamber Mounting-Stud Locknuts (chamber size in^2)	8		—	
12		7/16–14 stud		38–43 (52–58)
16		7/16–14 stud		38–43 (52–58)
16		1/2–13 stud		81–88 (60–65)
16		1/2–20 stud		65–70 (88–95)
20		5/8–11 stud		120–130 (162–176)
24		5 /8–11 stud		120–130 (162–176)
MGM Brake Chamber Mounting-Stud Locknuts (chamber size in^2)	8		—	
16		7/16–14 stud		35–40 (47–54)
20		5 /8–11 stud		100–115 (136–156)
24		5 /8–11 stud		100–115 (136–156)
Brake Chamber Bracket-to-Spider Capscrews	8	1/2–13	—	60–80 (81–108)
		5/8–11		142–196 (105–145)

Table 1, Torque Values

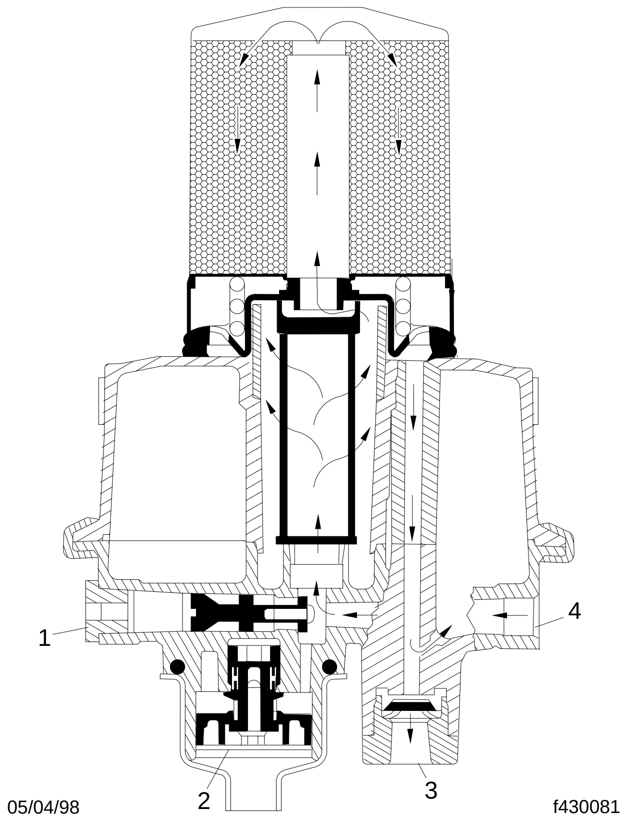
General Information

The function of the air dryer is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system.

The air dryer consists of a replaceable desiccant cartridge, coalescent filter, purge valve, check valve, and Turbo-Saver™ Valve. The desiccant cartridge, coalescent filter, and purge valve housing assembly, which includes the heater and thermostat assembly, can be serviced without removing the air dryer from the vehicle.

Principles of Operation

DRYING CYCLE



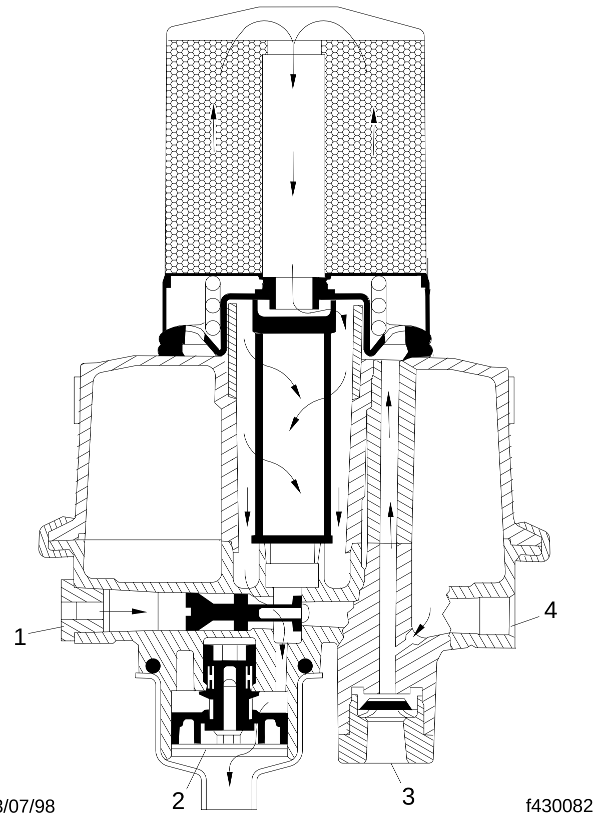
1. Control Port
2. Purge Valve
3. Outlet Port
4. Inlet Port

Fig. 1, Drying Cycle

Contaminated, wet compressed air at up to 160°F (71°C) coming from the air compressor enters the air dryer through the inlet port. See **Fig. 1**. The Turbo-Saver Valve, in the closed position, then forces the compressed air through the coalescent filter, where water droplets and contaminants are removed from the air stream.

The compressed air then moves through the desiccant cartridge bed and the remaining moisture is removed. Some of the clean, dry compressed air is diverted to the purge area to dry the desiccant bed. The balance flows through the outlet port into the vehicle air system.

PURGE CYCLE



1. Control Port
2. Purge Valve
3. Outlet Port
4. Inlet Port

Fig. 2, Purging Cycle

When the reservoir reaches the governor cutout pressure, air pressure from the governor unloading port enters the air dryer. See **Fig. 2**. This signal from the governor causes the Turbo-Saver Valve to shift, close and block the inlet, while simultaneously causing the purge valve to open. The sudden opening of the purge valve permits the pressurized air in the coalescent filter sump to flush moisture and contaminants from the housing. Decompressing rapidly, opening of the purge valve also back-flushes the desiccant bed and coalescent filter. Air trapped in the purged reservoir is metered through the purge orifice and allowed to slowly pass over the desiccant bed at a pressure slightly higher than atmospheric. The relatively small volume of air can easily absorb the water previously absorbed by the desiccant bed during the drying cycle. The moist air is then expelled through the purge valve.

Safety Precautions

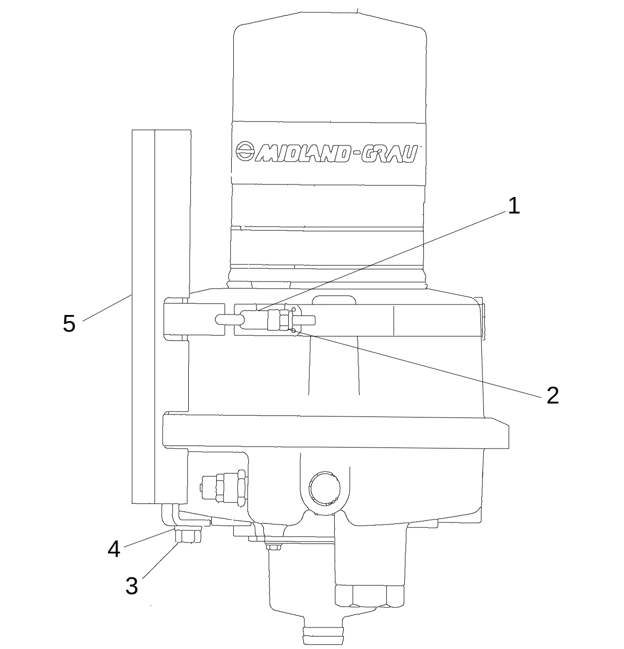
When working on or around air brake systems and components, observe the following precautions.

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.

Air Dryer Removal and Installation

Removal



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1. Mounting Strap
2. Mounting Strap Locknut
3. 3/8-Inch Bolt
4. Lockwasher
5. Mounting Bracket

Fig. 1, Air Dryer Removal and Installation

WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Park the vehicle on a level surface and chock the tires. Drain the air reservoirs.
2. Remove the air dryer.
   - 2.1 Mark and disconnect the air lines from the air dryer, and note the position of dryer ports relative to the vehicle.
   - 2.2 Unplug the vehicle wiring harness from the heater/thermostat assembly.
   - 2.3 Loosen the mounting strap locknut. See **Fig. 1**.
   - 2.4 Remove the 3/8-inch bolt from the bottom of the dryer.
   - 2.5 Remove the air dryer from the mounting bracket.

Installation

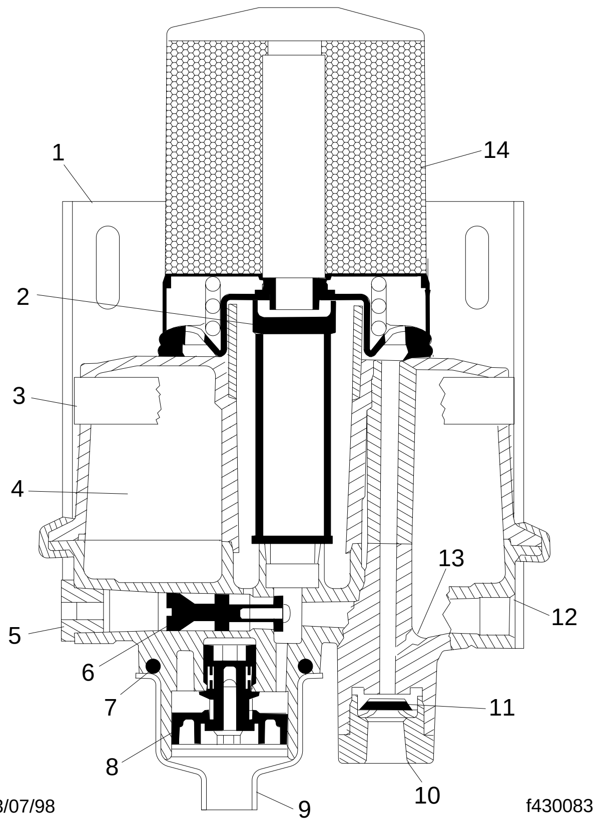
WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Position the air dryer through the mounting strap and bracket as noted in "Removal."
2. Insert the 3/8-inch bolt and lockwasher into the bottom of the dryer and tighten the bolt 20 to 25 lbf·ft (27 to 34 N·m). See **Fig. 1**.
3. Tighten the air dryer mounting strap locknut 50 lbf·in (565 N·cm).
4. As referenced earlier in "Removal", connect the air lines to their appropriate ports on the air dryer.
5. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector. Plug it into the air dryer connector until the lock tab snaps in place.
6. Test the air dryer following instructions in **Subject 170**.
7. Remove the chocks from the tires.

Air Dryer Disassembly, Inspection and Cleaning, and Assembly

Disassembly



1. Mounting Bracket
2. Coalescent Filter
3. Mounting Strap
4. Internal Purge Volume
5. Control Port
6. Turbo-Saver™ Valve
7. Heater
8. Purge Valve Assembly
9. Purge Exhaust Cover
10. Outlet Port
11. Outlet Check Valve
12. Inlet Port
13. Purge Orifice
14. Desiccant Cartridge

Fig. 1, Midland Air Dryer (sectional view)

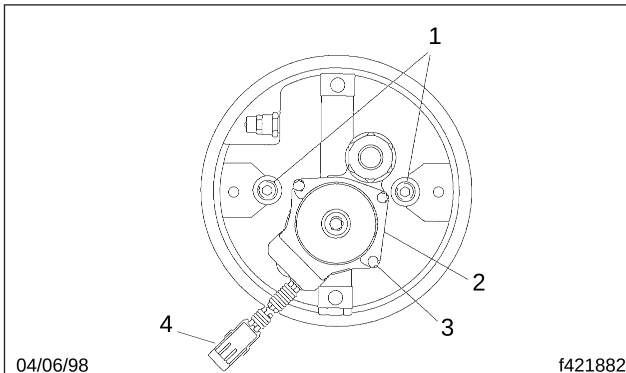
WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Shut down the engine, apply the parking brake and chock the tires.
2. Drain the air reservoirs.

IMPORTANT: Do not proceed with disassembly until the dryer has completed the purge cycle and the compressor is fully unloaded.

3. Remove the air dryer. See **Fig. 1**. For instructions, see **Subject 110**.
4. Using a strap wrench, loosen the desiccant cartridge at the base of the cartridge and remove it by hand.
5. Remove the coalescent filter.
6. Remove and discard the O-ring on the threaded cartridge mounting nipple.
7. Remove the three screws holding the plastic purge shield in place. See **Fig. 2**. Discard the screws and the old purge shield.



1. 3/8-Inch Pipe Plugs
2. Purge Shield/Retainer
3. Retaining Screw
4. Heater/Thermostat Harness

Fig. 2, Air Dryer (bottom view)

8. Remove the pressure relief valve assembly with a 11/16-inch deep socket or box end wrench.
9. Using a 5/16-inch allen wrench, remove the two 3/8-inch pipe plugs from the bottom side of the lower housing . See **Fig. 2**. Drain any water or other contaminants from the unit.

Inspection and Cleaning

1. Inspect the bottom of the coalescent filter cavity for contaminants or debris. The presence of solid contaminants or debris indicates the purge valve, Turbo-Saver™ Valve and outlet check valve should also be serviced and/or replaced.

Air Dryer Disassembly, Inspection and Cleaning, and Assembly

2. Clean any debris and/or contaminants from the interior of the air dryer.

Assembly

1. Install a new pressure relief valve. Tighten the valve 12 to 16 lbf·ft (16 to 22 N·m). If dry sealant is not present on the pipe threads, apply pipe sealant.

IMPORTANT: When installing the pressure relief valve, do not remove or damage the sponge rubber sleeve on the valve body. The sleeve is necessary to protect the valve from contamination.

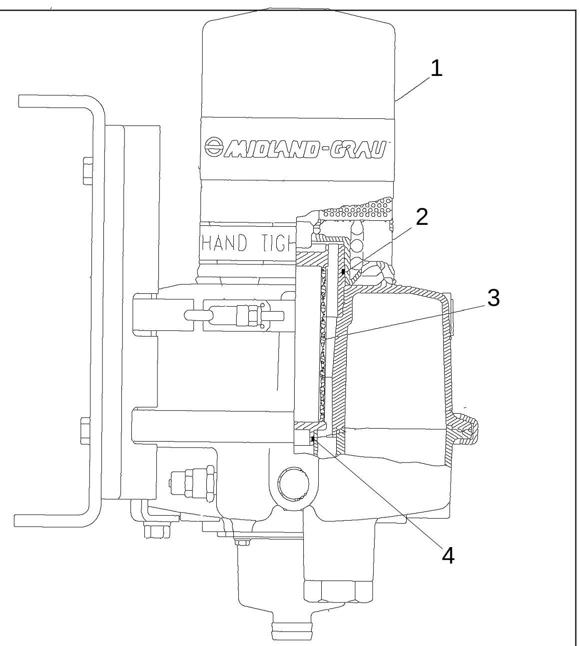
2. Position the heater in the recessed area in the bottom housing and install the new plastic purge shield and metal shield retainer with three new screws. Tighten each screw 30 to 50 lbf·in (339 to 565 N·cm).
3. Apply sealant to the 3/8-inch pipe plugs and install them in the bottom housing. Using a 5/16-inch allen wrench, tighten the screws 10 to 15 lbf·ft (14 to 20 N·m).
4. Install a small O-ring in the groove on the neck of the new coalescent filter. Apply a light coat of lubricant to the O-ring and insert the coalescent filter into the center bore of the upper housing. The filter must be centered in the cavity and the top of the filter must not extend above the cartridge mounting nipple.
5. Install the large O-ring in the groove on the cartridge mounting nipple. Apply a light coat of lubricant to the O-ring.
6. Apply a light coat of thread lubrication to the threads on the cartridge mounting nipple.
7. Apply a light coat of lubricant to the gasket on the desiccant cartridge and install the cartridge on the air dryer. Hand tighten the cartridge 1/2 to 1 full turn after the gasket makes contact.
8. Install the air dryer. For instructions, see **Subject 110**.

Desiccant Cartridge and Coalescent Filter Replacement

Replacement

WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.



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1. Desiccant Cartridge
2. O-Ring
3. Coalescent Filter
4. O-Ring

Fig. 1, Air Dryer (sectional view)

1. Park the vehicle, shut down the engine and chock the tires.
2. Drain the vehicle air reservoirs.
3. Using a strap wrench, loosen the desiccant cartridge at the base of the cartridge. Spin the cartridge off by hand and discard it. See **Fig. 1**.
4. Remove the O-ring from the threaded neck and discard it.
5. Remove the coalescent filter and discard it.
6. Install a new small O-ring on the bottom of the coalescent filter in the O-ring groove.
7. Insert the coalescent filter with the O-ring end going into the air dryer opening first. The "X" section of the coalescent filter will then be facing out.
8. Install the new medium size O-ring over the threaded neck of the desiccant cartridge.
9. Screw on the desiccant cartridge until resistance is detected. Then, tighten the cartridge 1/4 to 3/4 of a turn by hand.
10. Perform the operational tests in **Subject 170**.
11. Remove the chocks from the tires.

Turbo-Saver Valve Replacement

WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Shut down the engine, apply the parking brake, and chock the tires. Drain the air reservoirs.
2. Loosen the desiccant cartridge with a strap wrench at the base of the cartridge and spin off my hand.
3. Remove the coalescent filter.

NOTE: If necessary, replace the desiccant cartridge and coalescent filter during this procedure.

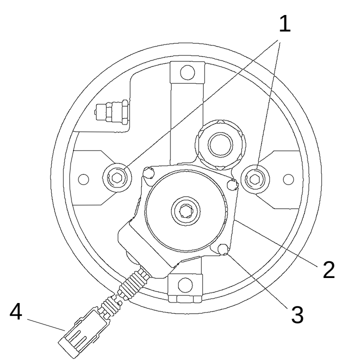
4. Remove the control port end cap and discard the O-ring.
5. Disconnect the inlet and control air lines from the dryer.
6. Using a large flat blade screwdriver in the control port side, and a 1/4-inch hex head screwdriver in the inlet side, loosen and remove the screw. Remove the turbo-saver piston and discard it. Using a long needle nose pliers, remove the valve disc through the coalescent filter housing.
7. Install the small O-ring on the turbo-saver piston body.
8. Using a long needle nose pliers, hold the valve disc in position through the coalescent filter housing.
9. Insert a 1/4-inch hex head thread forming screw through the dryer inlet, and through the valve disc. Lubricate the control port bore.
10. Through the control port opening, insert the new turbo-saver piston body and screw together. Tighten the screw 20 to 28 lbf·in (226 to 316 N·cm).
11. Install a new O-ring on the control port end cap and thread the end cap into the dryer. Tighten the end cap 35 to 50 lbf·ft (47 to 68 N·m).
12. Install the coalescent filter.
13. Thread the desiccant cartridge onto the dryer and hand tighten.
14. Reconnect the inlet and control air line.
15. Perform the operational checks in **Subject 170**.

Replacement

WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Shut down the engine, apply the parking brake, and chock the tires. Drain the air reservoirs.
2. Remove the three hexhead screws and purge valve cover shield and set aside. See **Fig. 1**.



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1. 3/8-Inch Pipe Plug
2. Retainer/Shield
3. Hexhead Screw
4. Heater/Thermostat Heater

Fig. 1, Purge Valve Replacement

3. Remove the large snap ring.
4. Using pliers, pull out the purge valve assembly and discard it.
5. Install the large and small O-rings on the new purge valve assembly.
6. Lubricate the purge piston bore.
7. Insert the new purge valve assembly in the dryer housing.
8. Install the new snap ring.
9. Install the purge valve cover shield and install the three hexhead screws. Tighten the screws 40 to 55 lbf·in (452 to 621 N·cm).
10. Remove the chocks.

Outlet Check Valve Replacement

Replacement

WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Shut down the engine, apply the parking brake, and chock the tires. Drain the air reservoirs.
2. Disconnect the dryer outlet air line.
3. Remove the outlet end cap.
4. Remove the O-ring from the end cap. Discard the seal assembly, spring and O-ring.
5. Install the new O-ring on the outlet end cap.
6. Install the new seal assembly and spring. The seal assembly must be centered.
7. Thread the outlet end cap into the dryer body and tighten it 35 to 50 lbf·ft (68 to 81 N·m).
8. Reconnect the air outlet line.
9. Remove the chocks.

Operational Check

WARNING

Before working on or around air brake systems and components, read Safety Precautions, 100. Failure to do so could result in personal injury.

1. Chock the tires, start the engine, and build the air pressure to 100 psi (689 kPa). Shut down the engine.
2. Check for air leaks at the inlet and the outlet of the dryer.
3. Correct any leakage. If leakage is detected, drain the air system and tighten the fittings.
4. Restart the engine and charge the air system to cut-out pressure. At cut-out pressure the purge valve opens and immediately expels a large volume of air, followed by a slow flow of air lasting about 30 seconds.
5. Check for leakage at the following locations to ensure that the air dryer does not cycle excessively.
   - Compressor unloader mechanism
   - Governor
   - Drain cock and safety valve in the supply reservoir
   - All air connections leading to and from the supply reservoir

For an air dryer air plumbing diagram, see **Specifications, 400**.

Troubleshooting Tables

Problem—Long Purge Cycle (More Than 40 Seconds)

Problem—Long Purge Cycle (More Than 40 Seconds)	
Possible Cause	**Remedy**
The outlet check valve is damaged.	Replace the outlet check valve. See **Subject 160**.
The purge orifice is partially plugged.	Clean the orifice with a wire or drill bit.

Problem—Slow Wet Tank Build-Up

Problem—Slow Wet Tank Build-Up	
Possible Cause	**Remedy**
The filter and/or desiccant is plugged.	Replace the desiccant cartridge and coalescent filter. See **Subject 130**.

Problem—Water Appears in the Wet Tank

Problem—Water Appears in the Wet Tank	
Possible Cause	**Remedy**
The desiccant cartridge is plugged or saturated.	Replace the desiccant cartridge. See **Subject 130**.
There is no purge cycle.	Refer to the table "No Purge Cycle" in this subject.
The purge orifice is blocked.	Clean the purge orifice with a wire or drill bit.

Problem—Relief Valve Opens During Operation

Problem—Relief Valve Opens During Operation	
Possible Cause	**Remedy**
The relief valve is faulty.	Replace the relief valve.
There are restrictions in the air lines.	Check for damaged or crimped air lines between the dryer and wet tank. If necessary, replace the lines.

Problem—Purge Cycle Causes Compressor Cut-In

Problem—Purge Cycle Causes Compressor Cut-In	
Possible Cause	**Remedy**
The purge valve seals are leaking.	Replace the purge valve. See **Subject 150**.
The air line between the governor and the dryer is damaged or oversize.	Replace the air line. For instructions, see **Section 42.02**.

Troubleshooting

Problem—No Purge Cycle

Problem—No Purge Cycle	
Possible Cause	**Remedy**
The governor is damaged.	Disconnect the air line from the governor. Air should come from the governor line when the compressor unloads. If not, repair/replace the governor. For instructions, see **Group 13**.
The air line between the governor and the air dryer is restricted or frozen.	Ensure the air line is clear of debris and/or water (ice).
The purge valve is stuck.	Replace the purge valve. See **Subject 150**.

Problem—Air is Constantly Leaking from the Purge Valve

Problem—Air is Constantly Leaking from the Purge Valve	
Possible Cause	**Remedy**
The purge valve seal is damaged.	Replace the purge valve. See **Subject 150**.
There are dirt particles on the valve seat.	Remove and clean the purge valve. See **Subject 120**.
The purge valve is frozen.	Inspect the heater/thermostat assembly. See the table "Heater is Inoperative."
The governor is faulty.	Disconnect the air line to the purge valve. If the purge air stops and air comes from the governor line, repair or replace the governor. For instructions, see **Group 13**.

Problem—Heater is Inoperative

Problem—Heater is Inoperative	
Possible Cause	**Remedy**
A fuse is blown.	Check the fuse. If it is blown, replace it with an 8 to 10 amp fuse.
Wires are broken or a connection is bad.	Repair or replace the wiring to the heater.
The element or thermostat is damaged.	Replace the heater/thermostat assembly.

Problem—The Heater Stays on Continuously

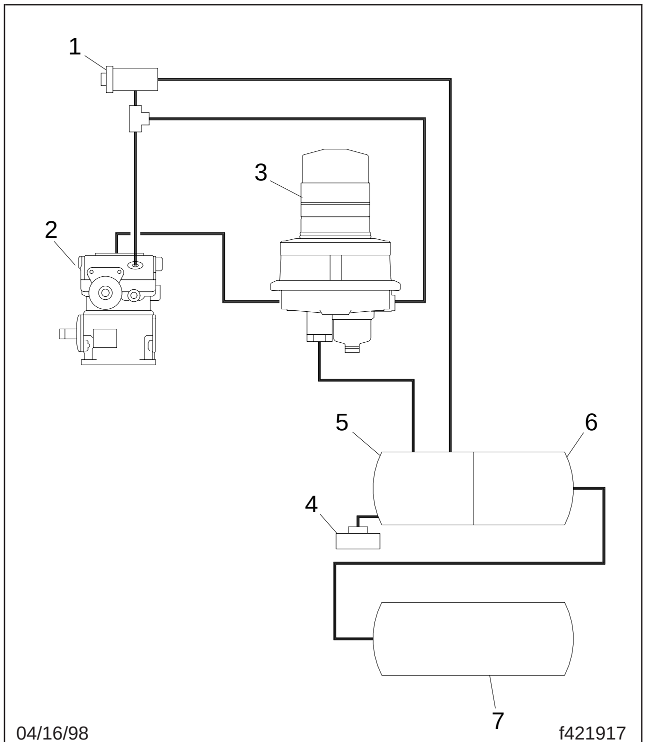
Problem—The Heater Stays on Continuously	
Possible Cause	**Remedy**
Damaged thermostat	Replace the heater assembly.

Specifications

For an air dryer air plumbing diagram, see **Fig. 1**.

Torque Values		
Description	Torque	
	lbf·in (N·cm)	lbf·ft (N·m)
3/8-Inch Mounting Bolt	—	20 to 25 (27 to 35)
Air Dryer Mounting Strap Locknut	50 (565)	—
Pressure Relief Valve	—	12 to 16 (16 to 22)
Purge Shield Retainer Screws	30 to 50 (339 to 565)	—
3/8-Inch Pipe Plugs	—	10 to 15 (14 to 20)
Turbo-Saver™ Piston Body Screw	20 to 28 (226 to 316)	—
Port End Cap	—	35 to 50 (47 to 68)

Table 1, Torque Values



1. Governor
2. Air Compressor
3. Air Dryer
4. Automatic Drain Valve
5. Wet Tank
6. Primary Air Reservoir
7. Secondary Air Reservoir

Fig. 1, Air Dryer Air Plumbing Diagram

General Information

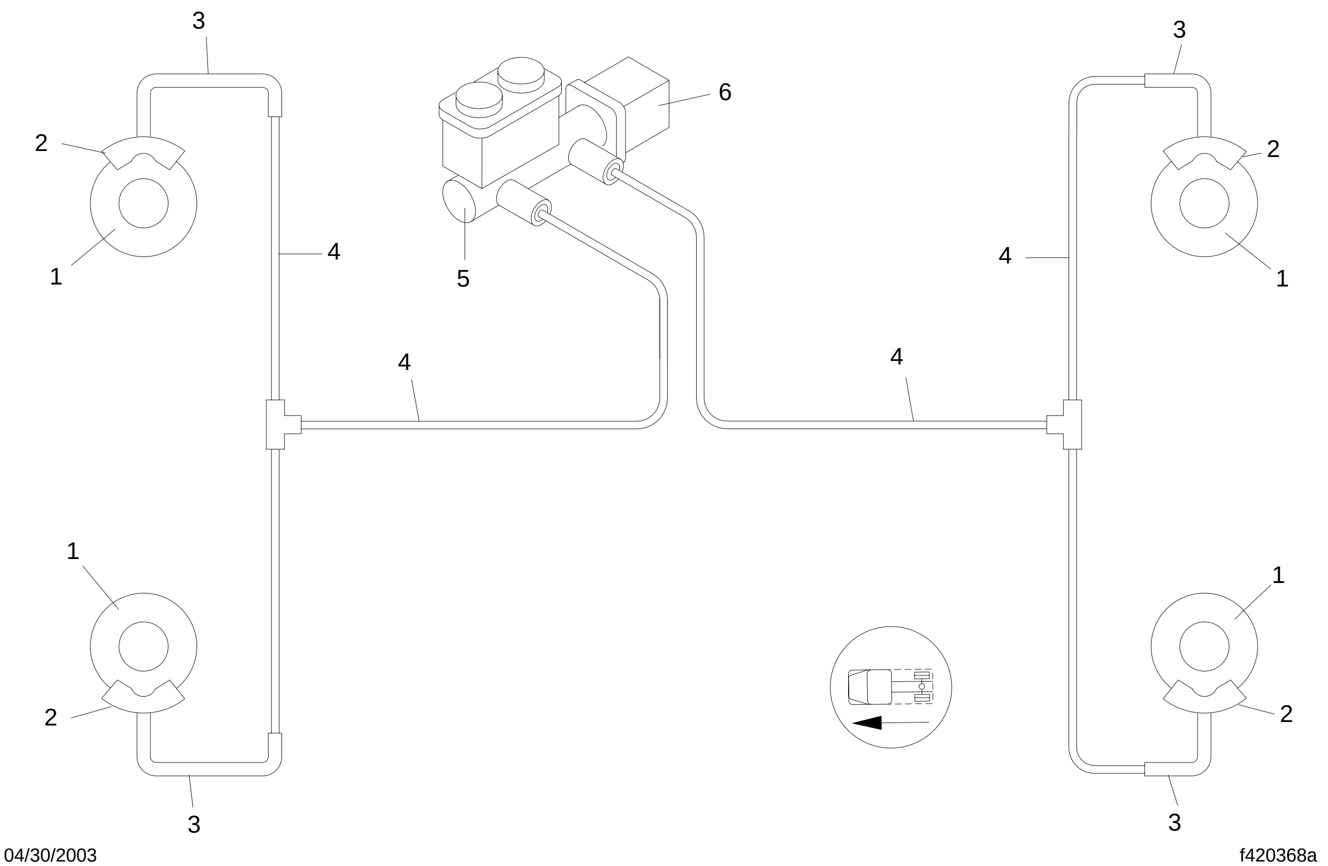
The major parts of the hydraulic disc brake system are:

- power brake booster
- master cylinder
- rigid steel hydraulic lines
- flexible rubber hydraulic lines
- brake caliper assembly at each rotor

See **Fig. 1**.

The hydraulic brake components include two completely separate hydraulic systems that use different and incompatible hydraulic fluids, lines, and seals. **The components of each** *must* **be kept separate from the other.** See **Fig. 2**, which shows the separate systems.

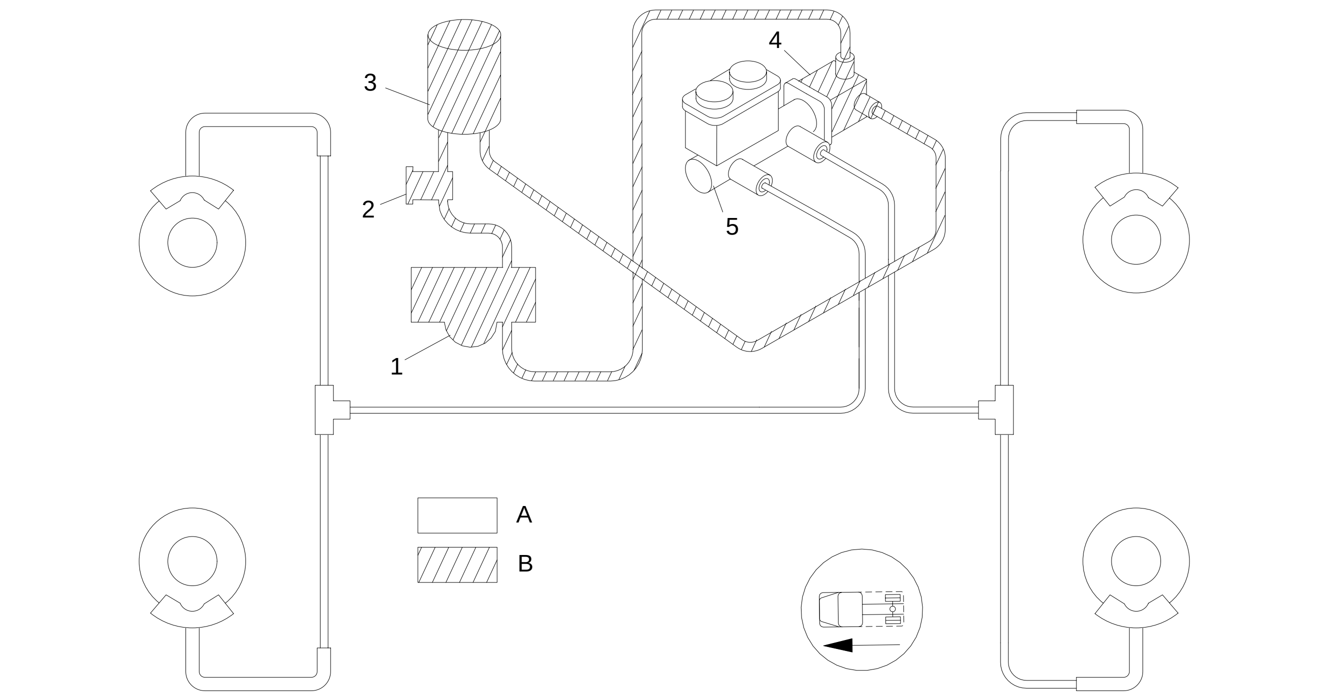
The power brake booster multiplies brake pedal effort to increase power to the brake master cylinder. The power increase comes from pressurized automatic transmission fluid (ATF) supplied by the power steering pump. **Note that the power steering system contains ATF, not "power steering fluid."**



1. Rotor
2. Caliper and Pad Assembly
3. Flexible Brake Line
4. Rigid Brake Line
5. Master Cylinder
6. Power Brake Booster

Fig. 1, Brake System Major Parts

General Information



A. Service Brake System (DOT 3 Brake Fluid)
B. Power Brake Booster and Power Steering System (ATF)

1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Power Brake Booster
5. Brake Master Cylinder

Fig. 2, Brake System Booster

CAUTION

Do not put ATF in the brake master cylinder.

Do not put DOT 3 brake fluid in the power brake booster.

Contaminating either hydraulic system with the wrong fluid causes serious damage.

Power Brake Booster

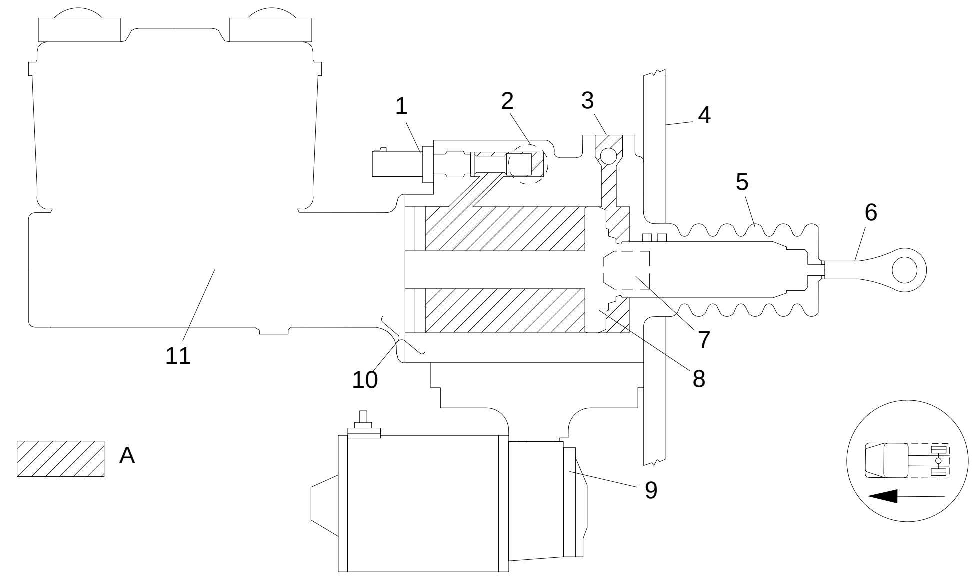
The major parts of the Hydro-Max® II power brake booster mounted on the frontwall are:

- reaction piston
- end-cap assembly
- electric backup pump

The brake master cylinder bolts to the front of the power brake booster.

The brake pedal rod connects the brake pedal to the power piston assembly in the power brake booster. See **Fig. 3**. The reaction piston is inside the power piston. The forward end of the power piston fits through the booster end-cap assembly and rests against the brake master cylinder. The end-cap assembly seals the ATF inside the power brake booster.

The power steering pump sends pressurized ATF to the power brake booster supply port. ATF returns to the power steering reservoir from the power brake booster return port. If the supply of pressurized ATF from the power steering pump to the power brake booster fails, a flow switch starts the electric backup pump to keep the power brakes working.



NOTE: Not all parts are shown.

A. Automatic Transmission Fluid (ATF)

1. Flow Switch
2. Return Port (to steering reservoir)
3. Supply Port (from steering gear)
4. Firewall
5. Rubber Boot
6. Brake Pedal Rod
7. Reaction Piston
8. Power Piston Assembly
9. Electric Backup Pump
10. End-Cap
11. Master Cylinder (DOT 3 brake fluid only)

Fig. 3, Power Brake Booster

Master Cylinder

The brake master cylinder bolts to the power brake booster and functions as a dual supply system. The primary subsystem supplies pressurized DOT 3 brake fluid to the rear brakes, the secondary subsystem supplies it to the front brakes. See **Fig. 4**. For safety, each subsystem is independent so a problem with one will not affect the other.

The master cylinder is mounted on the front of the power brake booster. For locations and names of the major master cylinder components, see **Fig. 5**.

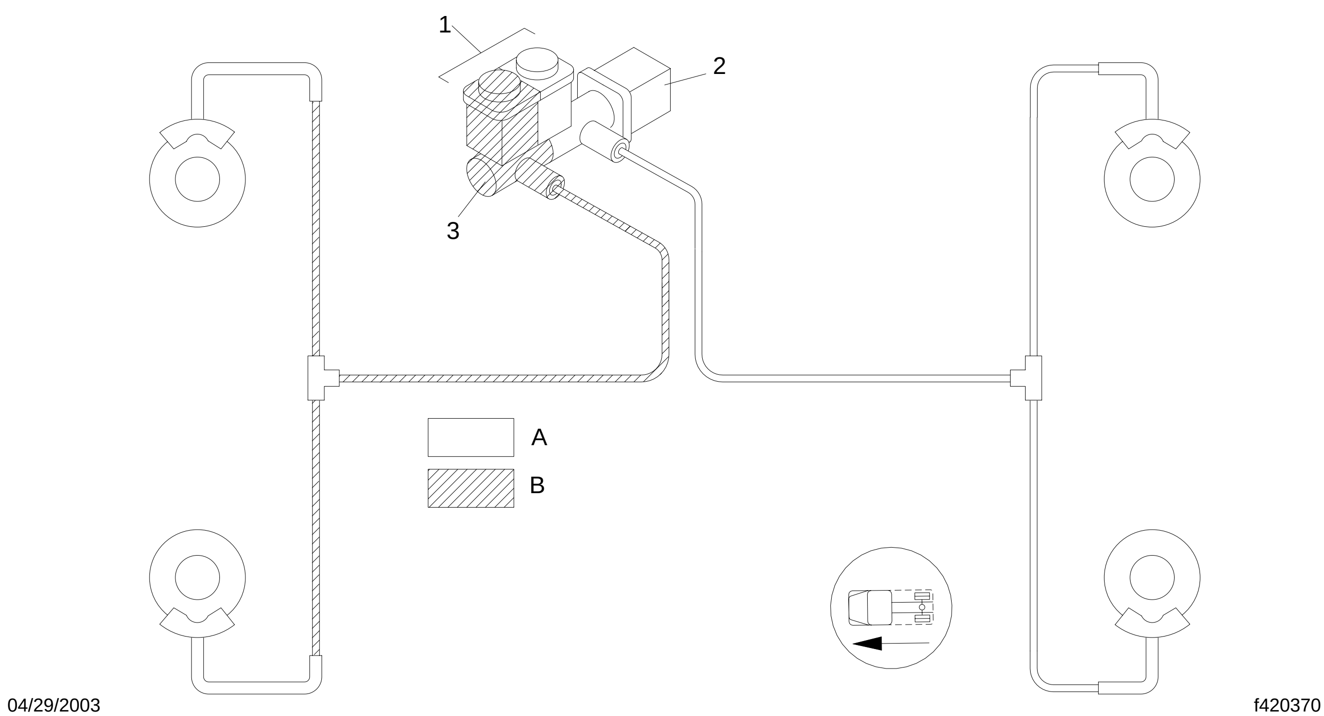
The pressure chambers connect to the front and rear brake caliper assemblies through hydraulic lines and hoses. There is a compensating valve at the bottom of each reservoir section that opens to connect the reservoir to its chamber in the master cylinder. When it is open, the compensation valve allows DOT 3 brake fluid in the reservoir to enter the brake lines to the calipers, to take up for lining wear. When it is closed, the compensation valve allows pressure to build in its subsystem. A pressure differential valve operates a pressure differential switch (not shown), which sets off a dash warning light and buzzer if one of the subsystems does not build pressure.

Non-ABS Brake Monitor Module

The brake monitor module, located behind the instrumentation control unit (ICU) on the driver side of the dash, monitors electrical signals from various sensors (but not ABS) in the service brake system and power brake booster system. If it detects a problem, the module lights the warning light and sounds the buzzer in the dashboard.

The monitor module has nine input terminals and three output terminals, with one ground terminal. See

General Information



A. Rear Brake Lines
B. Front Brake Lines

1. Master Cylinder Reservoir
2. Power Brake Booster (ATF only)
3. Master Cylinder (DOT 3 brake fluid only)

Fig. 4, Dual Supply System

Fig. 6. The output terminals connect to the brake system pressure and warning lights. The input terminals connect to sensors in the brake system that detect improper operation.

See **Table 1** for identification of the output and input terminals on the back of the module, and the circuits to which they are connected.

The monitor module, which operates on 9 to 16 volts DC, actively monitors the hydraulic brake system under any of the following conditions:

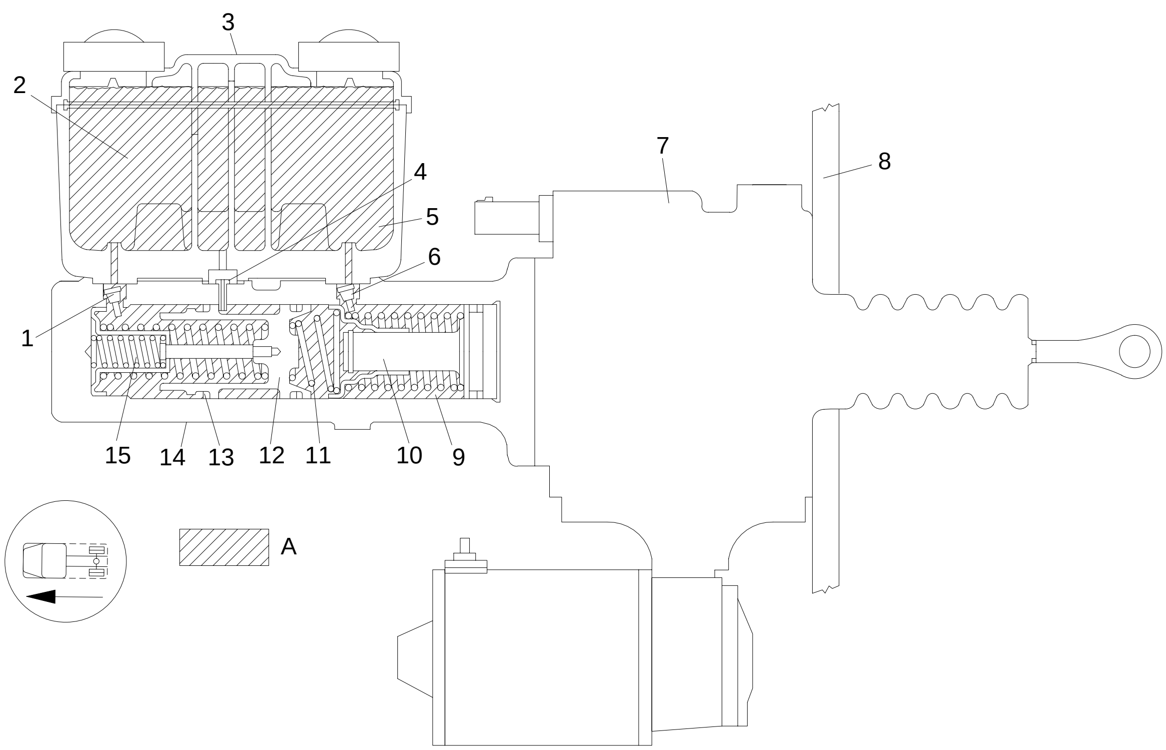
- when the ignition is on;
- when the brake pedal input terminal has power;
- if the ignition is off, but the driver's door is open and the parking brake is not applied.

When the ignition is turned on, the monitor module runs a self-test which lasts from 1 to 3 seconds. The warning light and buzzer come on, then go off if the system is working properly. The module then begins monitoring the hydraulic brake system. If it detects a problem, it turns on the brake warning light and buzzer.

NOTE: The buzzer is controlled by the instrumentation control unit (ICU).

Any of the following things can activate the brake pressure "R" light at output terminal 3.

- Reduced or lost flow of ATF to the power brake booster closes the flow switch on the power brake booster.
- Different pressures between the front and rear brake subsystems close the pressure differential switch.



NOTE: Not all parts are shown.
A. DOT 3 Brake Fluid

1. Secondary Compensating Valve (open)
2. Secondary Reservoir Section
3. DOT 3 Brake Fluid Reservoir
4. Piston Stop
5. Primary Reservoir Section
6. Primary Compensating Valve (open)
7. Power Brake Booster Assembly
8. Frontwall
9. Primary Pressure Chamber
10. Primary Piston/Actuator Assembly
11. Primary Piston Return Spring
12. Secondary Piston/Actuator Assembly
13. Secondary Pressure Chamber
14. Housing
15. Secondary Piston Return Spring

Fig. 5, Master Cylinder

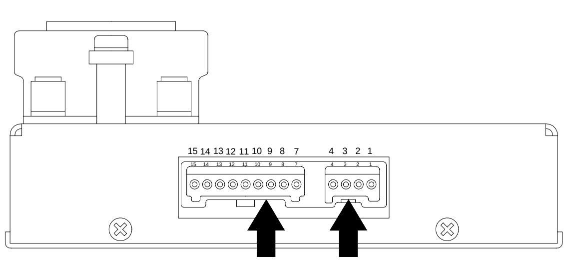


Fig. 6, Monitor Module Terminals

- A drop in master cylinder fluid level closes the switch on the reservoir.
- Too much electrical resistance in the backup pump motor. This is often caused by a bad ground.
- No power to the backup pump at startup.

  See **Table 2** for information about what activates the input terminals.

General Information

Monitor Module Terminal Identification		
Terminal Number	Function	Circuit Number
1	Not Used	—
2	Not Used	—
3	Light "R" (Brake System Pressure) Output	388H
4	Ground	GND
7	Ignition Input	81C
8	Not Used	—
9	Relay	388F
10	Not Used	—
11	Pressure Differential Switch Input	388A
12	Brake Pedal Input	388L
13	Backup Pump Motor	388C
14	Fluid Level Input	388B
15	Flow Switch Input	388G

Table 1, Monitor Module Terminal Identification

Applying the Brakes

Pushing the brake pedal moves the brake pedal rod against the actuator pin in the power brake booster, moving the reaction piston forward inside the power piston. See **Fig. 7**. This moves the throttle valve, restricting the flow of ATF through the power piston, which increases pressure. The increased ATF pressure pushes the power piston forward through the end-cap assembly and into the master cylinder.

As the primary piston/actuator assembly is pushed forward in the master cylinder, the primary compensating valve closes. This shuts the outlet at the primary reservoir section and raises hydraulic pressure in the primary pressure chamber.

The primary piston/actuator assembly motion also moves the secondary piston/actuator assembly. This closes the secondary compensating valve, pressurizing the secondary pressure chamber.

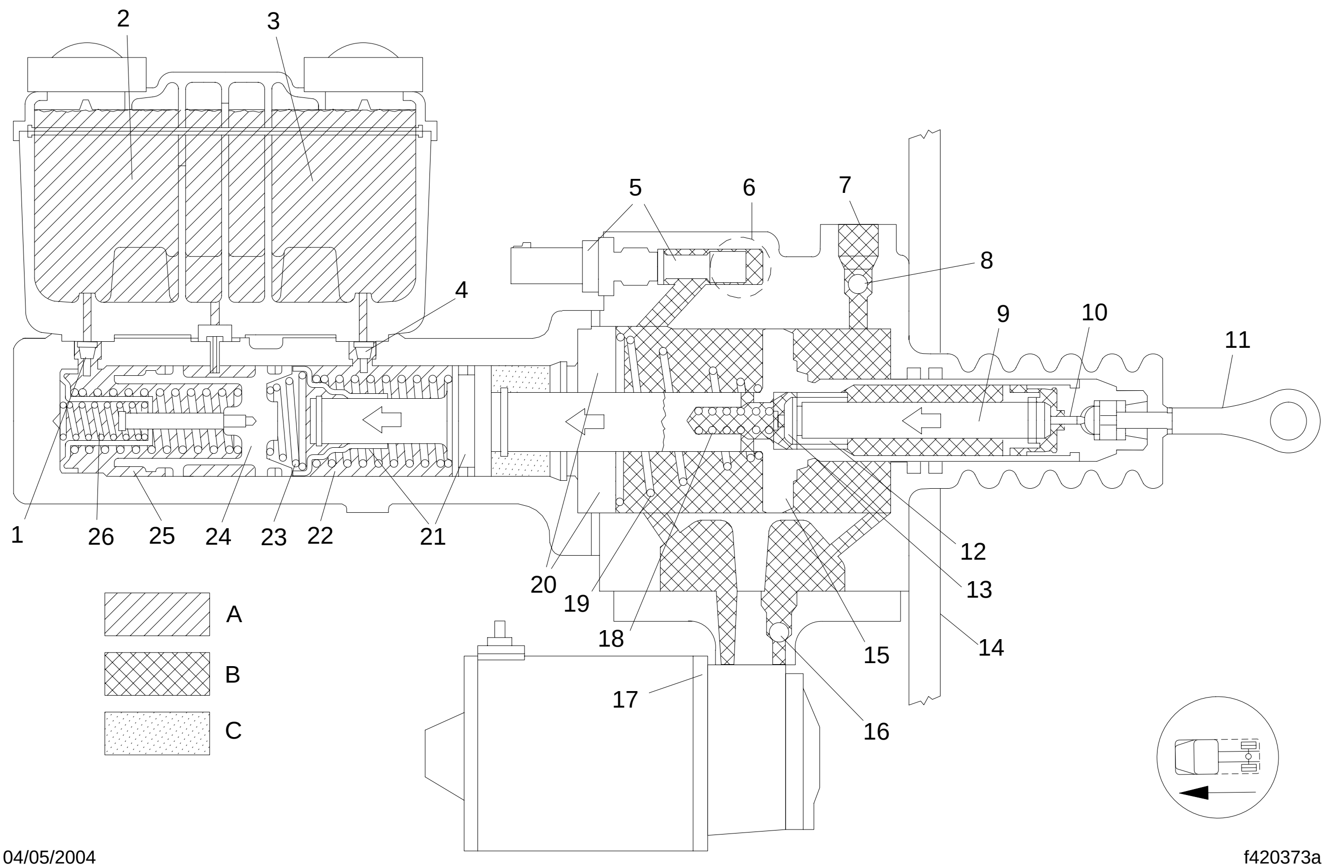
Both primary and secondary pressure chambers have outlets into individual brake lines leading to the brake calipers. The brake lines transmit the pressure through the brake fluid to the calipers, moving the dual piston pads against the rotors. Friction of the pads squeezing the rotors slows the wheel.

If the power brake booster loses pressure from the power steering pump, the flow switch turns on the backup pump. This closes the main supply check valve and opens the backup pump check valve. The electric backup pump then takes over pressurizing the ATF in the power brake booster, providing enough pressure for the master cylinder to operate the brakes.

Releasing the Brakes

When the brake pedal is released, a return spring in the booster opens the throttle valve, reducing ATF pressure in the power brake booster. See **Fig. 7**. The reduced power brake booster pressure allows the master cylinder and piston return springs to move the booster power piston back toward the frontwall side of the power brake booster housing.

In the master cylinder, the return springs push back the primary and secondary pistons, opening their compensating valves. This lowers hydraulic pressure in the master cylinder and the brake lines, allowing the caliper pistons and brake pads to back away from the brake rotors. With the brake pads no longer squeezing the rotors, the brakes let off and the rotors and wheel hubs can turn freely again.



NOTE: Not all parts are shown.

A. DOT 3 Brake Fluid
B. ATF
C. Air Space

1. Secondary Compensating Valve (closed)
2. Secondary Reservoir Section
3. Primary Reservoir Section
4. Primary Compensating Valve (closed)
5. Flow Switch Assembly
6. Return Port
7. Supply Port
8. Supply Check Valve (shown open)
9. Pressure Regulator Assembly
10. Actuator Pin
11. Brake Pedal Rod
12. Reaction Piston
13. Throttle Valve
14. Frontwall
15. Power Piston
16. Backup Pump Check Valve (shown closed)
17. Electric Backup Pump
18. Throttle Valve Return Spring
19. Piston Return Spring
20. End-Cap
21. Primary Piston/Actuator Assembly
22. Primary Pressure Chamber
23. Primary Piston Return Spring
24. Secondary Piston/Actuator Assembly
25. Secondary Pressure Chamber
26. Secondary Piston Return Spring

Fig. 7, Power Brake Booster and Master Cylinder

General Information

Input/Output Terminal Activation			
Terminal Number	Function	Circuit Number	Activated if
7	Ignition Input	81C	The ignition is on.
8	Not Used	—	—
9	Relay Output	388F	The ignition is on or brake pedal is depressed.
10	Not Used	—	—
11	Pressure Differential Switch Input	388A	Pressure difference between front and rear systems becomes more than 483 kPa (70 psi).
12	Brake Pedal Input	388L	Brake pedal depressed.
13	Pump Motor Input	388C	Electrical resistance of backup pump motor too high.
14	Fluid Level Input	388B	Fluid level of master cylinder below 25 percent capacity.
15	Flow Switch Input	388G	No hydraulic flow through power brake booster.

Table 2, Input/Output Terminal Activation

General Safety Precautions

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- **Always reline both sets of brakes on an axle at the same time.**
- **Always replace both rotors/drums on an axle at the same time.**
- **Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.**

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- Disconnect the batteries.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (NIOSH).

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air

Safety Precautions

(HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Bleeding

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

WARNING

The hydraulic brake and power steering systems must be bled whenever any fitting has been loosened or disconnected. Failure to bleed the system, or bleeding it improperly, allows air to remain in it. That decreases the vehicle braking ability and can result in an accident, property damage, and personal injury.

Properly dispose of used hydraulic brake fluid. Used hydraulic brake fluid is almost always contaminated. Reusing it can cause brake system damage, loss of braking, property damage, and serious personal injury.

Automatic transmission fluid (ATF) and brake fluid must not be mixed. Brake fluid may be used only in the master cylinder and brake lines. Use only ATF for the power brake booster. Mixing these two fluids will seriously damage the hydraulic system. ATF will damage the rubber parts of the ABS modulator, master cylinder, and brake calipers, and can cause damage, loss of braking, and serious personal injury.

Always use new DOT 3 brake fluid when bleeding the master cylinder and service brake system. Never reuse brake fluid, and do not use brake fluid containers for any other purpose. DOT 3 brake fluid exposed to the air absorbs water from it, so keep brake fluid containers tightly closed to keep new brake fluid clean and dry. Keeping the master cylinder reservoir properly filled to the bottom of the narrow filler neck helps reduce moisture absorption from the air.

IMPORTANT: Do not let DOT 3 brake fluid touch any painted surfaces. Brake fluid removes paint and may also damage other non-metallic surfaces. Do not let fluid get on brake pads or rotors.

Pressure Bleeding

Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit consisting of a tank, pressure pump and valve, gauge, tubing, and adapter. These are available from a number of manufacturers and include instructions for use. See **Fig. 1**.

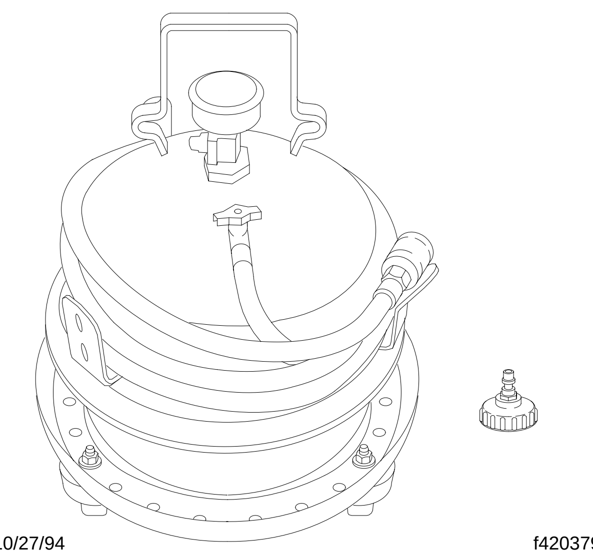


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Fig. 1, Pressure Bleeder Kit

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.

WARNING

Do not exceed 35 psi (241 kPa) at the master cylinder inlet. Exceeding this pressure could rupture the master cylinder assembly, spraying brake fluid around the area. This can result in vehicle paint damage and may cause other damage or personal injury.

2.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.

Hydraulic System Bleeding

2.2 Using the supplied adapter, connect the pressure bleeder to either one of the fill ports on the master cylinder reservoir.

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 tubing fits snugly. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

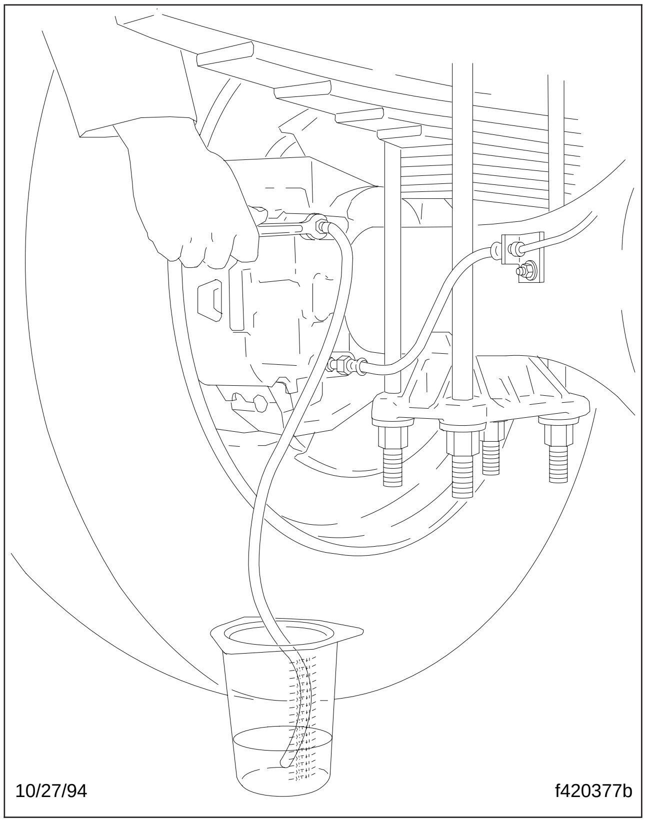


Fig. 2, Bleeding the Connections at the Rear Wheel Calipers First.

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. Firmly tighten the fitting.

3.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

4. Check the level frequently and add DOT 3 brake fluid to the master cylinder reservoir as it is needed. Be careful not to let it run low and suck air into the system as you bleed the brakes at the wheels.

5. Bleed the front wheel brake calipers, right side first.

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 other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

5.2 Loosen the bleeder fitting about 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Firmly tighten the fitting.

5.3 Move to the left front wheel caliper and repeat 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 pumping the brake pedal several times until it feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

8. Remove the chocks from the rear tires.

9. Repeat step 7. Check for operation of the brakes.

Manual Bleeding

If you do not have pressure bleeding equipment, you can use this manual bleeding procedure.

IMPORTANT: Do not let the brake master cylinder fluid level get too low during manual bleeding operations. Keep the master cylinder reservoir filled with new DOT 3 approved brake fluid. Allowing the brake fluid reservoir to empty will force air into the system, the opposite of what needs to be done.

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

2. Be sure the ignition is turned off. The ignition must remain off for the entire bleed procedure.

3. Bleed the master cylinder, as follows.

NOTE: It will not usually be necessary to bleed the master cylinder unless the brake fluid reservoir has run dry or master cylinder components have been replaced.

3.1 Holding a rag underneath the master cylinder to absorb leaking brake fluid, loosen, about one turn, the rear outlet port fitting. See **Fig. 3**.

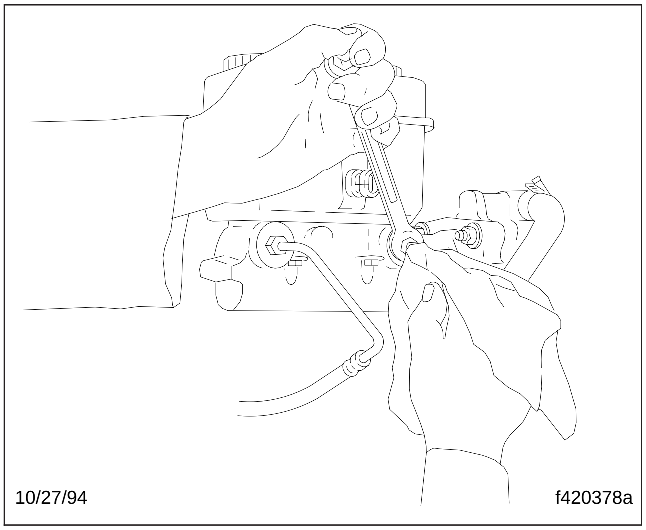


Fig. 3, Loosening the Fitting at the Rear Outlet Port

3.2 Have someone push the brake pedal down slowly to the floor and *hold it there*. Brake fluid and any air in the master cylinder will squirt from the fitting into your shop rag.

3.3 *With the brake pedal held down*, firmly tighten the rear hydraulic line fitting.

IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

3.4 Release the brake pedal.

3.5 Loosen the fitting again and bleed the line until no air escapes from the fitting and the brake pedal feels firm.

3.6 Check the fluid level in the master cylinder reservoir. Add new DOT 3 approved brake fluid as needed to raise the level to the bottoms of the narrow filler necks.

3.7 Using a wrench and holding a rag under it to absorb leaking brake fluid, loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

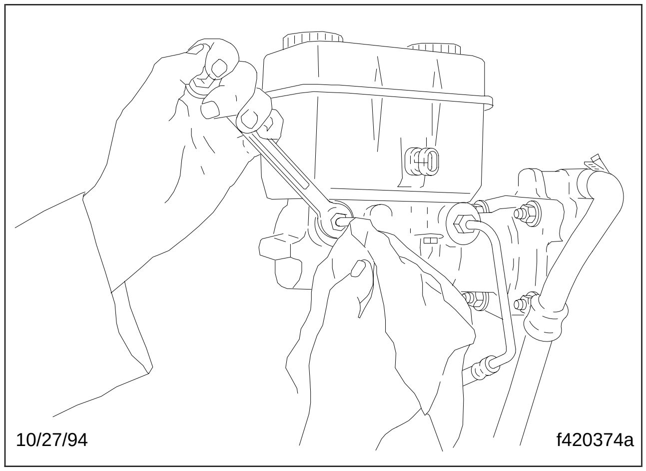


Fig. 4, Loosening the Fitting at the Front Outlet Port

3.8 Repeat steps as required for the front outlet port.

3.9 Check the brake fluid level in the master cylinder reservoir. Add new DOT 3 heavy-duty brake fluid as needed.

4. Bleed the brake lines at the wheel calipers, as follows, starting at the right rear wheel caliper.

4.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of snug-fitting clear tubing to the bleeder fitting. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

4.2 Loosen the bleeder fitting about 3/4-turn.

4.3 Have an assistant slowly push the brake pedal to the floor and hold it down. *Hold the brake pedal down* as you tighten the bleeder fitting.

IMPORTANT: Do not let off the brake pedal until the caliper fitting is tightened. Releasing the pedal before the fitting is tightened will suck air into the system.

4.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat bleeding as required until

Hydraulic System Bleeding

the fluid in the tube is completely free of air bubbles.

4.5 Check the brake fluid level in the reservoir. Add new DOT 3 heavy-duty brake fluid as needed.

4.6 Repeat the steps for bleeding the left rear caliper, the right front caliper, and the left front caliper. When finished, fill the reservoir to the bottoms of the narrow filler necks.

5. Connect the batteries.

WARNING

Do not move the vehicle until you are sure the brakes are working properly.

6. Check the operation of the brakes by pumping the brake pedal several times until it feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

   Remove the chocks from the tires.

Power Brake Booster Bleeding

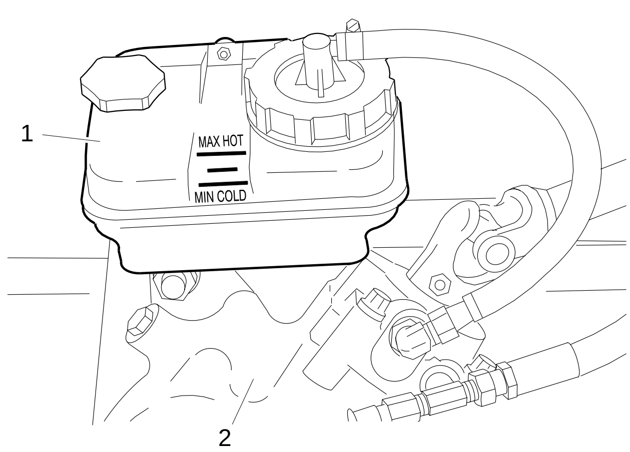
WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

WARNING

The power brake booster uses automatic transmission fluid (ATF), not "brake fluid." Use only clean, approved ATF for the procedure below. Do not use DOT 3 brake fluid. Putting DOT 3 brake fluid in the power brake booster system seriously damages the seals and O-rings in the power brake booster, the power steering pump and the power steering gear. This could result in a loss of power steering and/or braking, which could possibly cause an accident resulting in property damage or serious personal injury.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Check the level of fluid in the power steering reservoir. See **Fig. 1**. Fill it with approved ATF as needed. See **Specifications 400** for approved ATF.



1. Power Steering Reservoir
2. Steering Gear

Fig. 1, ATF Level Check

3. Place the transmission in neutral and crank the starter several times, but do not start the engine.
4. Check the ATF level in the power steering reservoir. Fill, if needed.
5. Crank the starter and check the fluid level again.
6. Check the operation of the brakes, as follows.
   - 6.1 With the key off, push the brake pedal. The dash warning light and buzzer should come on and the backup pump should come on.
   - 6.2 Turn the key to the ON position, but do not start the engine. The dash warning light and buzzer should come on, and the backup pump should start to run.
   - 6.3 Start the engine. Depress the brake pedal. The dash warning light, buzzer, and backup pump should stay off. If they come on, see **Troubleshooting 300** and find the problem.
   - 6.4 Shut down the engine. Check the ATF level in the power steering reservoir. Fill it as needed.
7. Remove the chocks from the rear tires.

Replacing Hydraulic Lines

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

Power Brake Booster System

Pressurized ATF reaches the power brake booster through its connection with the power steering gear. From the power brake booster, the ATF returns into the power steering reservoir. See **Fig. 1**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Replace all power steering hoses that are leaking or showing signs of cracking, softening, or bulging. If a hose is damaged, replace the entire hose; do not attempt to repair it.

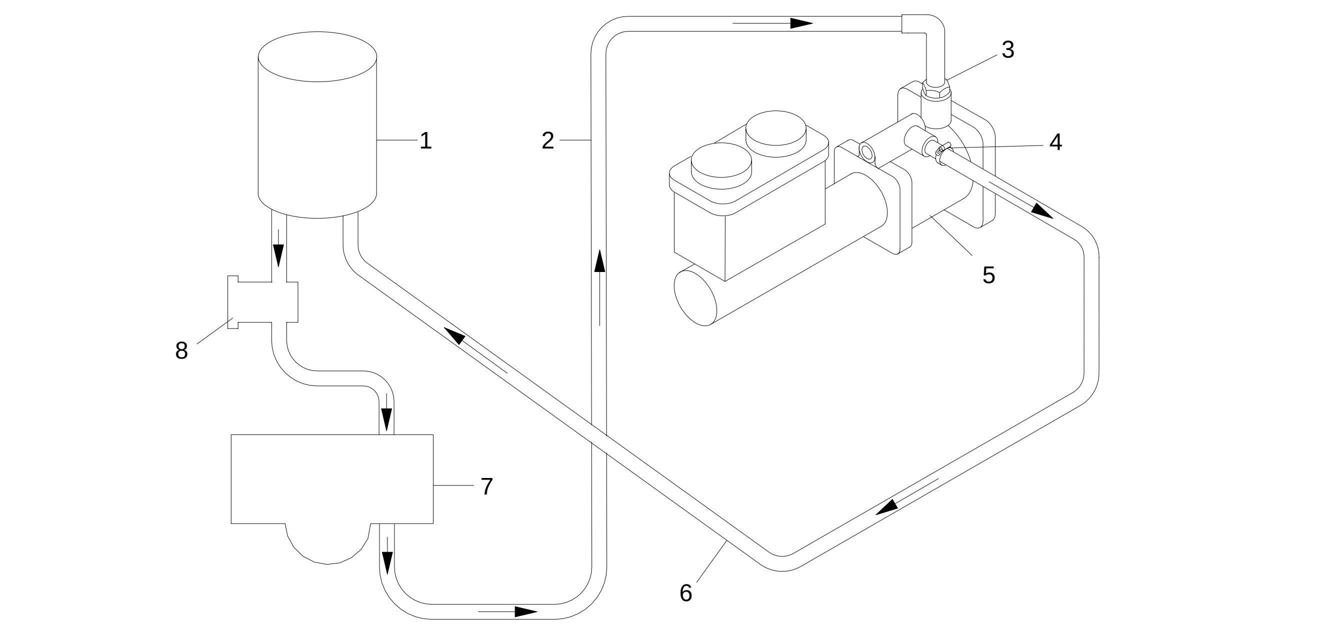
   2.1 Remove all hose clamps and tie straps used for routing the hose.

   2.2 Using a shop towel over the fittings to catch dripping ATF, disconnect both ends of the hose being replaced.

   2.3 Install the new hose.

   If replacing the power brake booster supply hose, tighten the supply port connection 21 ±5 lbf·ft (28 ±6 N·m), and the outlet connection on the power steering gear 41 lbf·ft (56 N·m).

   If replacing the power brake booster return hose, tighten the hose clamps firmly at the



1. Power Steering Reservoir
2. Hydraulic Supply Line
3. Steel Fitting with O-Ring Seal
4. Hose Clamp
5. Power Brake Booster
6. Hydraulic Return Line
7. Power Steering Gear
8. Power Steering Pump

Fig. 1, Power Brake Booster System

Replacing Hydraulic Lines

booster return fitting and the power steering reservoir.

2.4 Install the hose clamps and replace any tie straps removed earlier.

Check the routing of the hose. Make sure it is away from heat sources and moving parts such as the steering and driveline. Make sure there are no kinks or sharp bends in the hose, and that it can not be rubbed or pinched by other parts as they move.

3. Bleed the power brake booster system, following the instructions in **Subject 120**.
4. Remove the chocks from the tires.

Service Brake System

The service brake system has two types of hydraulic brake lines: rigid steel tubing, and flexible rubber hose.

The steel brake lines are 1/4-inch o.d. double-walled tubing, and run from the master cylinder to points on the chassis near each wheel. The rubber brake hoses are 1/8-inch i.d. low-expansion rubber; they connect the end of each rigid line to the caliper assembly at each wheel.

IMPORTANT: Replace lines or hoses only with lines or hoses approved for use in high-pressure brake fluid applications.

Do not attempt to repair brake lines or hoses. Faulty lines or hoses must be replaced.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Locate the leak in the brake line. Determine the length and configuration (if a steel line) of the section involved.
3. If necessary, remove any brackets that hold 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 end of the leaking brake line. Disconnect the line.

   Plug both ends of the connection. Repeat at the connection on the other end of the leaking brake line, and remove it from the vehicle.
5. Remove the plugs installed earlier. Install the new section of brake line and tighten the connections.
6. Install any brackets that were removed.
7. Bleed the brake system, following the procedure in **Subject 110**.
8. Remove the chocks from the rear tires.

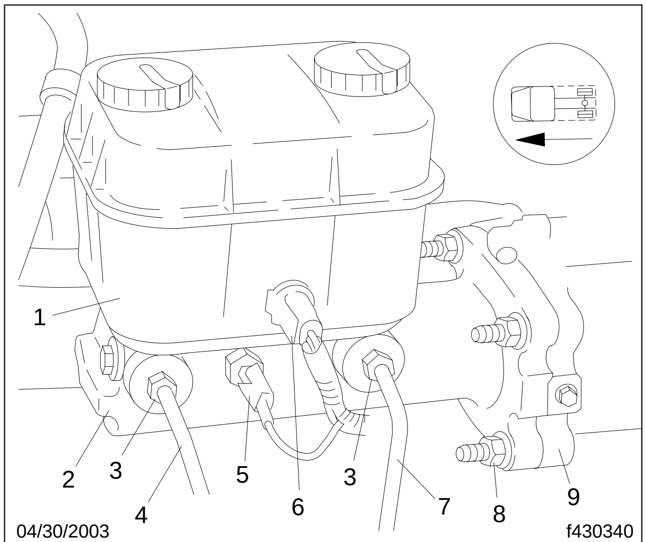
Master Cylinder Removal and Installation

Removal

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the wires from the pressure differential switch on the master cylinder body and the fluid level sensor on the reservoir. See **Fig. 1**.



1. Reservoir
2. Master Cylinder Housing
3. Brake Line Tube Nuts
4. Secondary Subsystem Brake Line
5. Pressure Differential Switch
6. Fluid Level Sensor
7. Primary Subsystem Brake Line
8. Flanged Hexnut
9. Power Brake Booster Mounting Flange

Fig. 1, Master Cylinder Assembly

CAUTION

Do not let the brake fluid get on any painted surface; it can damage the paint. Wrap a rag around the fitting you are working on, or put a container underneath it to catch any fluid leaking as it is disconnected.

3. Disconnect the brake lines from the outlet ports of the master cylinder. See **Fig. 2**. Plug the brake lines to prevent contamination and leakage.

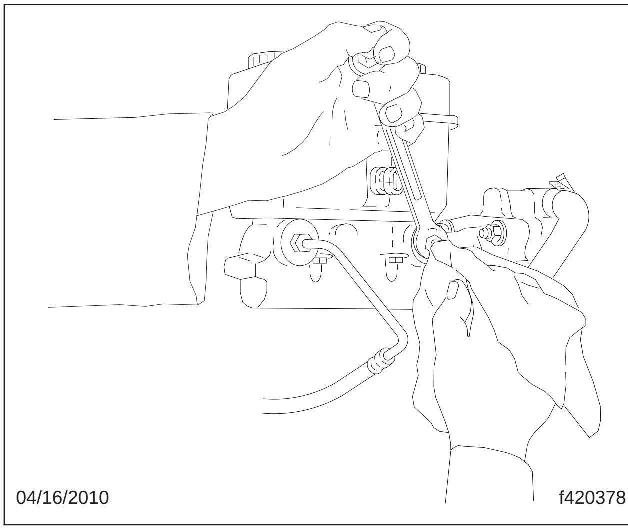


Fig. 2, Removing the Brake Lines

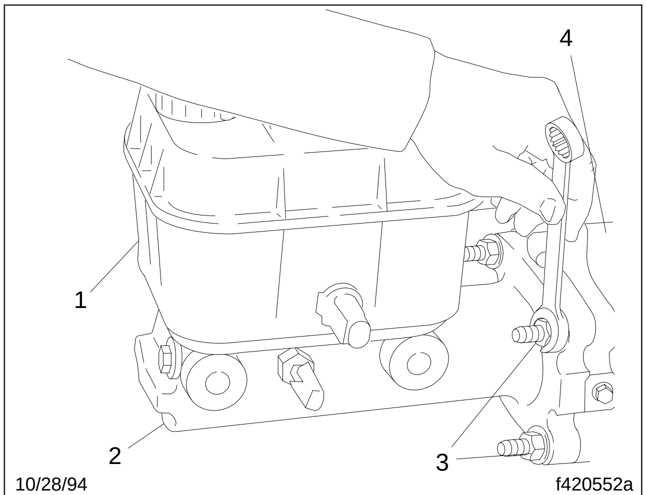
4. Remove the four flanged hexnuts that attach the master cylinder to the power brake booster unit. See **Fig. 3**.

   Remove the master cylinder from the vehicle. See **Fig. 4**. Keep it upright, with a rag wrapped around it so you do not drip any brake fluid.
5. Remove the caps from the master cylinder reservoir, then carefully turn it over and dump the brake fluid into a container. Dispose of used brake fluid in a responsible and approved manner.

Installation

1. Bench bleed the master cylinder, as follows.
   - 1.1 Put the master cylinder and reservoir assembly in a vise.
   - 1.2 Install the plastic adapter and clear tubing on the master cylinder outlet ports, as shown in **Fig. 5**.
   - 1.3 Put the other end of each tube up into the reservoir, as shown in **Fig. 5**.

Master Cylinder Removal and Installation



1. Reservoir
2. Master Cylinder
3. Flanged Hexnut
4. Power Brake Booster

Fig. 3, Removing the Hexnuts

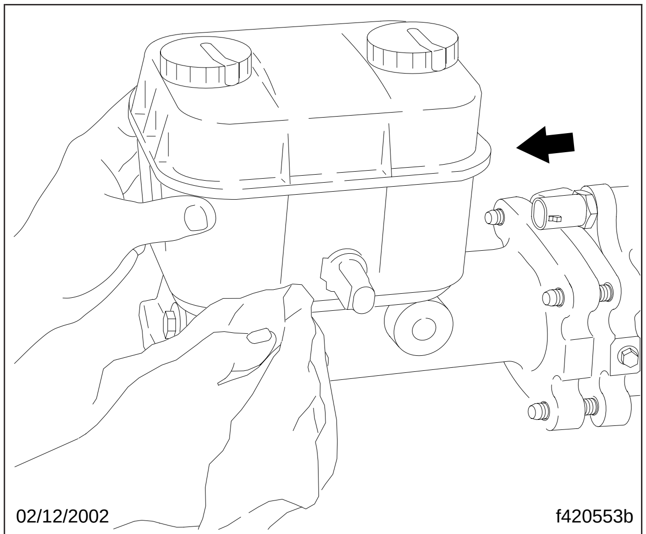


Fig. 4, Removing the Master Cylinder

1.4 Fill the reservoir about half full with new DOT 3 heavy-duty brake fluid.

1.5 Use a metal rod with a rounded end to push and release the primary piston several times. This purges air bubbles trapped in the master cylinder while returning fluid to the master cylinder reservoir.

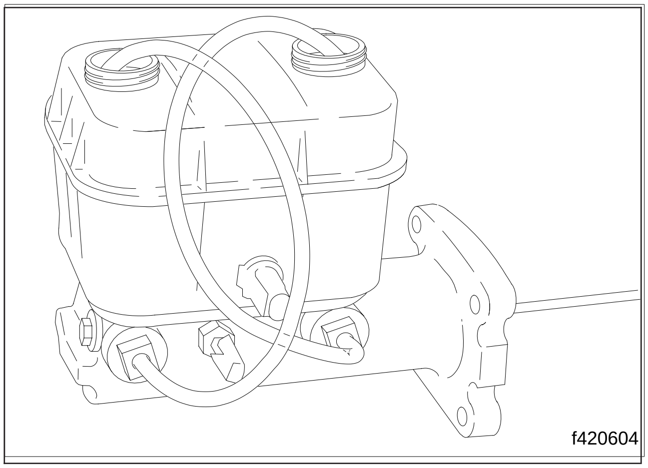
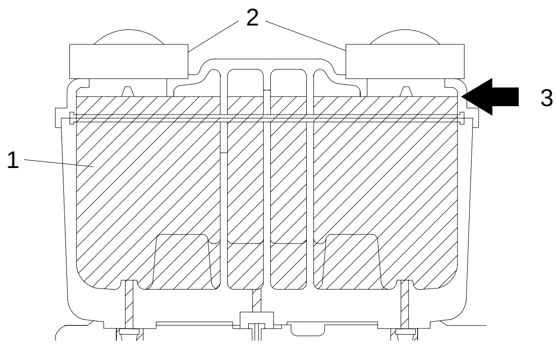


Fig. 5, Outlet Ports With Master Cylinder Bleeder Tubes

The brake bleeder plastic adapters and tubing may be left in place to keep the fluid from dripping. Remove them when the master cylinder is in place and the vehicle brake lines are to be installed.

2. Slip the master cylinder onto its studs on the front of the power brake booster. Install the four flanged nuts on the studs of the power brake booster and tighten them 27 lbf·ft (37 N·m).
3. Remove the plastic bleeder tubes if they were left on after bench bleeding. Connect the secondary circuit line to the front outlet port on the master cylinder, and the primary circuit line to the rear outlet port. Tighten the fittings to a maximum 16 lbf·ft (22 N·m).
4. Connect the wires to the pressure differential switch and the fluid level sensor. See **Fig. 1**.
5. Fill the reservoir to the bottom of the narrow throat formed by the fill opening with new DOT 3 heavy-duty brake fluid. See **Fig. 6**.
6. Bleed the entire brake system following the instructions in **Subject 110**.
7. Remove the chocks from the tires.



1. DOT 3 Brake Fluid
2. Filler Caps
3. Fill to Bottom Ring of Filler Neck

Fig. 6, Master Cylinder Fill Level

Hydro-Max® II Power Brake Booster Removal and Installation

Removal

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries at the negative cables.
3. If the brake master cylinder is still mounted on the power booster, remove it following the instructions in **Subject 140**.
4. Below the dash, remove the cotter key, washer, and clevis pin that connect the power booster pushrod to the brake pedal. See **Fig. 1**.

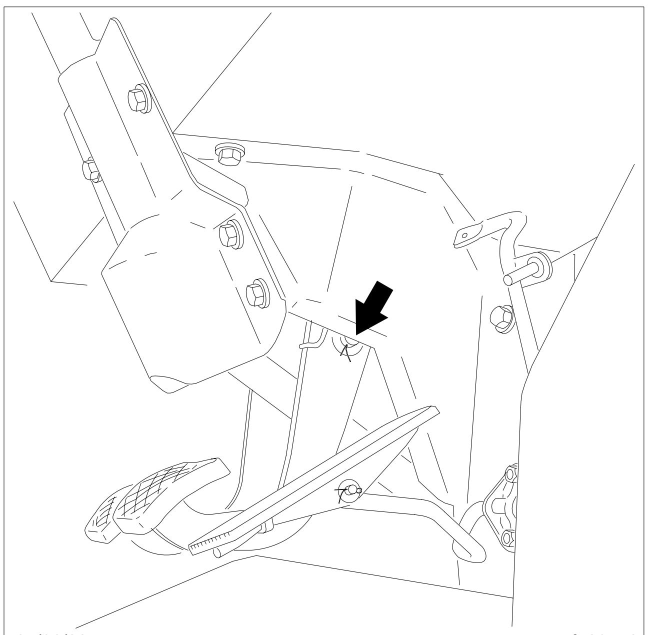
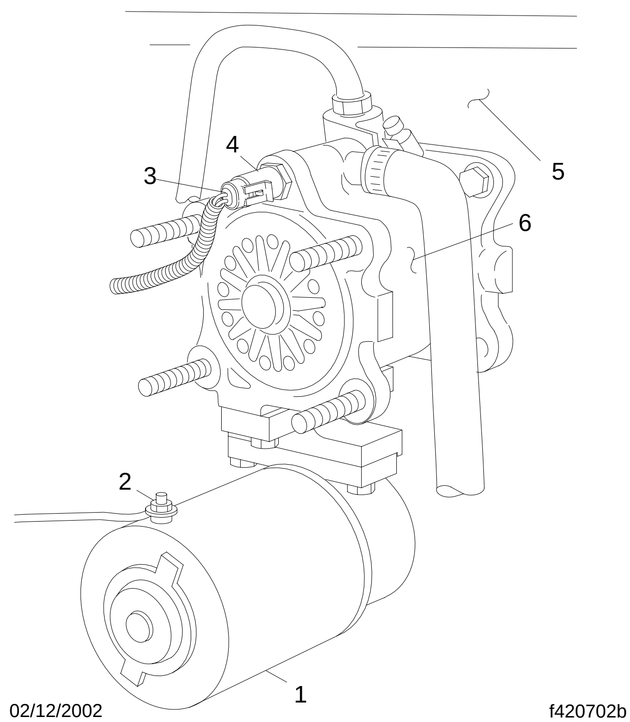


Fig. 1, Brake Pedal

5. Disconnect the wiring from the backup pump assembly. See **Fig. 2**.
6. Disconnect the wiring from the flow switch at the front of the power brake booster. See **Fig. 2**.
7. Using a shop towel or a container to catch leaking ATF, disconnect the hydraulic supply and return lines from the power brake booster. See **Fig. 3**. Plug the lines.



1. Backup Pump
2. Backup Pump Power Lead
3. Flow Switch Wiring
4. Flow Switch
5. Firewall
6. Power Brake Booster Housing

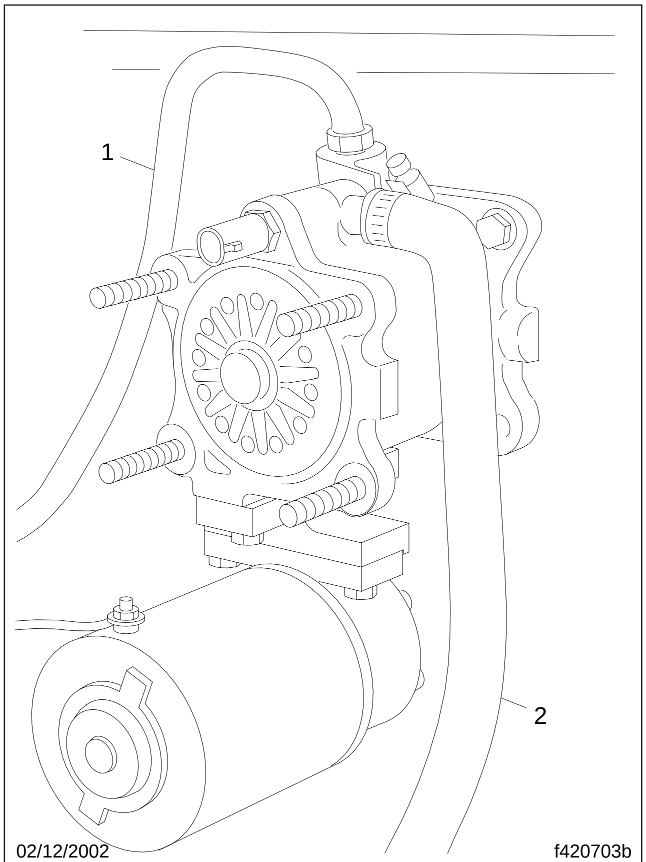
Fig. 2, Backup Pump Assembly (actual appearance may vary)

8. Remove the four hexbolts and washers that attach the power brake booster to the firewall. See **Fig. 4**. Pull the power brake booster straight out from the firewall. See **Fig. 5**.

Installation

1. Position the power brake booster on the firewall so the brake pedal rod fits through the large hole and into the cab. See **Fig. 5**.
2. Line up the four holes in the power brake booster with those on the firewall. Install the four mounting hexbolts and washers. See **Fig. 4**. Tighten 27 lbf·ft (37 N·m).

Hydro-Max® II Power Brake Booster Removal and Installation



1. Supply Line (steel)
2. Return Line (rubber)

Fig. 3, Power Brake Booster Lines (actual appearance may vary)

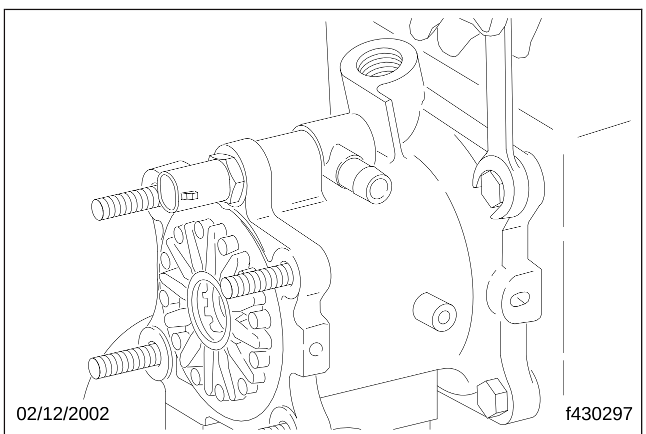


Fig. 4, Power Brake Booster Mounting (actual appearance may vary)

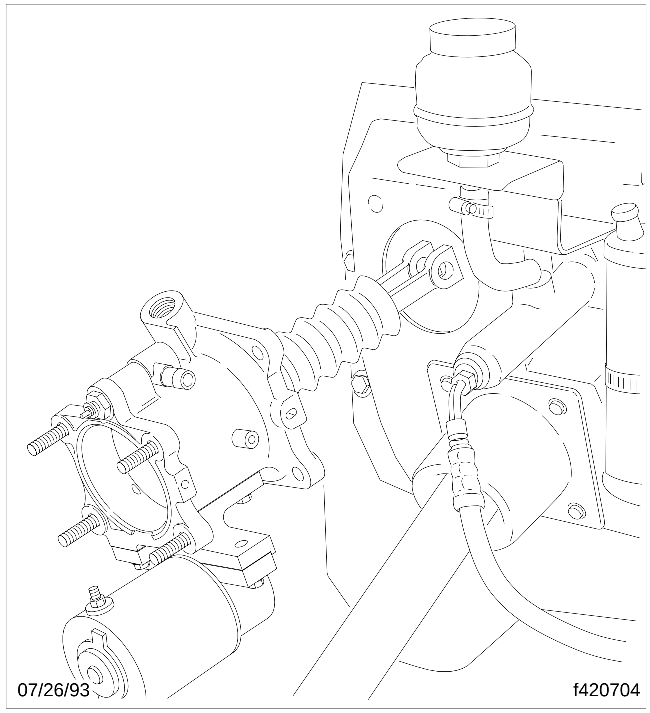
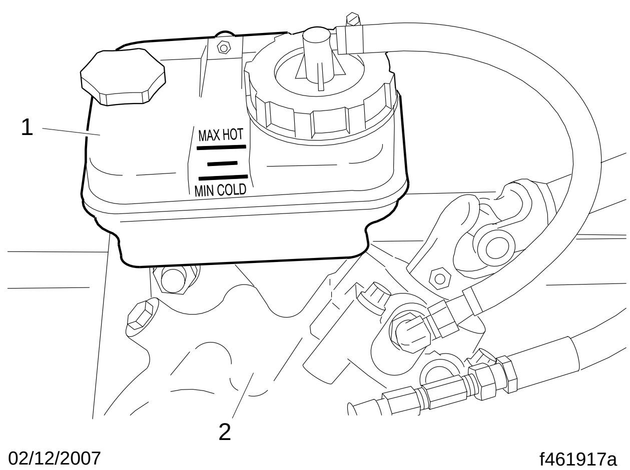


Fig. 5, Power Brake Booster Removal

3. Install the master cylinder on the power brake booster, following the instructions in **Subject 140**.
4. Connect the hydraulic supply and return lines. See **Fig. 3**. Tighten the supply line 21 lbf·ft (28 N·m). Tighten the hose clamp on the return line.
5. Connect the wiring to the backup pump assembly and to the flow switch assembly. See **Fig. 2**.
6. Check the ATF level in the power steering reservoir. See **Fig. 6**. Add approved ATF if needed. See **Specifications 400** for the approved ATF.
7. Connect the batteries.
8. Bleed the power brake booster following the instructions in **Subject 110**.
9. Remove the chocks from the rear tires.

Hydro-Max® II Power Brake Booster Removal and Installation



1. Power Steering Reservoir
2. Steering Gear

Fig. 6, Fluid Level Check

Hydraulic Brake Electronic Monitor Module Removal and Installation

NOTE: The monitor module is located on the driver side of the dash behind the instrumentation control unit (ICU3).

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries at the negative terminals.
3. Inside the cab, remove the dash trim panel. See **Fig. 1**.

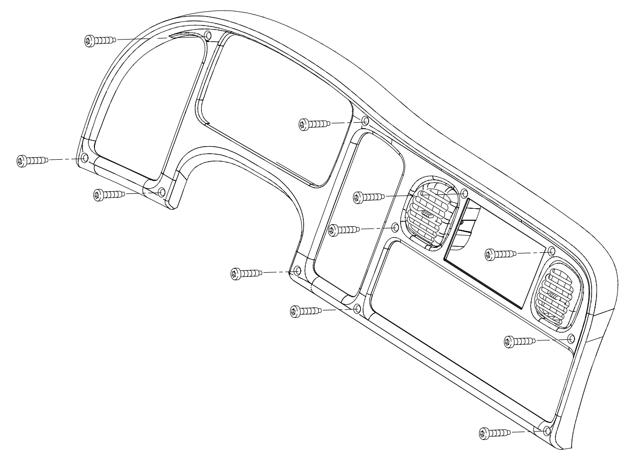


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Fig. 1, Dash Trim Panel

4. Find the monitor module behind the instrumentation control unit (ICU3-M2). Disconnect the 9-pin connector and the 4-pin connector from the module.
5. If necessary, in order to remove the monitor module, remove the ICU3-M2. For instructions, see **Section 54.06, Subject 100**.
6. Remove the monitor module.

Installation

1. Connect the 9-pin and the 4-pin connectors to the monitor module.
2. Install the monitor module on the mounting bracket.
3. If it was removed, install the ICU3-M2. For instructions, see **Section 54.06, Subject 100**.
4. Install the dash trim panel. See **Fig. 1**.
5. Connect the batteries.
6. Remove the chocks from the rear tires.
7. Verify proper operation of the monitor module. See **Subject 120**.

Flow Switch Removal, Inspection, and Installation

NOTE: Refer to **Fig. 1** when performing the following procedures.

The most likely problems requiring service of the flow switch include the following.

- Contamination of the metering piston.
- Damaged contact assembly.
- Leaking at the contact assembly.
- The backup pump runs continuously when the engine is running.
- The backup pump not running when it should be.

Removal

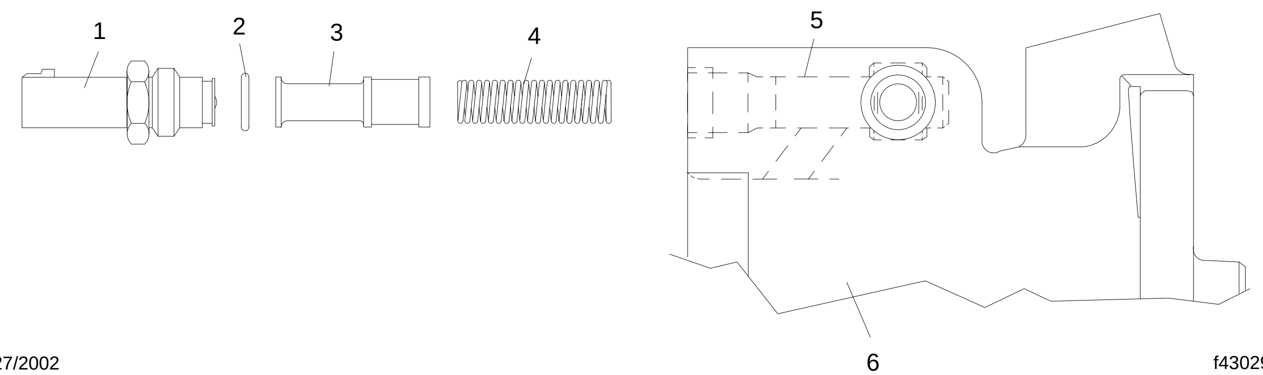
WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Place a container under the booster to catch any automatic transmission fluid (ATF) that may drain out while removing the flow switch contact assembly.
4. Disconnect the wiring harness flow switch connector from the flow switch contact assembly.
5. Remove the contact assembly from the booster. Be prepared to catch the metering piston; it may be pushed out of the booster housing by the spring.
6. If the metering piston did not come out by itself, use a small magnet to extract the metering piston and spring from the bore.

Inspection

1. If the contact assembly is damaged, replace it.
2. If the O-ring seal is damaged, replace it.
3. Inspect the opening into the booster and inspect the flow switch bore. These surfaces must be clean and free of particles, chips, or any other form of contaminant. Remove any contaminant.
4. Inspect the metering piston and spring for cleanliness. Remove any contaminants.



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1. Contact Assembly
2. O-Ring
3. Metering Piston
4. Spring
5. Flow Switch Bore
6. Booster

Fig. 1, Flow Switch Assembly (exploded view)

Flow Switch Removal, Inspection, and Installation

Installation

1. If a new contact assembly or O-ring is being used, install the O-ring onto the contact assembly.
2. Install the spring and metering piston into the flow switch bore.
3. Install the contact assembly and O-ring into the booster. Tighten 20 to 40 lbf·in (230 to 450 N·cm).
4. Connect the wiring harness flow switch connector to the flow switch contact assembly.
5. Fill the power steering pump reservoir to the proper level with ATF. Do not reuse old ATF from the booster.
6. Connect the battery ground cable.
7. Confirm proper installation of the switch, as follows.
   7.1 Start the engine. With the engine running, the power steering pump circulates ATF through the system. This automatically purges air from the booster.
   7.2 While the engine is running, press on the brake pedal several times to make sure the pedal feels normal.
8. Shut the engine off. Press on the brake pedal several times to make sure the pedal feels normal in the backup pump mode.
9. Check for leakage at the flow switch contact assembly.
10. Confirm that the backup pump does not run when the engine is running.
11. Confirm that the backup pump runs when:
    - the engine is off and the ignition key is on, **and,**
    - the ignition key and engine are off but the brake pedal is depressed.
12. Recheck the ATF level in the power steering pump reservoir. If necessary, add ATF.
13. Road test the vehicle to ensure proper steering and braking operation.

Troubleshooting Index

Hydraulic Brake Troubleshooting Index	
Problem	**Figure**
Brake warning lamp and buzzer (related to parking brake)	Fig. 1
Brake warning lamp and buzzer (related to service brake)	Fig. 2
Backup pump runs continuously	Fig. 3
Backup pump does not run	Fig. 5
Abnormal brake pedal conditions	Fig. 6
Brake pedal feels hard	Fig. 8
Hydraulic system leakage	Fig. 9, Fig. 10, Fig. 12
Brakes are dragging	Fig. 13, Fig. 14
Short pad life, uneven pad wear, overheated brakes	Fig. 13, Fig. 14

Table 1, Hydraulic Brake Troubleshooting Index

Brake Warning Lamp and Buzzer Related to Parking Brake

NOTE: There are two warning lamps generally relating to brakes: the parking/service brake warning lamp and an ABS warning lamp. Coverage is only for the parking/service brake warning lamp, not the ABS warning lamp. There is a single buzzer for all brake signals.

The brake warning lamp and buzzer come on together when triggered by one or more of the following:

- parking brake switch
- flow switch
- fluid level indicator switch
- differential pressure switch
- electric backup pump

See **Fig. 1** for troubleshooting if the problem seems to be with the parking brake or **Fig. 2** if the service brakes seem to be the problem.

NOTE: Technicians can refer to wiring diagrams in PartsPro, Module 877, in addition to those in Subject 400.

Backup Pump Runs Continuously

Normally, the backup pump will run only if the flow switch has activated its relay.

A properly working relay starts the backup pump only if it is triggered by the flow switch and there is power to the relay coil. A defective relay can stick "on," making the backup pump run even though it is not triggered by the flow switch and there is no power to the relay coil.

See **Fig. 3** for troubleshooting and **Fig. 4** for the electrical components of the master cylinder and power brake booster.

Backup Pump Does Not Run

The backup pump will not run if there is no voltage to the motor or if the motor is damaged—burnt out or jammed, for instance. Some of the possible reasons for the backup pump not running include:

- a dead battery
- a broken relay
- a broken wire between the battery and pump motor
- a break in the circuit between the ignition switch/brake warning lamp switch and the flow switch
- flow switch is not grounded

Troubleshooting

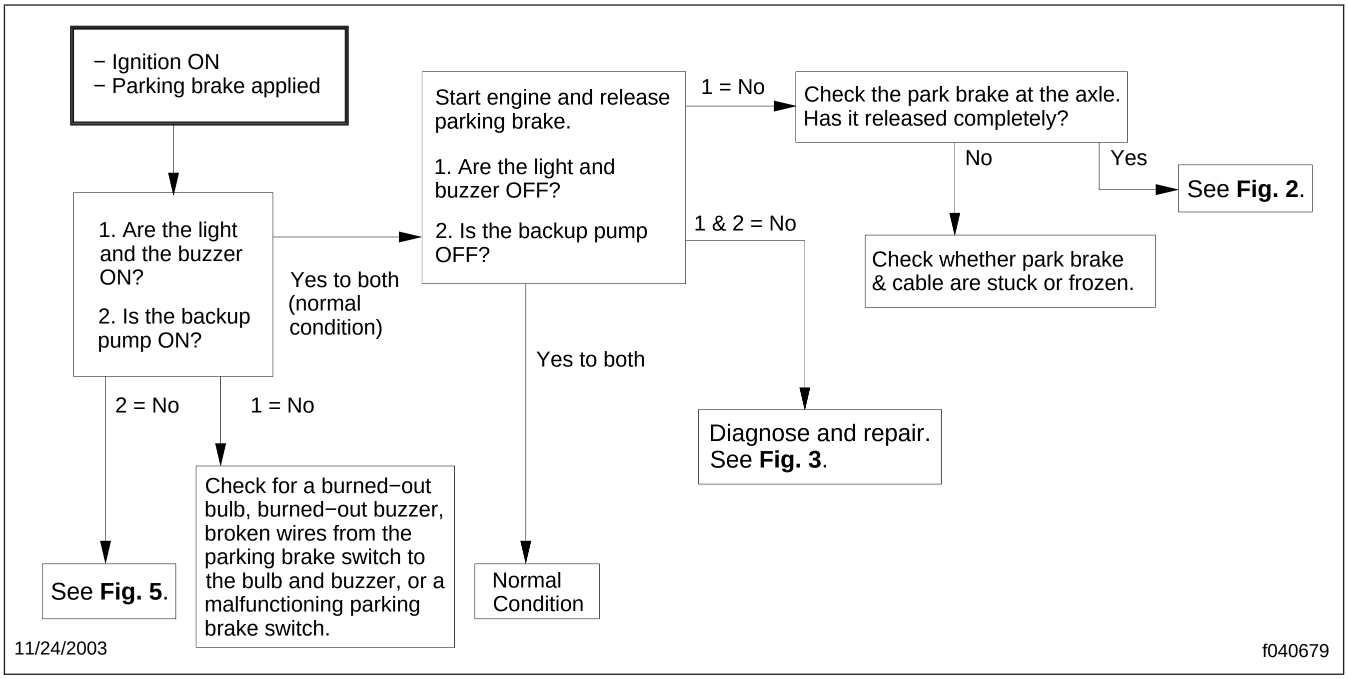


Fig. 1, Flow Chart: Brake Warning Lamp and Buzzer Relating to Parking Brake

See **Fig. 5** for troubleshooting and **Fig. 4** for the electrical components of the master cylinder and power brake booster.

Abnormal Brake Pedal Conditions

Abnormal pedal conditions covered under this heading include the following. See **Fig. 6** for flow chart diagnosis.

- Brake pedal dropping 1/2 inch (13 mm) when the engine is started
- The brake pedal feels spongy, springy, or soft
- The brake pedal continues to fall with steady foot force
- The brake pedal feels very hard

Most common reasons for a very hard pedal are—

- Insufficient flow or pressure from the power steering pump;
- ABS is blocking flow of brake fluid to the calipers.

Less likely causes include:

- contaminated power brake booster
- contaminated master cylinder
- binding pedal linkage
- binding power brake booster
- binding master cylinder
- blocked or kinked brake fluid tubes or hoses

With the engine OFF other causes are—

- Backup pump does not run;
- The backup pump does not provide sufficient pressure.

See **Fig. 6** for abnormal brake conditions flow chart.

Figure 7 shows a typical swollen master cylinder reservoir cap seal due to ATF, power steering fluid, or motor oil contamination in the master cylinder.

See **Fig. 8** for flow chart regarding very hard brake pedal feel.

Hydraulic System Leakage

If hydraulic fluid leakage is suspected, see **Fig. 9**, **Fig. 10**, and **Fig. 11** to diagnose and locate the problem.

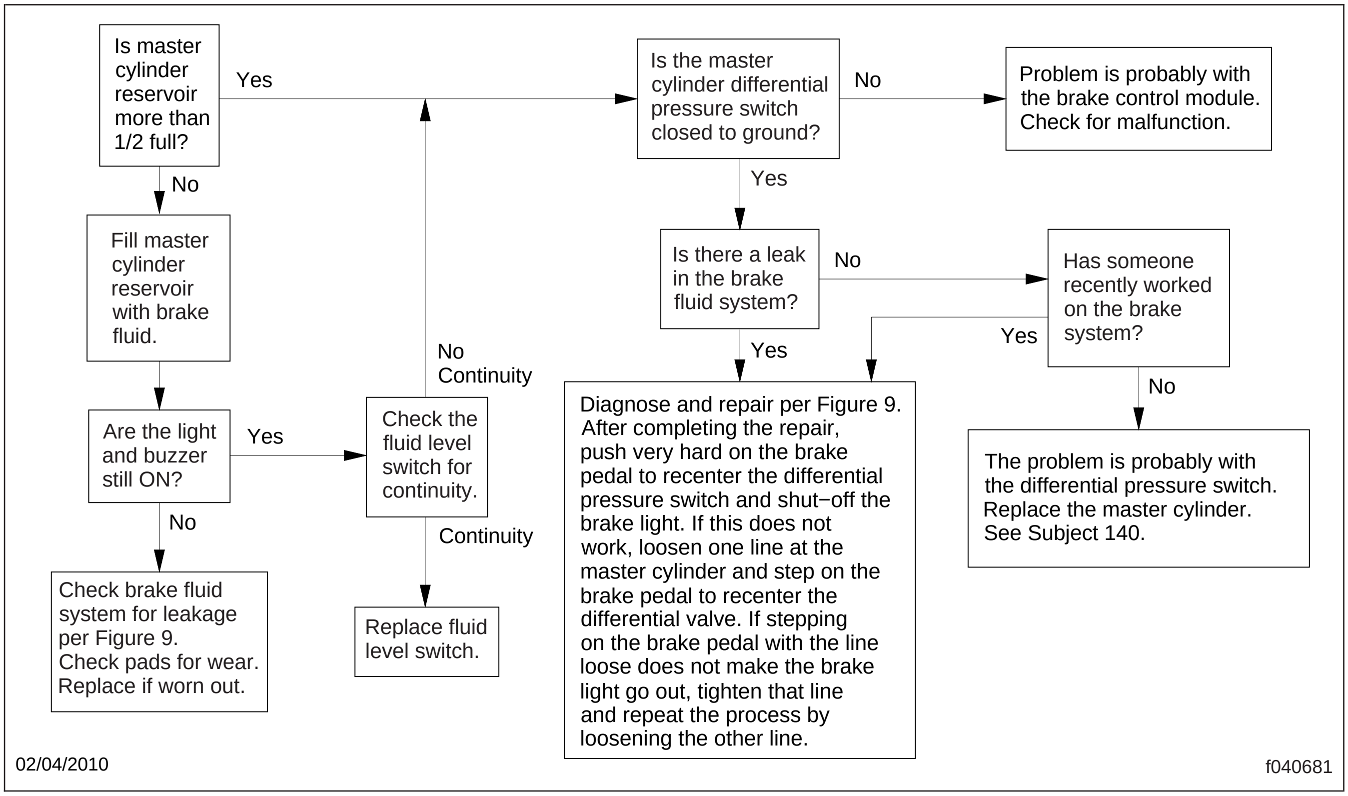


Fig. 2, Flow Chart: Brake Warning Lamp and Buzzer for Service Brake Problems

See **Fig. 12** for the most frequent leak points at the power brake booster.

Brakes are Dragging

The following are possible causes for brake drag:

- The power brake booster does not return to the released position.
- The brake pedal linkage not returning to the released position.
- The master cylinder does not return to the released position.
- The ABS system is trapping hydraulic pressure.
- The brake calipers do not release.
- The brake lines or hoses are plugged, kinked, or collapsed.

IMPORTANT: Some tests require doing things in the driver's seat while at the same time watching what happens at the brakes. These tests require two people.

See **Fig. 13** and **Fig. 14** for complete brake-drag diagnostics.

Short Pad Life, Uneven Pad Wear, or Overheated Brakes

NOTE: Because of the great differences in vehicle types, usage, terrain, loads, driving style and many other factors, accurately predicting brake wear is impossible. Severe use, even without other brake system problems, sometimes wears out brakes quickly.

1. Check whether the brake pads are wearing abnormally. For example, check whether the inner and outer pads are wearing unevenly.
2. If the brakes are dragging, smoking, overheating, smelling, pulling, or if there is poor acceleration, see **Fig. 13**.

Troubleshooting

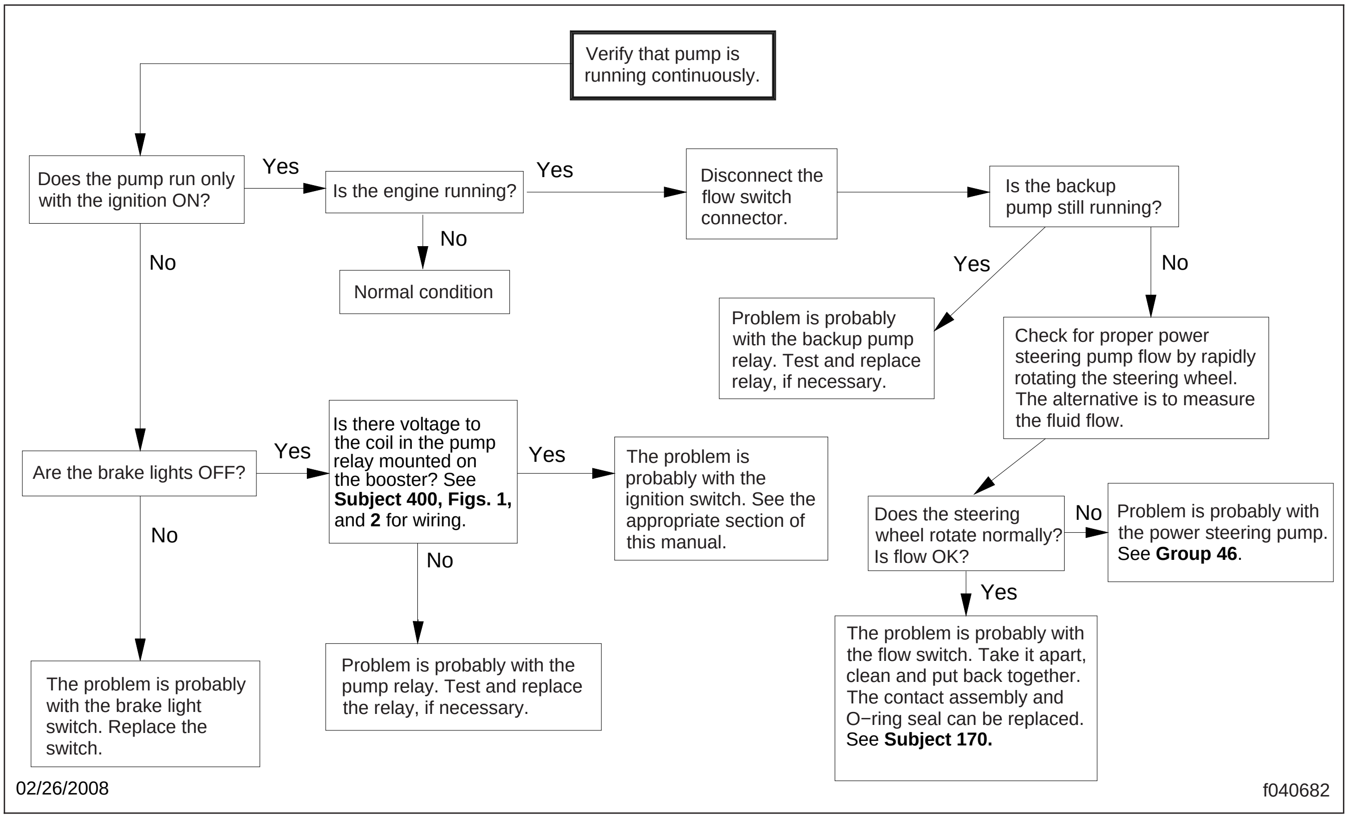
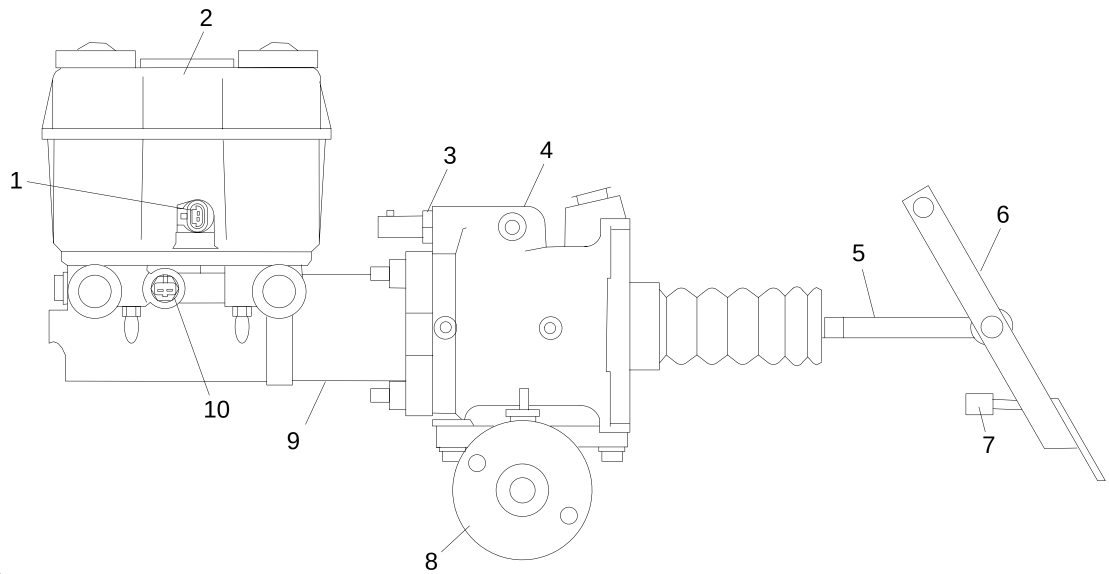


Fig. 3, Flow Chart: Backup Pump Runs Continuously

If the brake wear is not caused by one of these conditions, the problem is probably caused by vehicle usage or the driver's braking habits. For low temperature or light duty conditions, consult the brake manufacturer for appropriate replacement linings.



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1. Fluid Level Indicator Switch
2. Master Cylinder Reservoir
3. Flow Switch
4. Power Booster
5. Brake Pedal Linkage
6. Brake Pedal
7. Brake Warning Lamp Switch
8. Backup Pump
9. Master Cylinder
10. Differential Pressure Switch

Fig. 4, Components of the Master Cylinder and Power Brake Booster

Troubleshooting

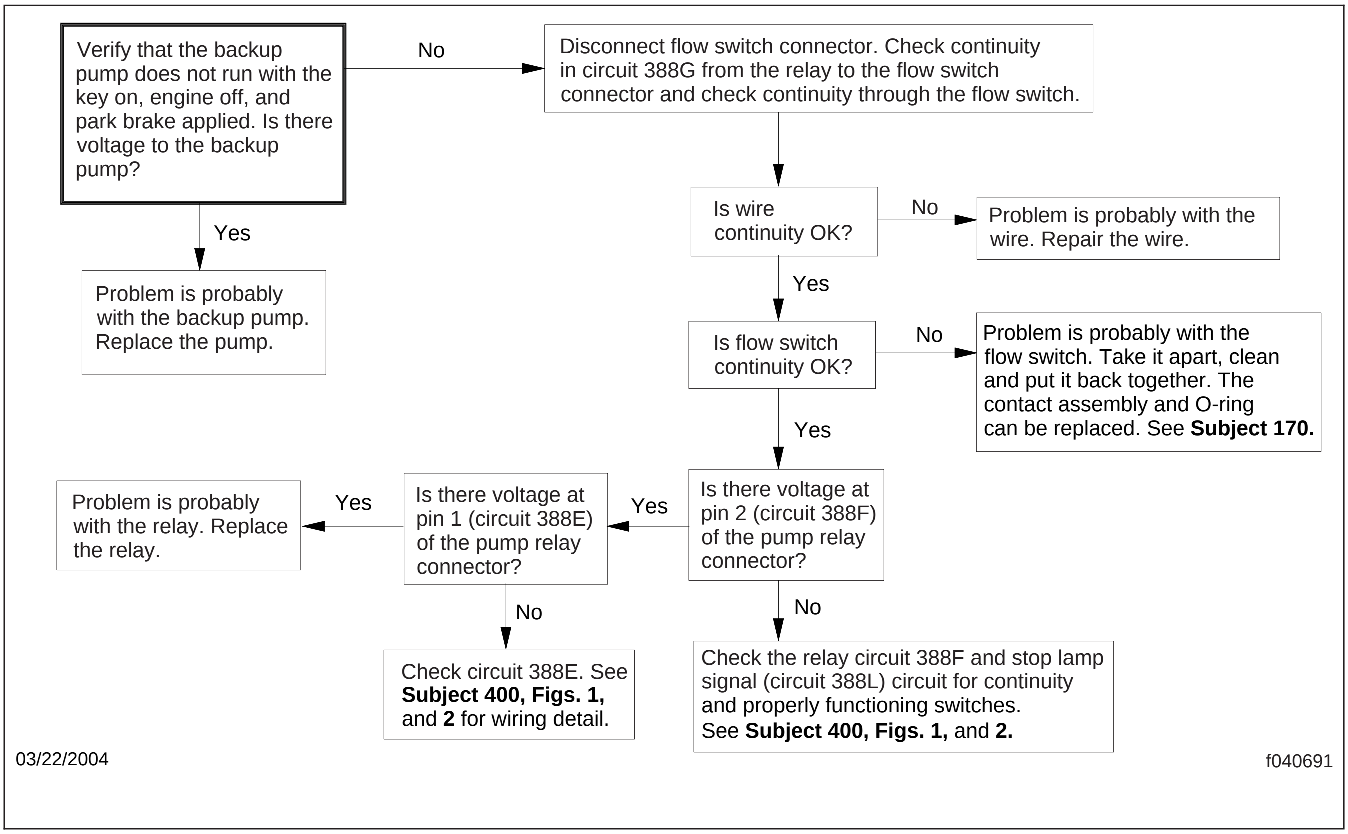


Fig. 5, Flow Chart: Backup Pump Does Not Run

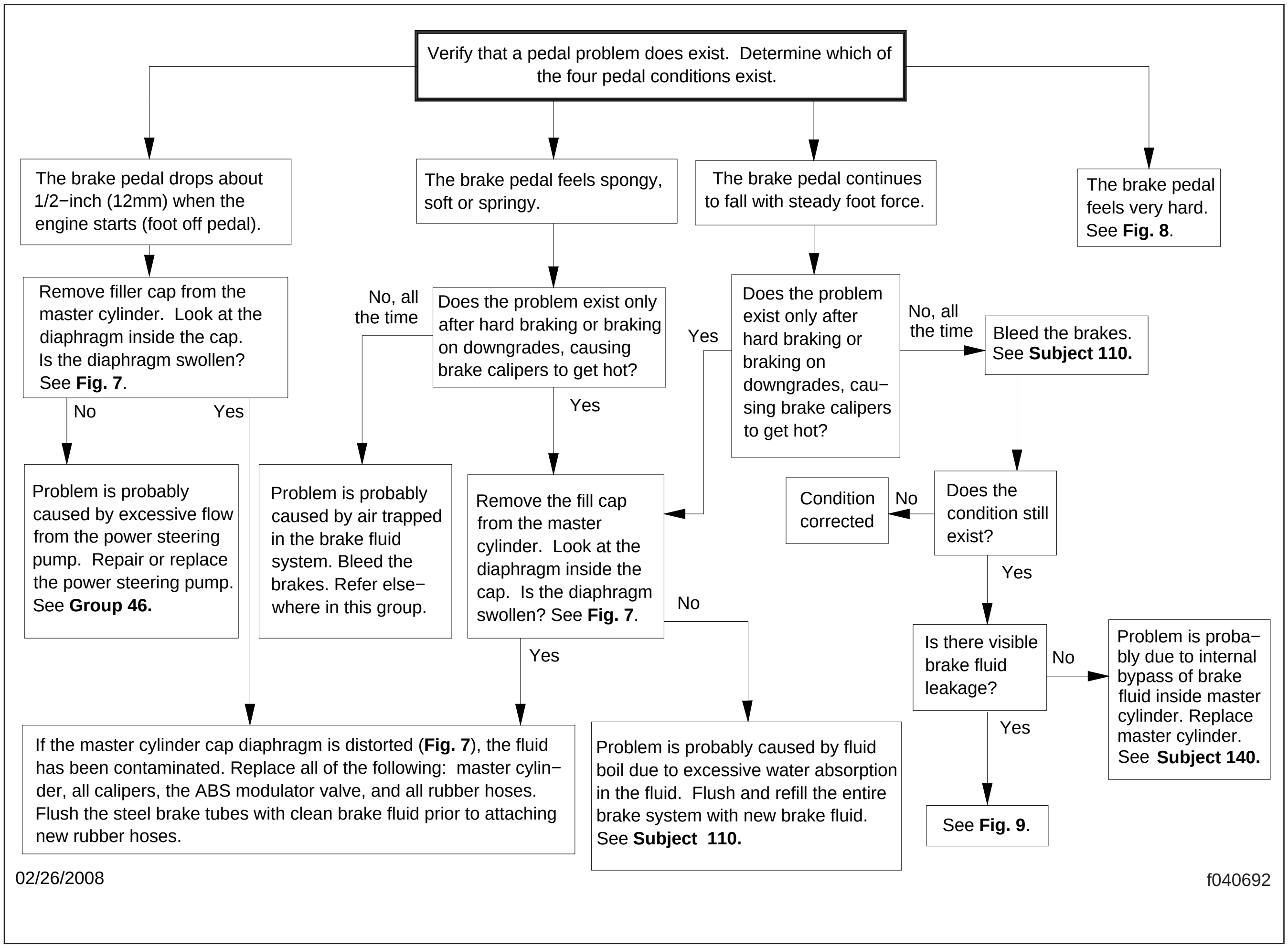
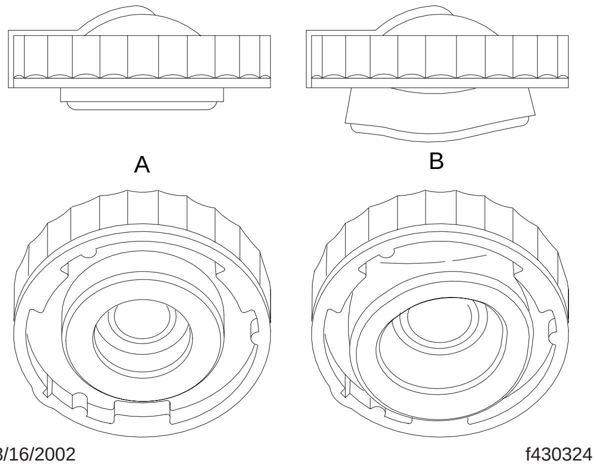


Fig. 6, Flow Chart: Abnormal Brake Pedal Conditions

Troubleshooting



A. Reservoir cap and diaphragm from uncontaminated system.
B. Reservoir cap and diaphragm from a system contaminated with power steering fluid, motor oil, or ATF.

Fig. 7, Undamaged and Damaged Master Cylinder Fluid Reservoir Caps and Diaphragms

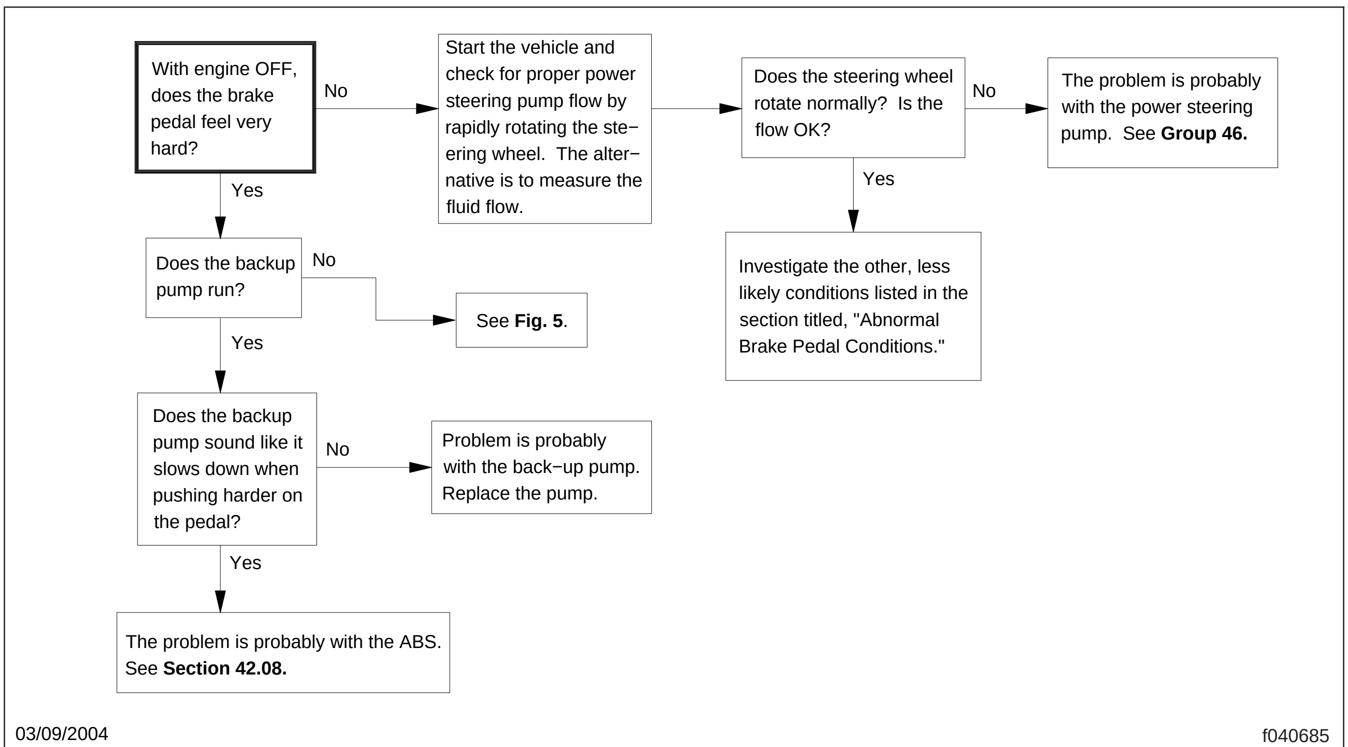


Fig. 8, Flow Chart: Brake Pedal Feels Very Hard

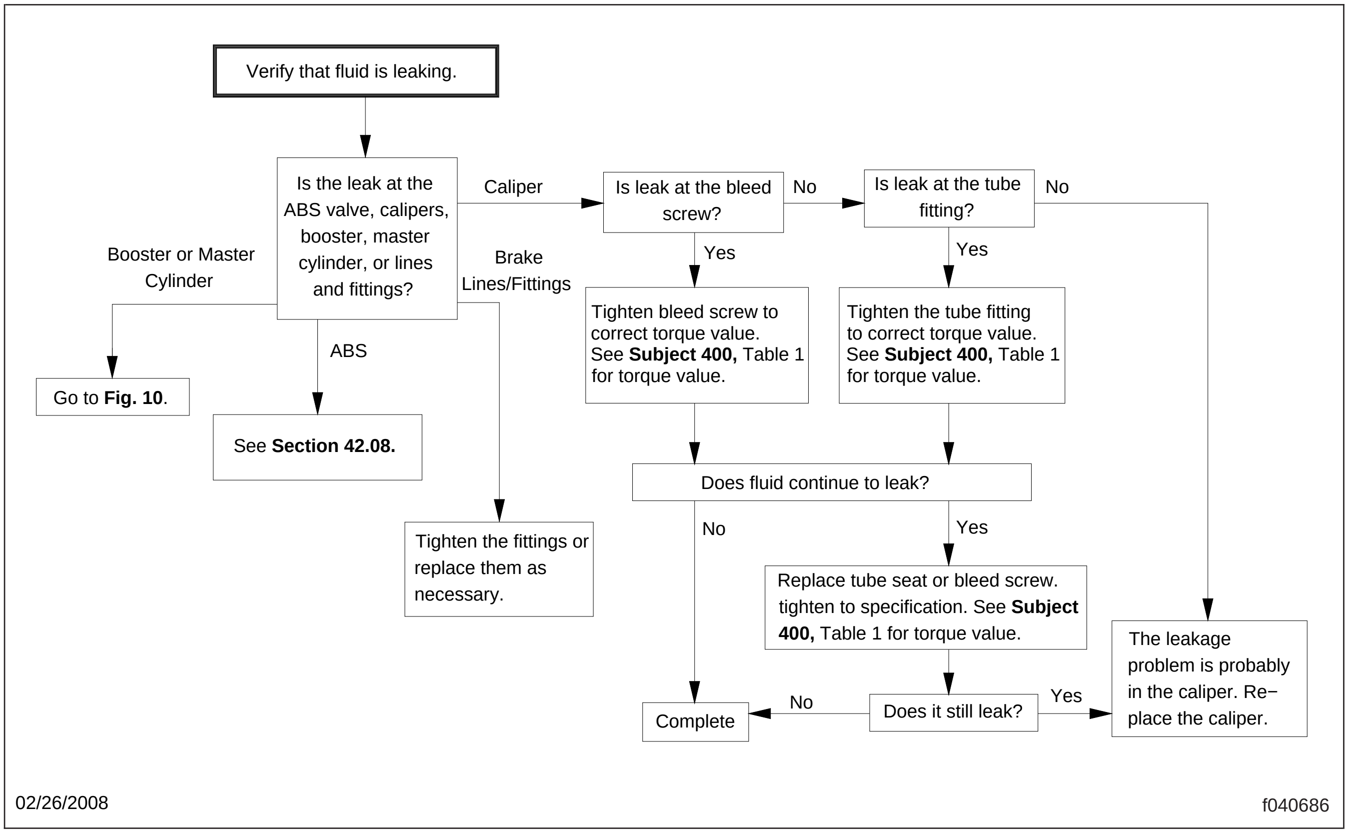


Fig. 9, Flow Chart: Hydraulic System Leakage

Troubleshooting

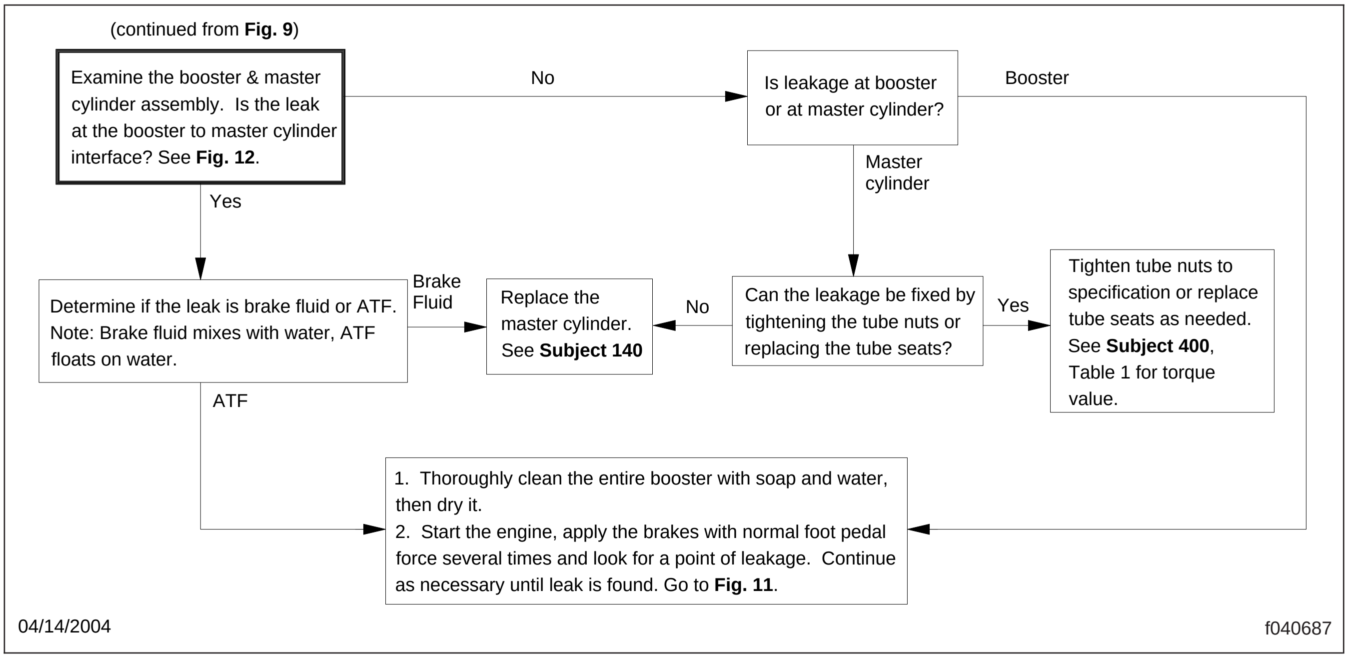


Fig. 10, Flow Chart: Hydraulic System Leakage (cont.)

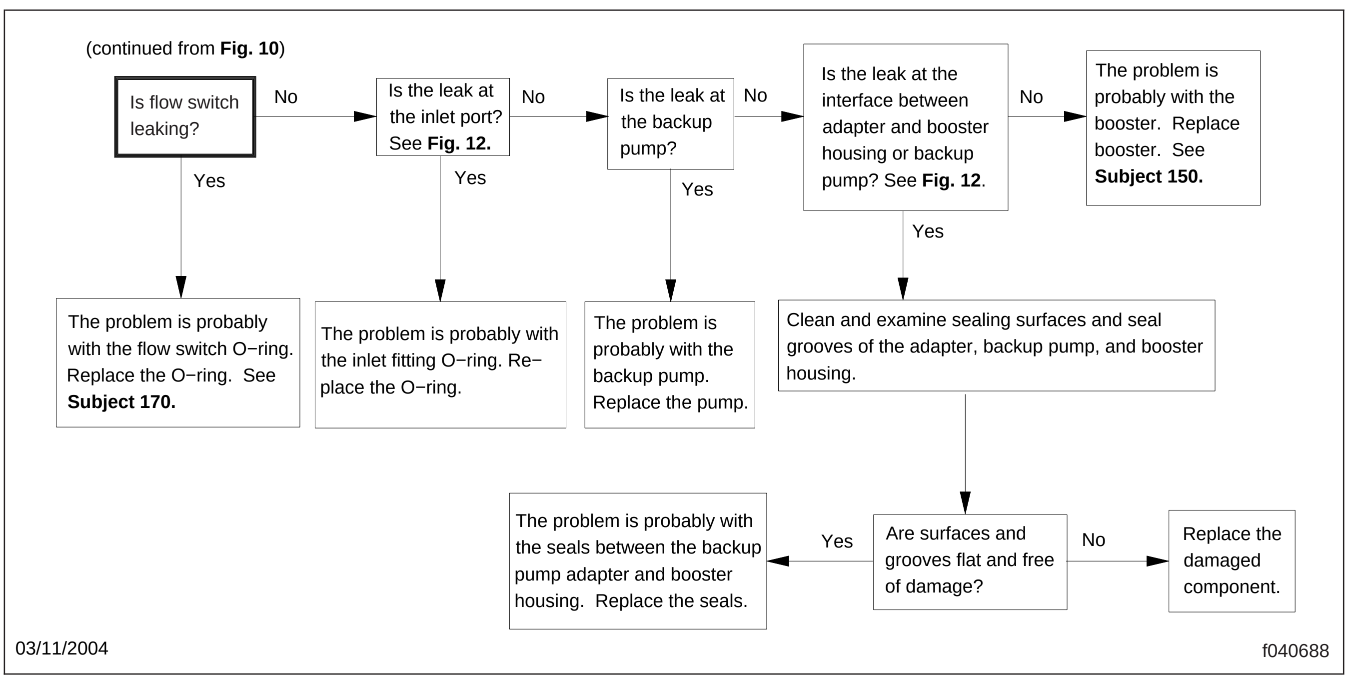
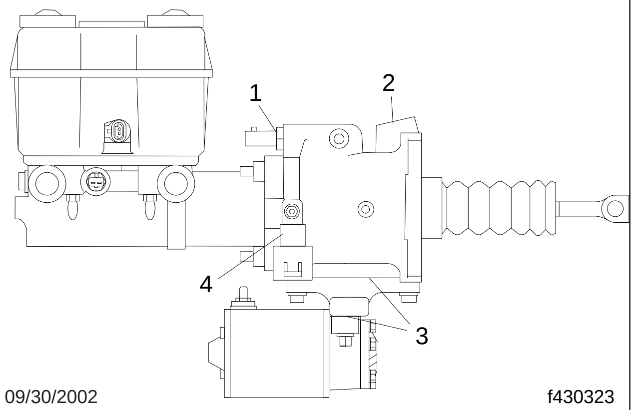


Fig. 11, Flow Chart: Hydraulic System Leakage (cont.)



1. Flow Switch and Power Brake Booster Interface
2. Inlet Port
3. Booster, Adapter, and Pump Interface
4. Power Brake Booster and Master Cylinder Interface

Fig. 12, Potential Hydraulic Fluid Leak Points

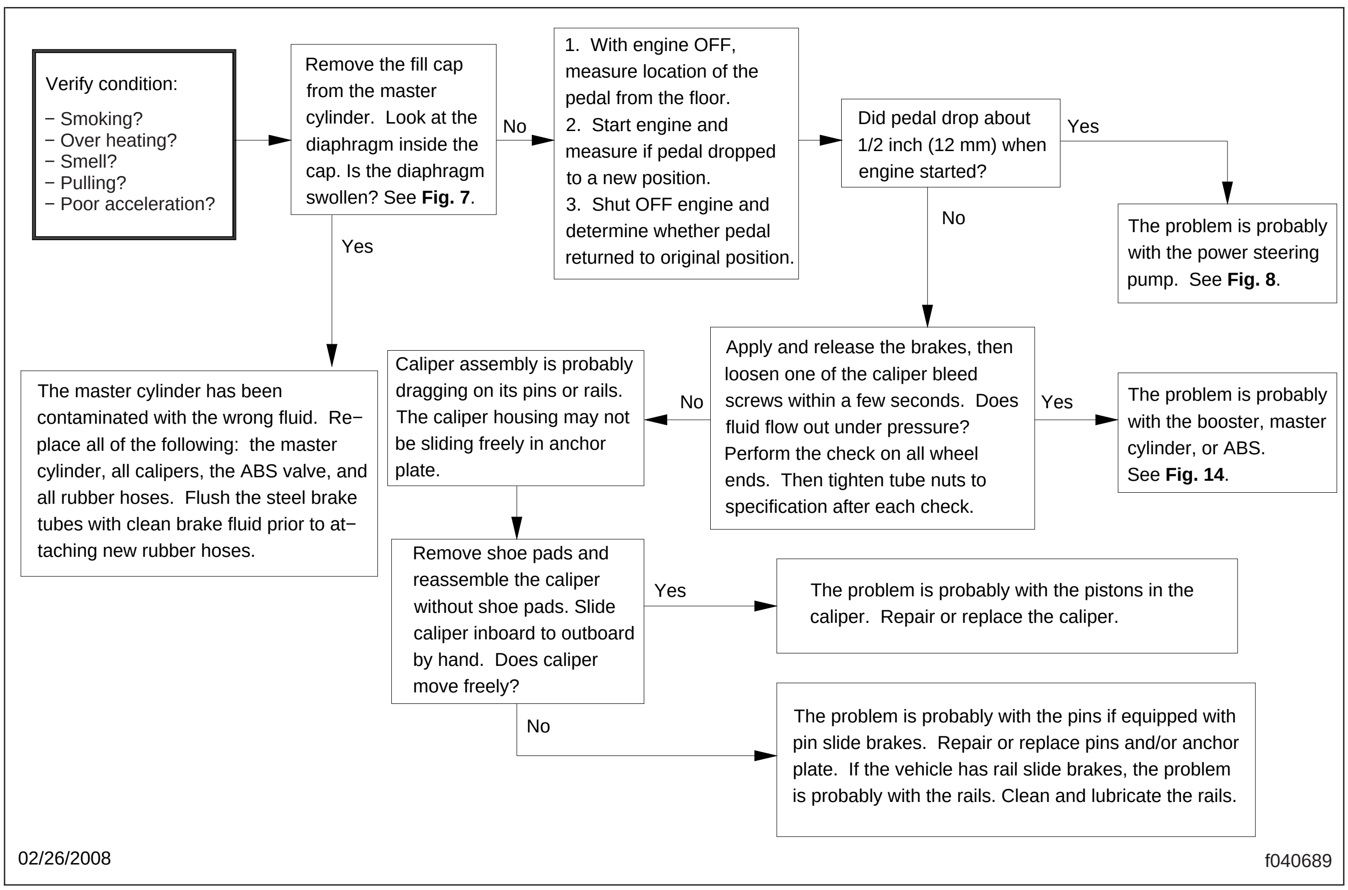


Fig. 13, Flow Chart: Brakes are Dragging

Troubleshooting

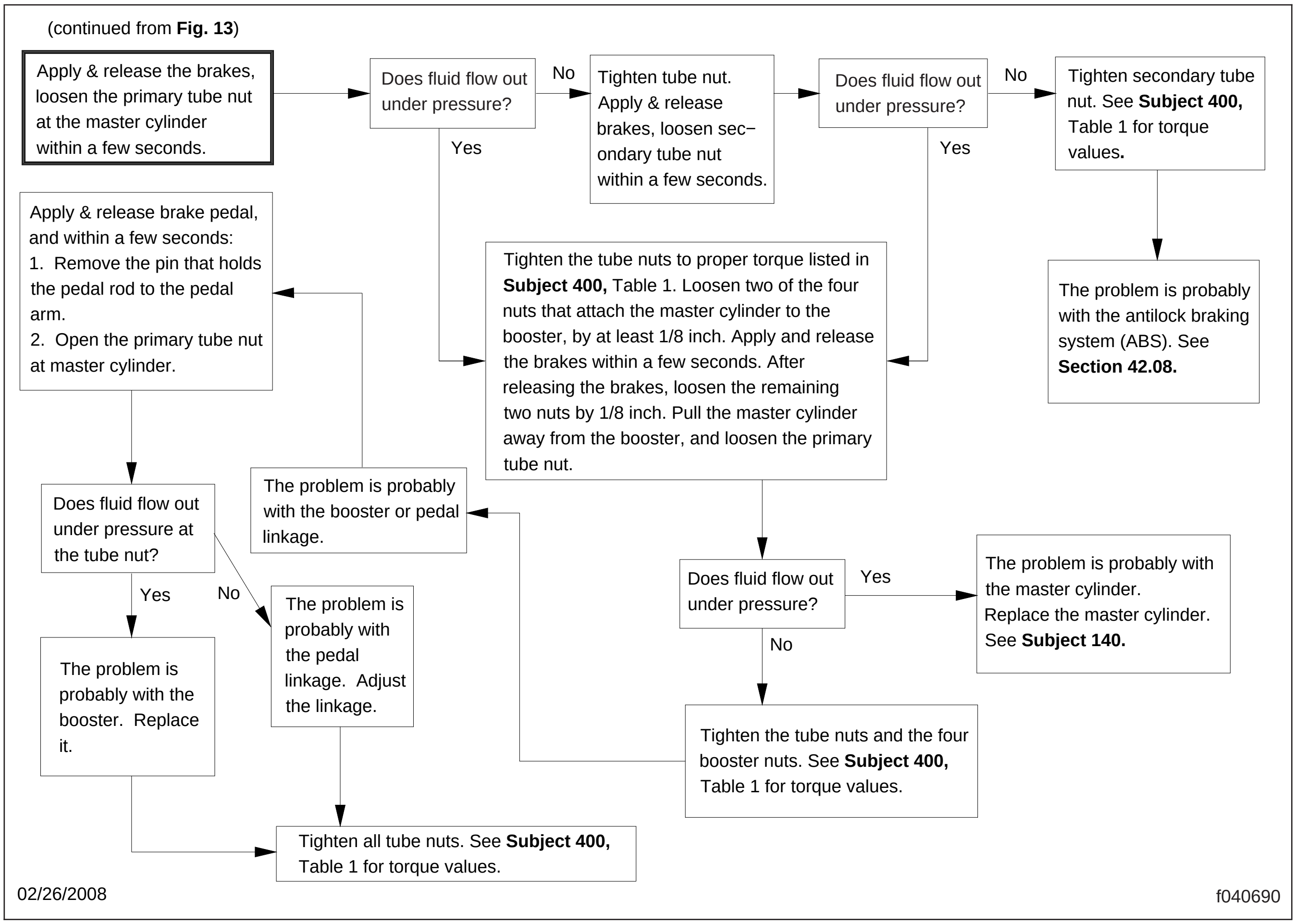
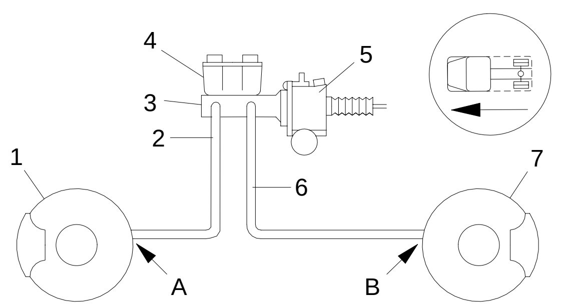


Fig. 14, Flow Chart: Brakes are Dragging (cont.)

Brake System Pressure Tests

NOTE: On most vehicles in the field, the primary master cylinder piston controls the rear brakes, the secondary piston, the front brakes. But on some vehicles the primary master cylinder piston controls the front brakes, the secondary master cylinder piston controls the rear brakes. Either configuration is considered normal and they are functionally identical. Technicians should check vehicle configuration for appropriate diagnosis and repair.

1. Install two low-pressure gauges with a range of 0 to 50 psi (345 kPa) — one at the rear wheels, and one at the front wheels. See **Fig. 1**.



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A. Install gauge #2 here.
B. Install gauge #1 here.

1. Front Brake
2. Front Brake Lines
3. Master Cylinder
4. Reservoir
5. Power Brake Booster
6. Rear Brake Lines
7. Rear Brake

Fig. 1, Gauge Installation

2. Bleed the brakes following the procedure in **Subject 110**.
3. With the ignition off, lightly apply the brakes several times. Do not push hard on the brake pedal or you may damage the low-pressure gauges.
4. Release the brakes. Read the residual pressure on both gauges. Record the information.
5. If the residual pressure on either gauge is less than 2 psi (14 kPa), go to "System Pressure Test" below.

   If the residual pressure on one or both gauges is more than 2 psi (14 kPa), check the linkage between the brake pedal and the booster. Repair the linkage if needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" below. If the problem is not solved, continue these steps.
6. Check the hydraulic lines for internal blockage or kinking and replace them as needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" below. If the problem is not solved, continue with these steps.
7. Check for residual pressure at the master cylinder. Replace as needed. Go to "System Pressure Test" below.

System Pressure Test

1. Install two pressure gauges with a range of 0 to 2500 psi (17 238 kPa) — one at the rear wheels, and one at the front wheels. See **Fig. 1**.
2. Bleed the brakes following the procedure under **Subject 110**.
3. Make a copy of **Table 1**. Use this copy to record the results from the next step.

Test Results				
Pressure Test	Gauge 1 (installed at rear wheel)		Gauge 2 (installed at front wheel)	
Rapid Pressure Rise	Yes	No	Yes	No
Slow Pressure Rise	Yes	No	Yes	No
Highest Reading (psi)		psi		psi
Pressure Constant	Yes	No	Yes	No

Table 1, Test Results

4. Start the engine. Quickly apply the brakes using full pedal force. Hold the pedal down for 15 to 20 seconds. Record the speed of the pressure rise, the highest pressure registered on each gauge and whether the pressure stayed constant while the pedal was held down. Use a copy of **Table 1** to record your observations.
5. If the pressure reading on both gauges is not within 10 percent, the ABS may be affecting readings. Replace the master cylinder if needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

Pressure Testing

6. If the pressure reading on both gauges is within 10 percent but the gauges show less than 1770 psi (12 204 kPa), turn off the engine but leave the ignition on. Apply the brakes hard and hold the pedal down 15 to 20 seconds to test pressure from the backup pump.

   If both gauges show at least 860 psi (5930 kPa), replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If both gauges do not show at least 860 psi (5930 kPa), replace the power brake booster. Bleed the system following the instructions in **Subject 110**.
7. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1770 psi (12 204 kPa), but the pressure came up slowly on both gauges, turn off the engine leaving the ignition on. Apply the brakes hard, hold down the pedal 15 to 20 seconds. If there was a rapid pressure rise on both gauges, repair or replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If the pressure rose slowly on both gauges, repair or replace the power brake booster. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.
8. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1770 psi (12 204 kPa), but the pressure comes up rapidly on one gauge and slowly on the other, there is probably a restriction in the brake system with the slow gauge. Remove the gauge and install it closer to the master cylinder until the pressure rises rapidly. The restriction is between that point and the point of previous installation. Repair or replace the brake line as needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.
9. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 204 kPa) and the pressure came up rapidly on both gauges but the gauges do not hold constant pressure while the pedal is held down, turn off the engine. Leave the ignition on. Push hard on the brake pedal and hold it down for 15 to 20 seconds. If both gauges hold constant pressure while the pedal is down, repair or replace the power steering pump. Bleed the system following the instructions in **Subject 110**.

   If either gauge does not show constant pressure with the pedal held down, there is probably leakage between the master cylinder and the calipers.
10. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 204 kPa), the pressure comes up rapidly on both gauges and there is constant gauge pressure while the pedal is depressed but the brake pedal did not stay firm, there is probably leakage in the lines between the master cylinder and calipers.
11. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 204 kPa), the pressure comes up rapidly on both gauges, there is constant gauge pressure while the pedal is depressed and the brake pedal stays firm, the system is good. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**. If the problem still exists, check the foundation brakes.

See **Fig. 1** and **Fig. 2** for views of the hydraulic brake system wiring.

NOTE: Technicians can refer to wiring diagrams in PartsPro, Module 877, in addition to those shown here.

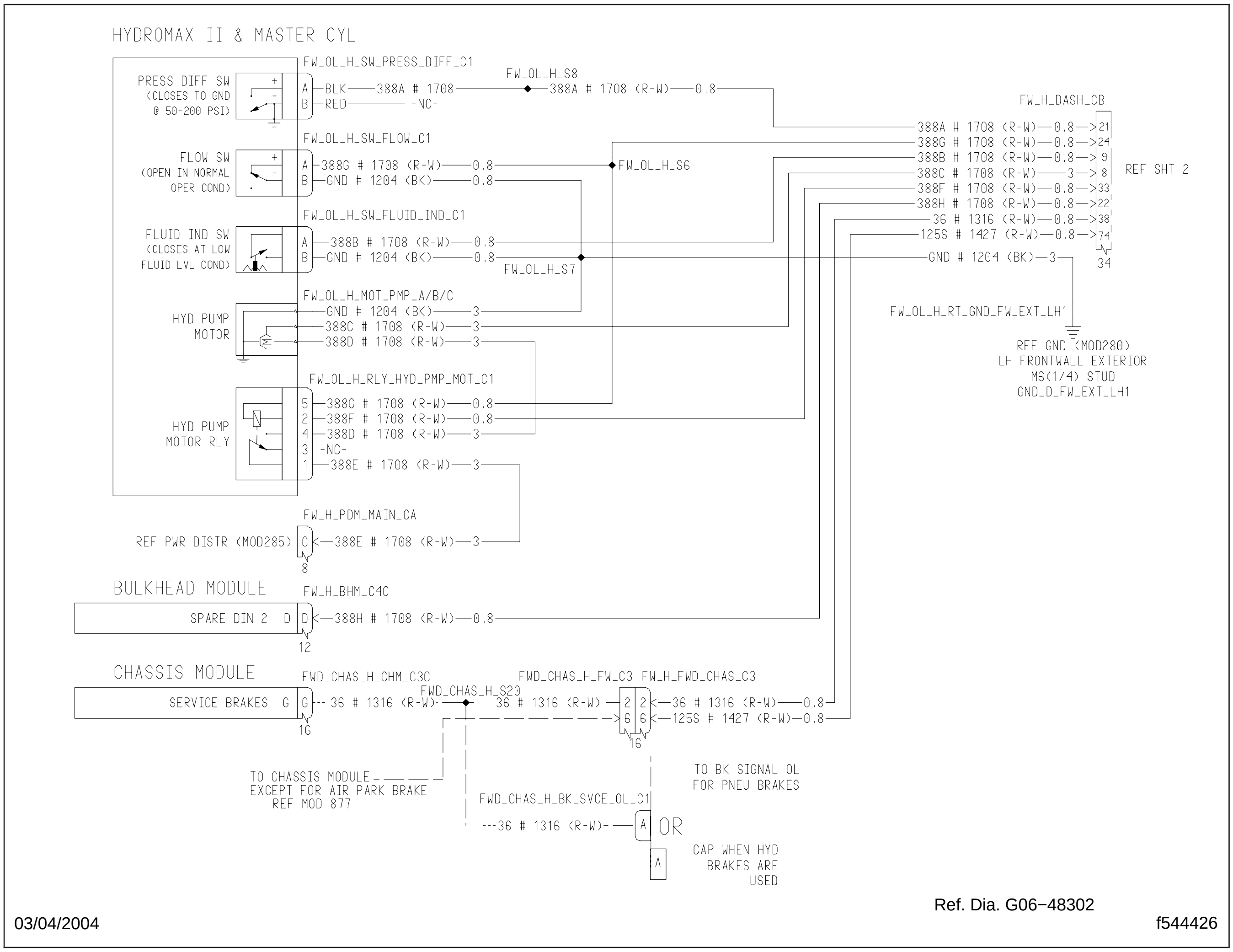


Fig. 1, Hydraulic Brake Frontwall Wiring

Specifications

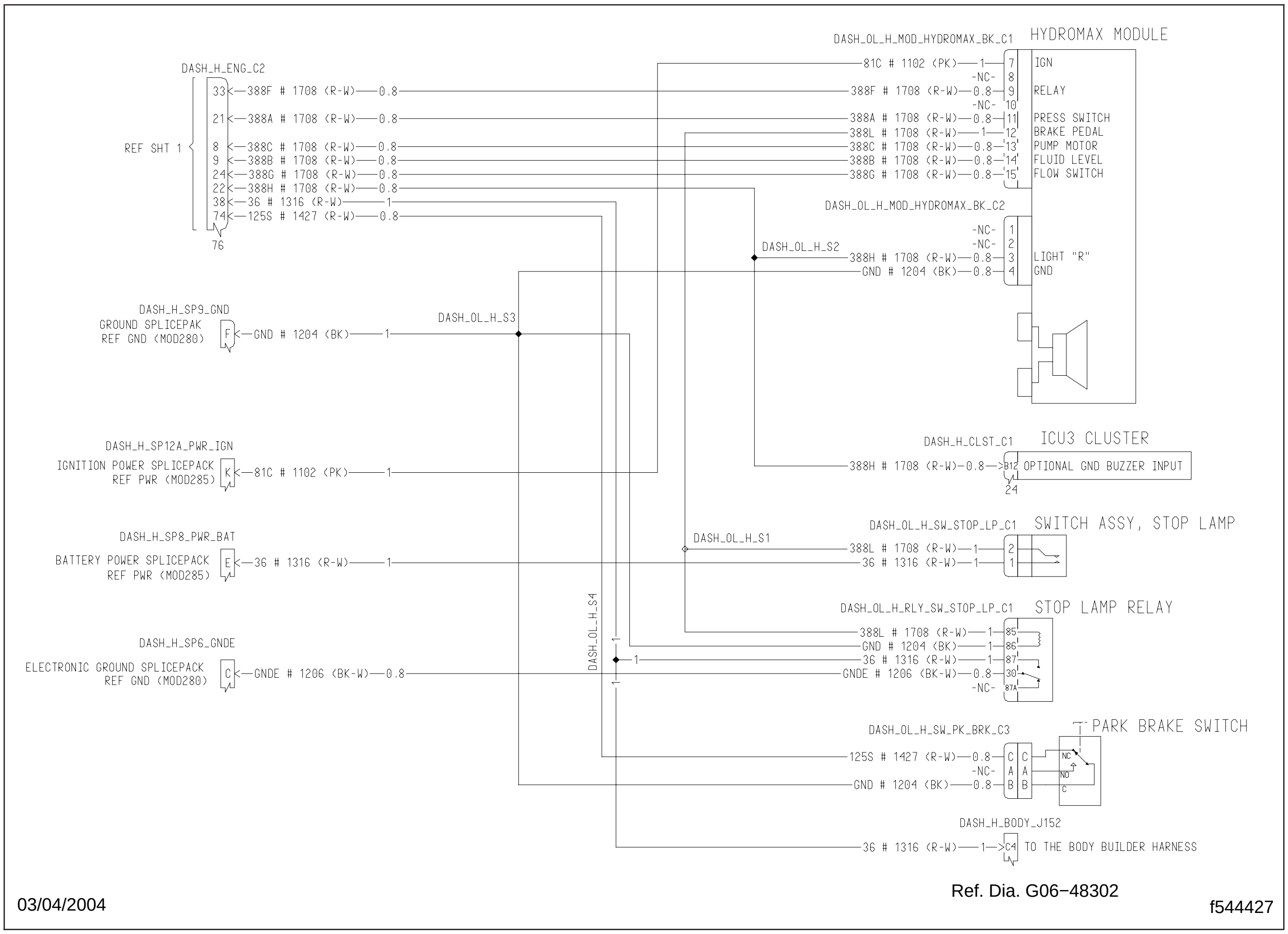


Fig. 2, Hydraulic Brake Dash Wiring

Fastener Torque Values		
Description	**Torque: lbf·in (N·cm)**	**Torque: lbf·ft (N·m)**
Power Brake Booster Mounting Bolts	—	16–24 (22–32)
Master Cylinder Tube Nuts	—	16 (22)
Master Cylinder Mounting Nuts	—	25–29 (34–39)
Power Brake Booster Supply Line Fitting	—	16–26 (22–34)
Backup Pump Mounting Screws	—	18–25 (24–34)
Relay Mount Screw	75–81 (850–915)	—
Flow Switch Contact Assembly	27–33 (300–375)	—
Differential Pressure Switch Contact Assembly	9–15 (100–170)	—
Backup Pump Terminal Nut	13–21 (145–235)	—

Table 1, Fastener Torque Values

Specifications

Approved Fluid for Power Brake Booster	
Fluid Type	**Recommended Fluid**
Automatic Transmission Fluid (ATF)	Dexron® VI

Table 2, Approved Fluid for Power Brake Booster

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluid**
DOT 3 Brake Fluid	Wagner-Premium Plus Super HD Delco Supreme II Dow HD 50-4

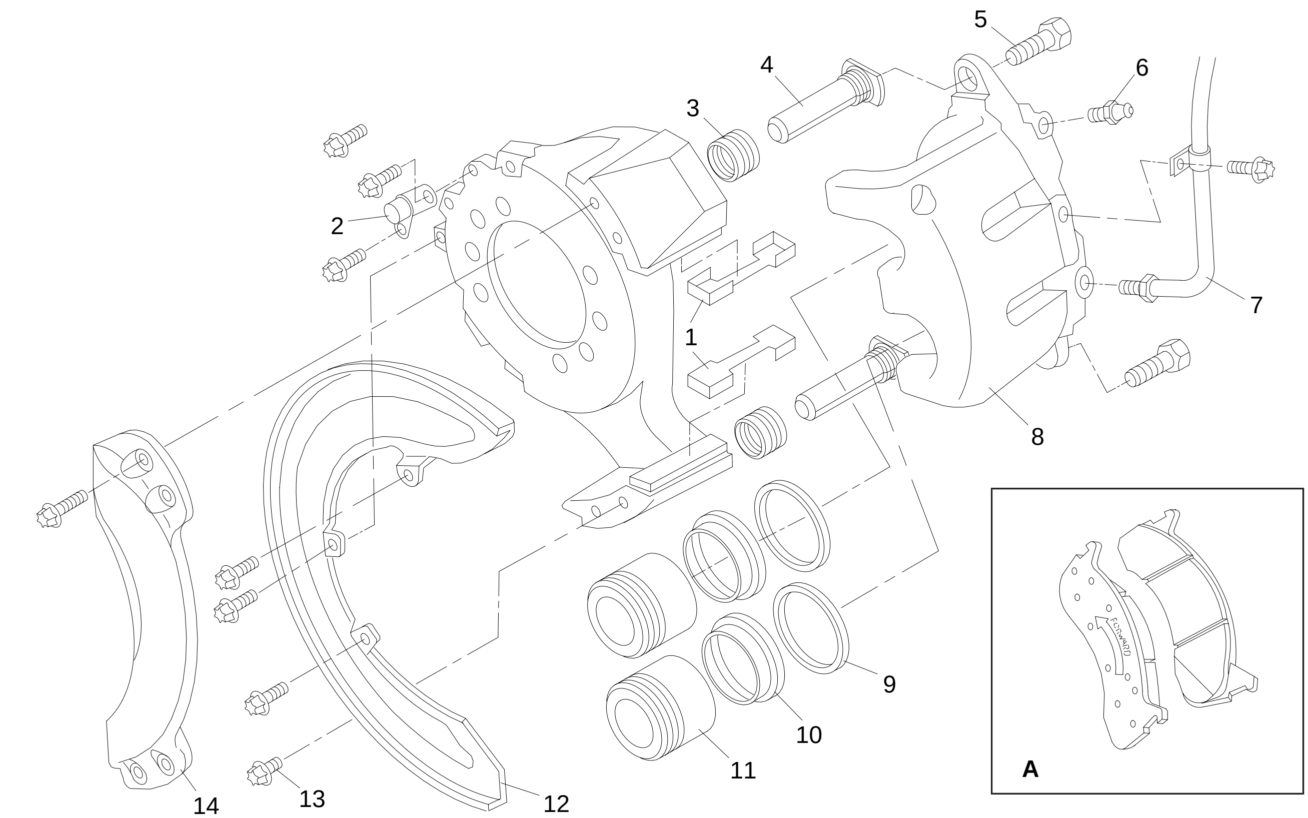
Table 3, Approved Brake Fluid for Brake System

General Information

Bosch® hydraulic pin slide disc brakes are two-piston sliding caliper brakes for use at both front and rear wheels. See **Fig. 1**. Each pin slide caliper disc brake wheel installation is comprised of three major components. See **Fig. 2**.

Caliper Assembly

The caliper assembly includes two hydraulic piston bores. The piston bores contain the pistons, piston seals, and piston boots. The caliper assembly attaches to and slides on sealed pins located in an anchor plate. The anchor plate is mounted on the steering knuckle flange on front axles or on the axle flange on rear axles. Two sizes of calipers are used: 66 mm Twin (2 piston) and 73 mm Twin (2 piston). See **Fig. 3**.



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A. Brake Pads

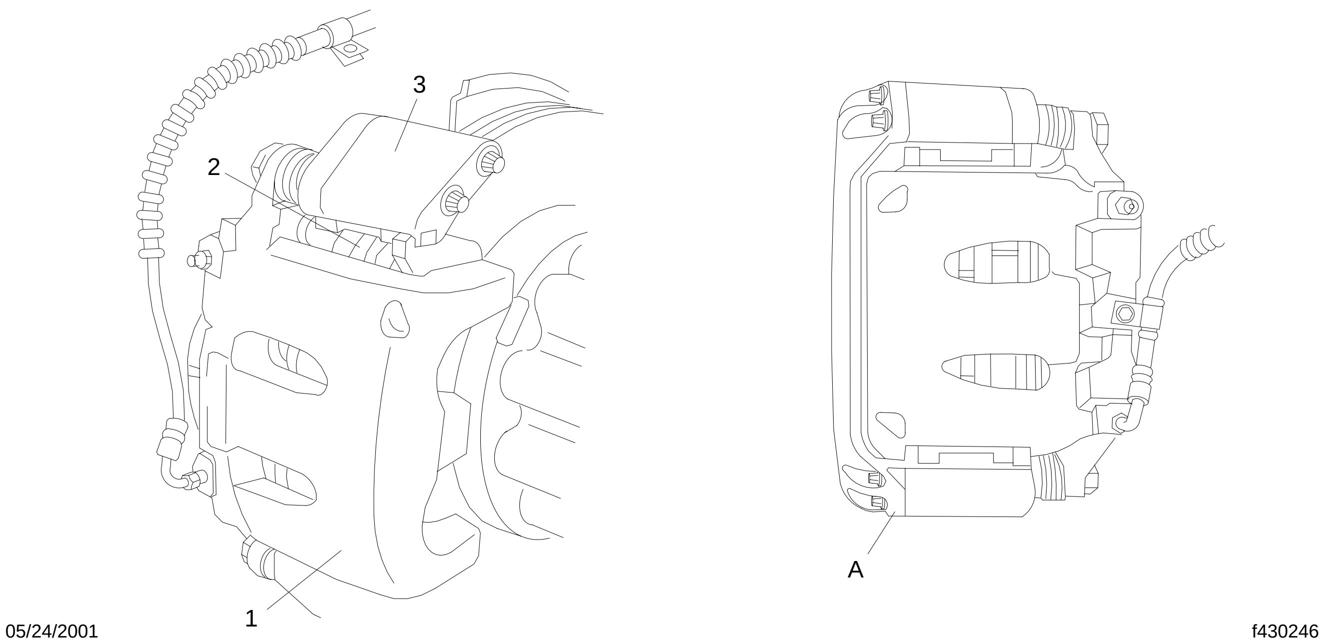
1. Slipper
2. Antilock Brakes Sensor Bracket
3. Guide Pin Boot
4. Guide Pin
5. Guide Pin Bolt
6. Bleed Screw
7. Brake Line
8. Caliper
9. Caliper Boot Seal
10. Piston Boot
11. Caliper Piston
12. Splash Shield
13. Plug (66 mm only)
14. Tie Bar (73 mm only)

Fig. 1, Pin Slide Brake (exploded view)

Disc Brake Pads

The inboard and outboard disc brake pads are positioned with both ends mounted on the anchor plate pad abutments. The pads rest on stainless steel slippers covering the anchor plate pad abutments. Inboard and outboard disc brake pads may be chamfered, and if so are marked with an arrow and the

General Information



A. 73 mm slider disc brakes incorporate a tie bar between the anchor plate abutment arms.

1. Caliper Assembly
2. Brake Pads
3. Anchor Plate Assembly

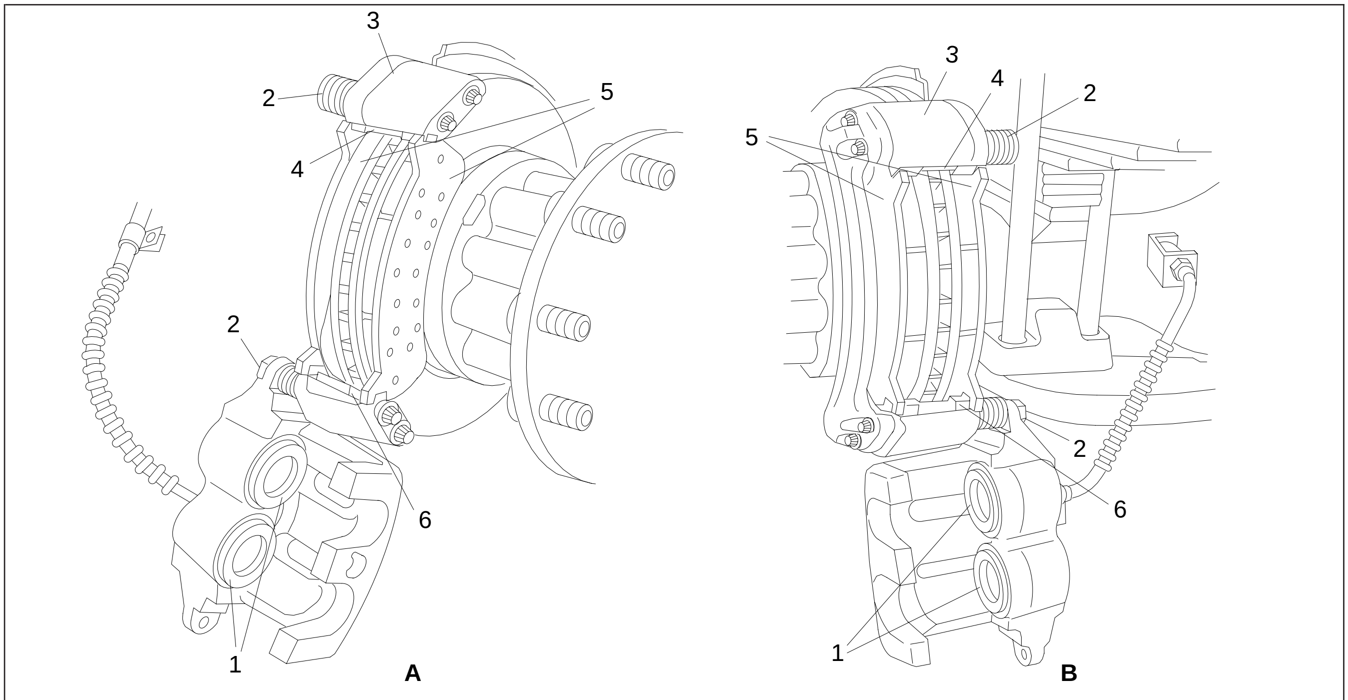
Fig. 2, Bosch Pin Slide Brakes Major Components

word FORWARD for proper installation. Brake pads may not be interchangeable inner to outer, so correct location is required during assembly.

Anchor Plate Assembly

The anchor plate includes lubricated floating guide pins sealed by rubber boots and anchor plate pad abutments protected by stainless steel slippers. A tie bar which spans the anchor plate abutment arms is used on 73 mm pin slide disc brake installations only. A splash shield on the back of the rotor helps protect the brake assembly from road contamination. Bosses are provided for mounting an antilock brake system speed sensor. See **Fig. 4**.

General Information

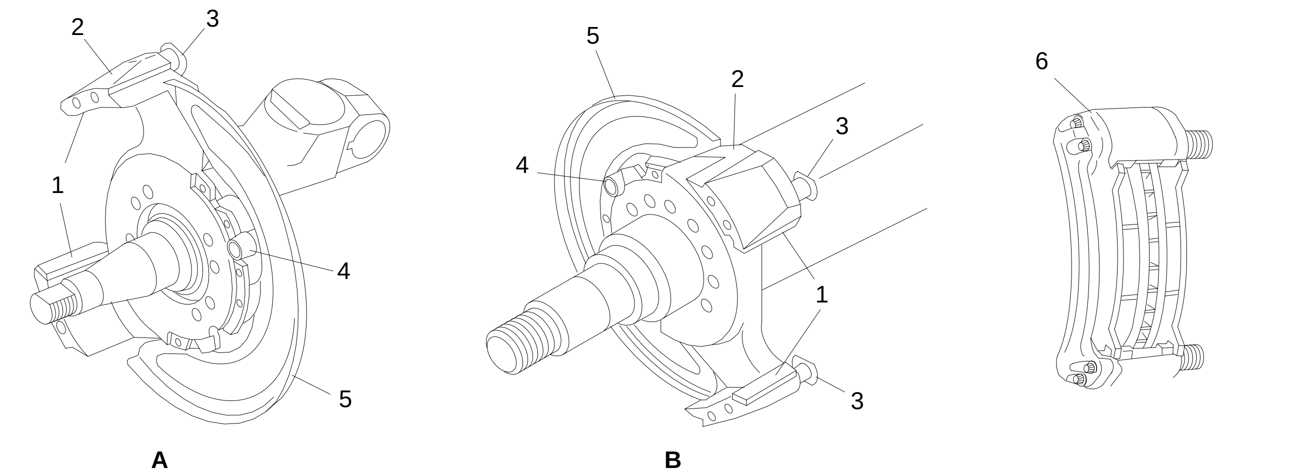


A. Front (66 mm shown)
B. Rear (73 mm shown)

1. Hydraulic Pistons with Seals and Boots
2. Sealed Pins
3. Anchor Plate
4. Upper Slipper
5. Brake Pads
6. Lower Slipper

Fig. 3, Bosch Pin Slide Brakes System Components

General Information



A. Front

1. Pad Abutment
2. Anchor Plate
3. Floating Guide Pin

B. Rear

4. Antilock Braking System Sensor Mounting
5. Splash Shield
6. Tie Bar (73 mm brakes only)

Fig. 4, Anchor Plate and Splash Shield

General Safety Precautions

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- **Always reline both sets of brakes on an axle at the same time.**
- **Always replace both rotors/drums on an axle at the same time.**
- **Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.**

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- Disconnect the batteries.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (NIOSH).

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air

Safety Precautions

(HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Brake Pad Removal, Inspection, and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

IMPORTANT: It is recommended that all disc brake pads on the vehicle be replaced at the same time. This will maintain balanced braking. If complete replacement is not desirable or necessary, make sure that at a minimum all disc brake pads on one axle (both ends) are replaced at the same time.

Removal

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brake.
2. If removing rear axle wheel pads, remove about half of the fluid from the rear section of the master cylinder reservoir. See **Fig. 1**. If removing front axle wheel pads, remove about half of the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
3. Chock the front or rear tires, depending on which axle is being worked on. Jack up the axle and support it with jackstands.
4. Remove the tires.
5. Inspect all brake pad linings. Lining pads should be replaced when the remaining lining reaches 3/16-inch (5-mm) thickness or less.

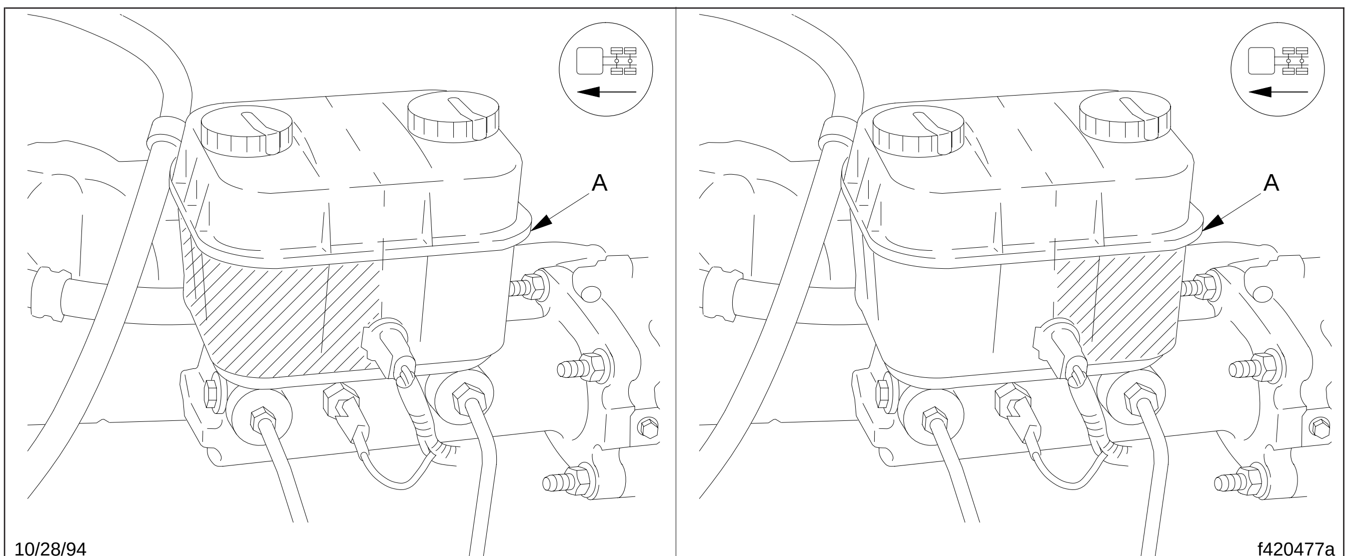
CAUTION

Care must be taken when positioning the pry bar. Incorrect positioning of the pry bar could result in damage to the caliper.

6. Insert a pry bar in one of the rotor cooling fin slots and pry the caliper outboard, pushing the caliper pistons into the piston bores. See **Fig. 2**.
7. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 2**.

IMPORTANT: When servicing disc brake pads only, remove the upper (top) caliper guide pin bolt. Do not loosen the lower (bottom) guide pin bolt. See **Fig. 3**.

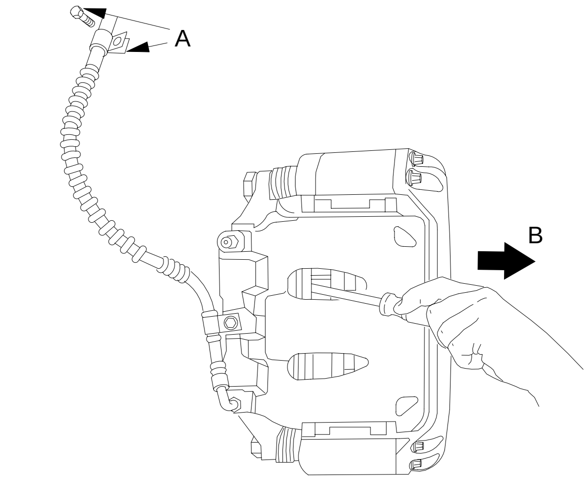
8. Remove only the upper (top) guide pin bolt.



A. Fill Level for brake fluid.

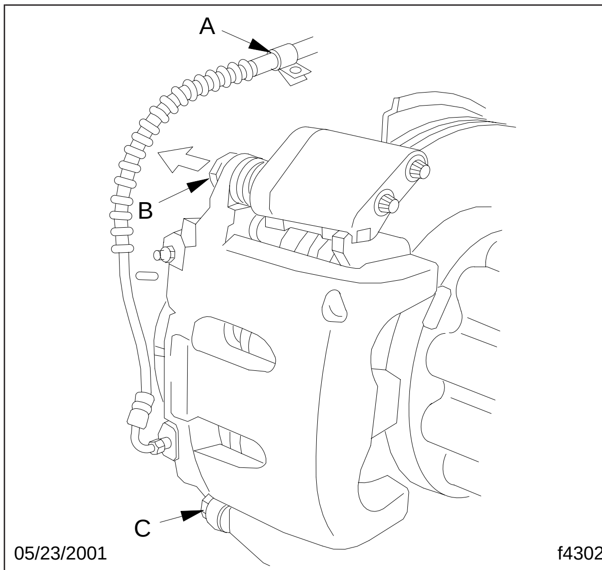
Fig. 1, Master Cylinder Reservoir

Brake Pad Removal, Inspection, and Installation



A. Remove this screw and clip on front axles only.
B. Move the caliper outboard to push the pistons in.

Fig. 2, Piston Retraction and Brake Line Clip Removal



A. Make sure this clip is detached from the support bracket.
B. Remove the upper guide pin bolt.
C. Do not loosen the lower guide pin bolt.

Fig. 3, Caliper Upper Guide Pin Bolt Removal

IMPORTANT: Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

9. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower guide pin and bolt. See **Fig. 4**. Do not allow the brake line hose to become pinched or kinked.
10. Remove the inboard and outboard disc brake pads from the anchor plate pad abutment slippers.

IMPORTANT: Do not mark on the pad face.

11. If the original disc brake pads are to be reused, be sure to mark them in some manner so that they are installed in the same location.

Inspection

IMPORTANT: Do not damage or dislodge the guide pin boots while cleaning the machined surfaces.

1. Inspect the machined surfaces of the caliper, guide pin mounting face, and anchor plate. If rust or corrosion is present, use a hand-held wire brush to clean the surfaces.
2. Inspect the caliper, piston seals, and pistons for leakage or damage. If leakage or damage is found, repair or replace the piston(s) as required.
3. Inspect the anchor plate for damage to the mating surfaces at the anchor plate pad abutment slippers and guide pin heads. If damage is found, repair or replace as required.
4. Inspect the rotor for scoring, warping, cracks, bluing, heat spots, or other damage. See **Fig. 5**. If any damage is found, repair or replace the rotor. For instructions, see **Subject 140**.

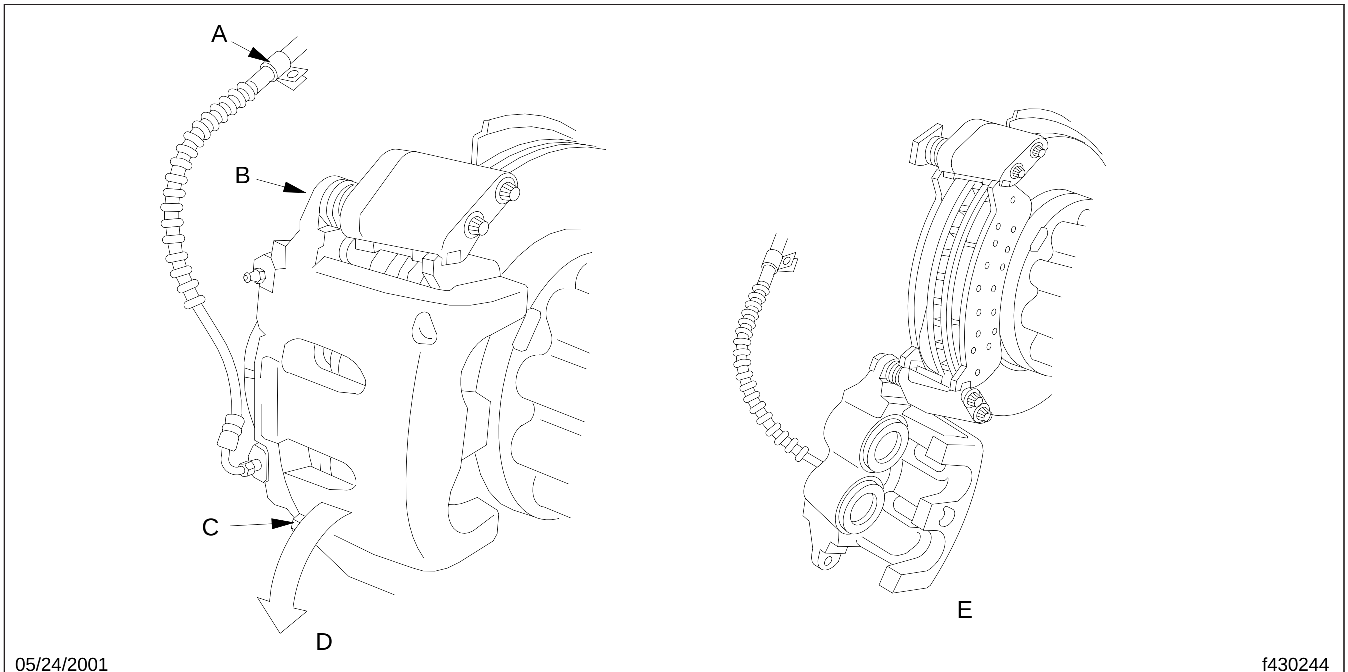
Installation

1. Position a metal plate across both caliper pistons. Use a C-clamp to push both pistons into the caliper to provide clearance for the new disc brake pads. See **Fig. 6**.

CAUTION

When replacing disc brake pads, use the same lining material on both axles. Mixing lining types

Brake Pad Removal, Inspection, and Installation



A. Make sure this clip is detached from the support bracket.
B. Upper guide pin bolt has been removed.
C. Do not loosen the lower guide pin bolt.
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 4, Opening the Caliper to Access Brake Pads and Pistons

can result in unbalanced braking, increased pad wear, or degraded stopping performance.

IMPORTANT: Inboard and outboard brake pads may not be interchangeable. The word FORWARD and a forward rotor rotation direction arrow may appear on each pad backing plate. Orient the pads as indicated by the arrow.

2. Position the inboard and outboard disc brake pads onto the anchor plate pad abutment slippers with the lining facing toward the rotor. See **Fig. 7**.

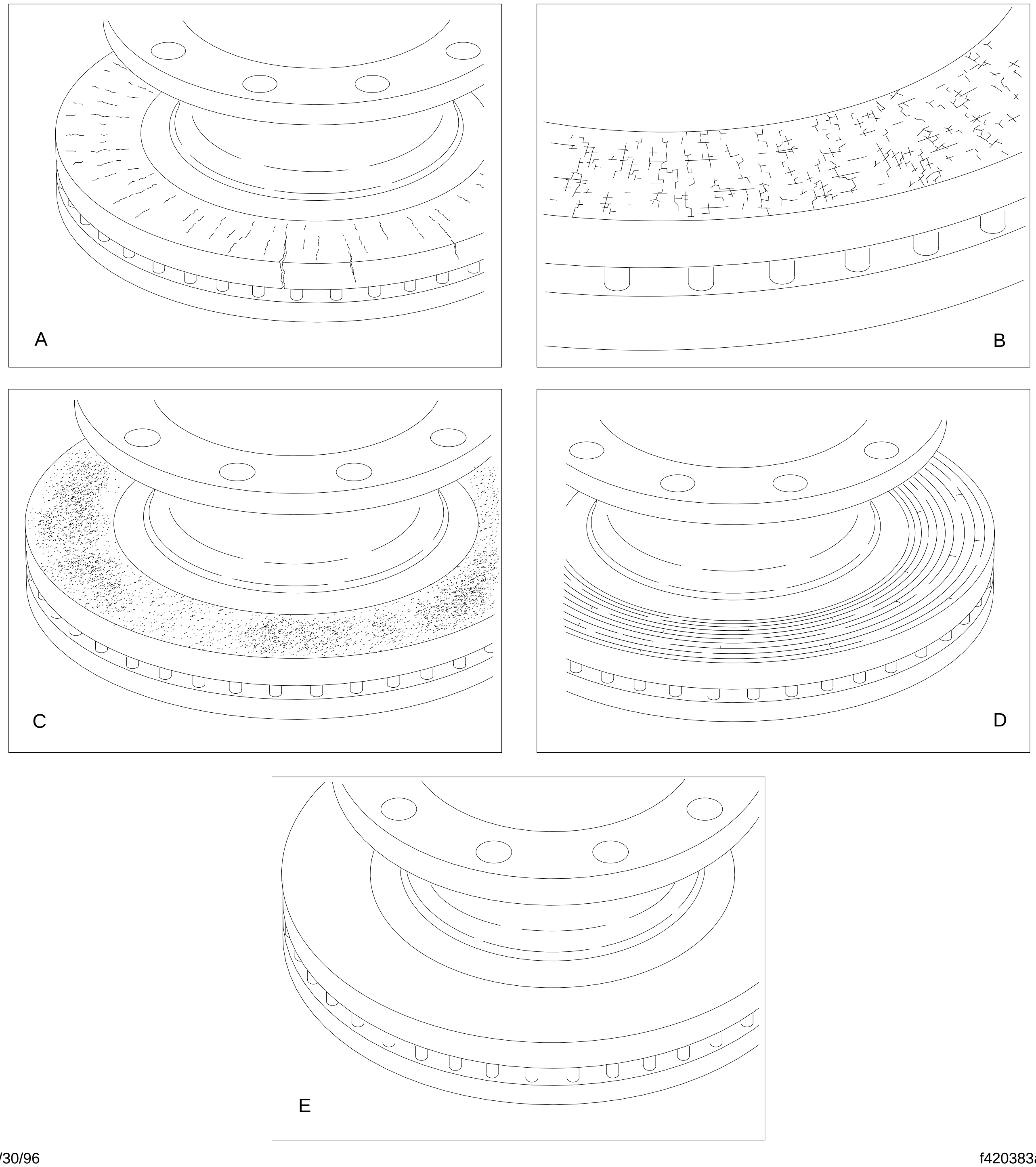
IMPORTANT: Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head, to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

3. Carefully rotate the caliper closed about the lower guide pin and bolt. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 8**.

IMPORTANT: Do not overtighten caliper pin bolts. Increased brake drag may result from incorrect tightening. If the lower guide pin bolt was loosened, see **Fig. 9** before tightening either the upper or lower guide pin.

4. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand thread the guide pin bolt, then tighten it 93 to 107 lbf·ft (126 to 145 N·m). See **Fig. 9**.
5. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
6. Inspect all components serviced. Make sure the guide pins are tightened according to the specifications in this procedure. Make sure the pads are seated and positioned to slide along the pad abutment slippers.
7. Install the tires, remove the jackstands, and lower the vehicle.

Brake Pad Removal, Inspection, and Installation



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 5, Rotor Surface Check

Brake Pad Removal, Inspection, and Installation

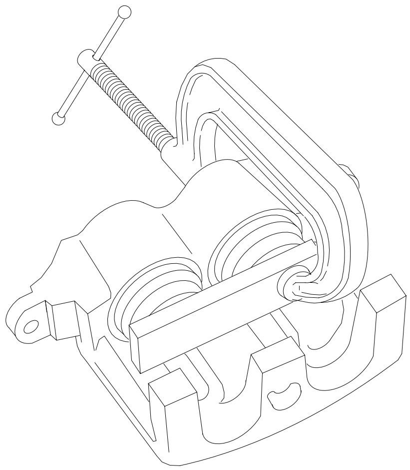


Fig. 6, Retracting Pistons Into the Caliper

8. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.
9. Pump the brake pedal until it feels firm. If it does not get firm, check for leaks or air in the brake system. Repair any leaks, if needed, then bleed the system, following the instructions in **Subject 160**.

WARNING

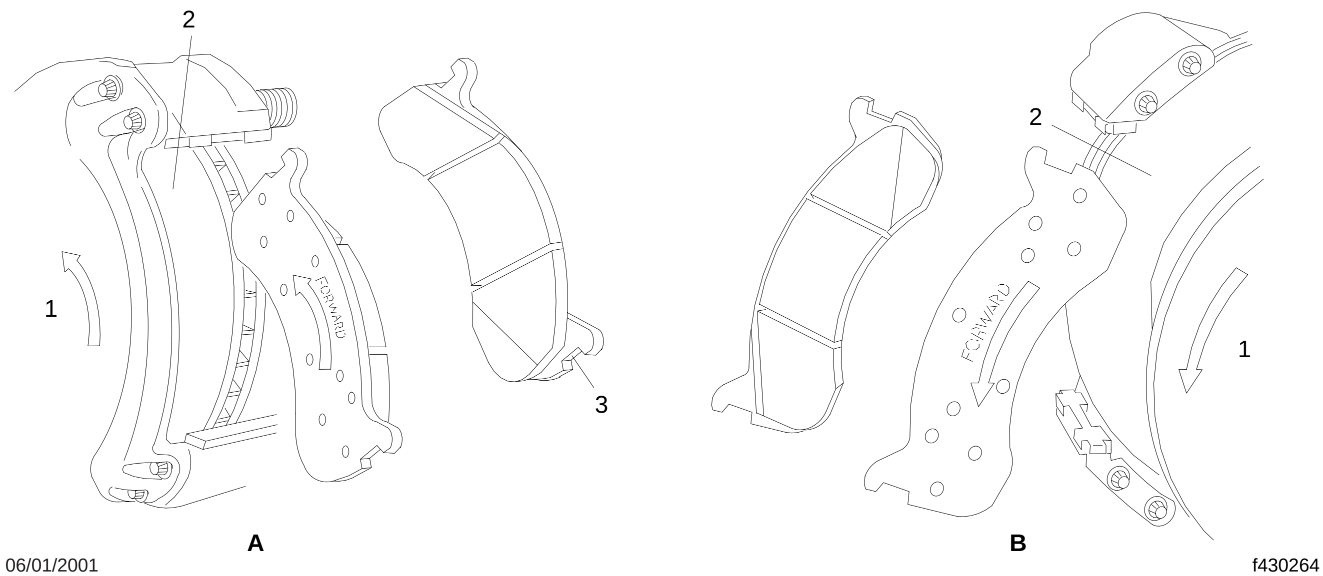
Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

10. Close the hood and remove the chocks from the tires.
11. Road test the vehicle and seat the brake pads, as follows.

    11.1 Accelerate the vehicle to 30 mph (48 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

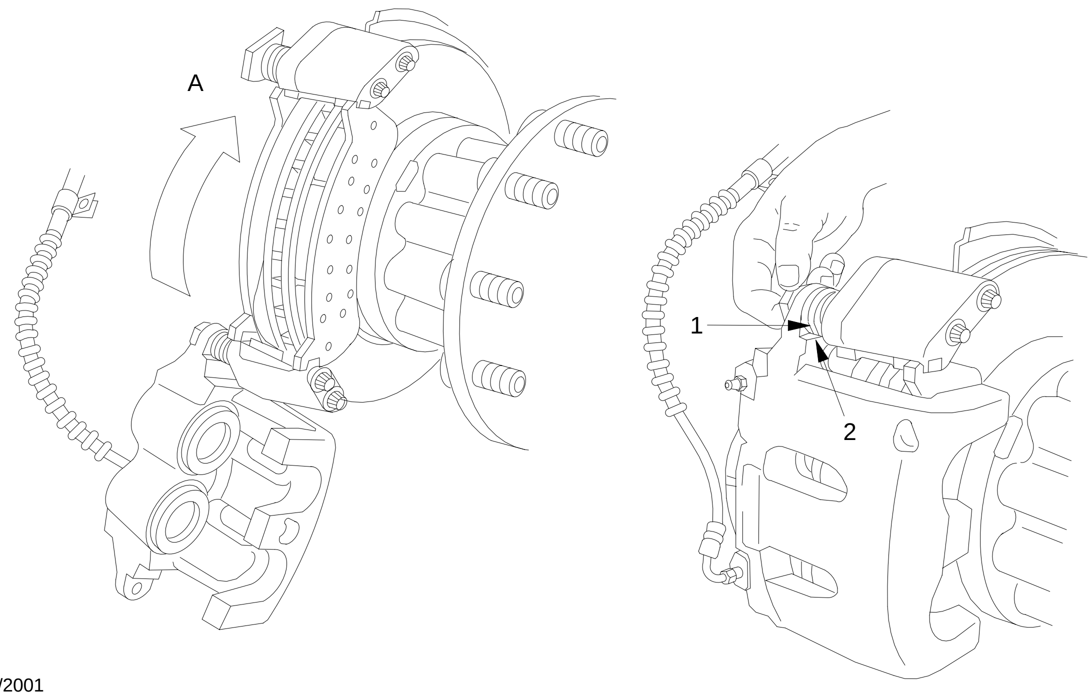
    11.2 Repeat this step between 4 or 5 times, allowing a one-minute interval between brake applications.

Brake Pad Removal, Inspection, and Installation



A. Driver Side Rear
B. Driver Side Front
1. Wheel Rotation
2. Rotor Face
3. Pad Notch

Fig. 7, Replacing Brake Pads on Front and Rear Brakes

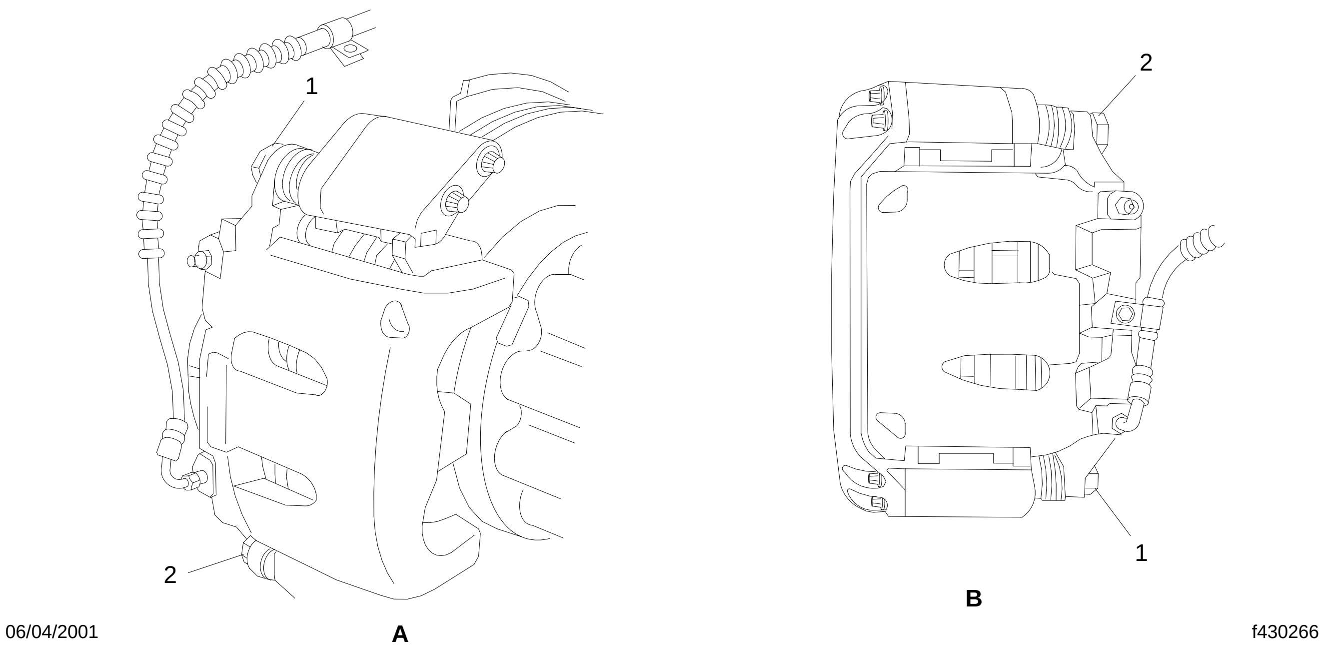


A. Swing the caliper up into position.

1. Flat on Guide Pin
2. Flat on Caliper

Fig. 8, Closing the Caliper Over Brake Pads and Rotor

Brake Pad Removal, Inspection, and Installation



A. Front Brakes
1. Tighten First
B. Rear Brakes
2. Tighten Second

Fig. 9, Tightening Sequence for Caliper Mounting Bolts

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine.
2. Open the hood.
3. If removing the rear wheel caliper(s), remove half the fluid from the rear section of the master cylinder reservoir. See **Fig. 1**. If removing the front wheel caliper(s), remove half the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Chock the front or rear tires, depending on which axle is being worked on. Jack up the axle and support it with jackstands.
5. Remove the tires.
6. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 2**.
7. Remove the upper (top) guide pin bolt. See **Fig. 2**.

CAUTION

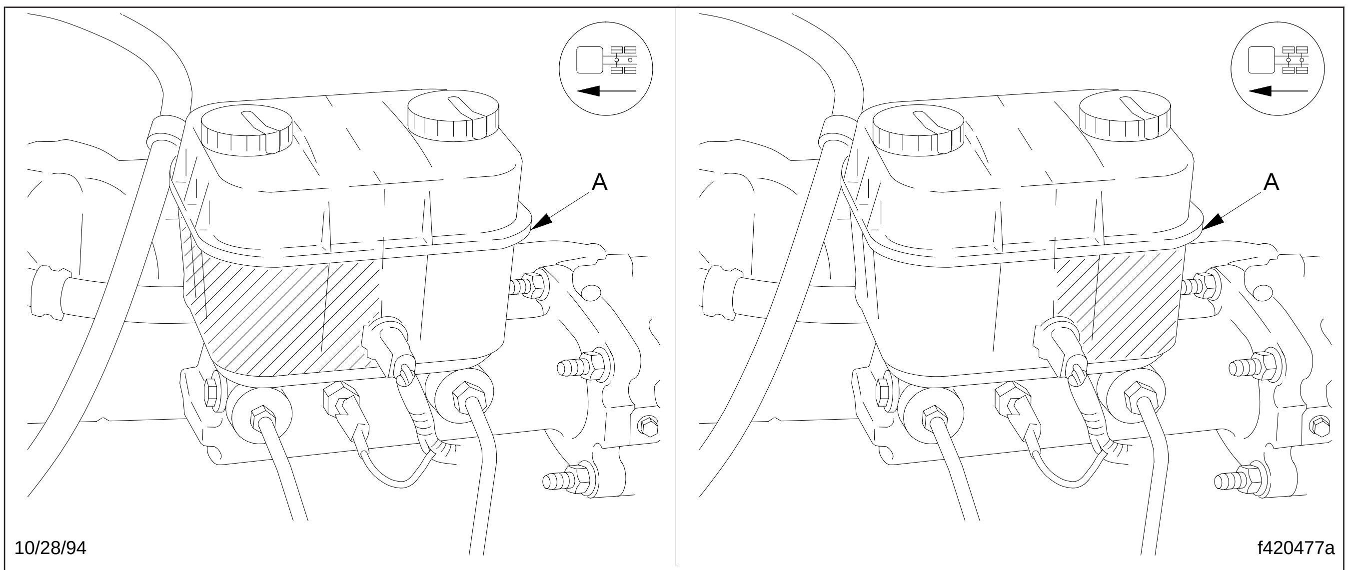
Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

8. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower guide pin and bolt. See **Fig. 3**. Do not allow the brake line hose to become pinched or kinked.
9. Disconnect the brake fluid line from the caliper. See **Fig. 4**.
10. Remove the lower guide pin bolt and remove the caliper from the anchor plate.

Installation

IMPORTANT: Use isopropyl alcohol to clean the brake seals, boots, and pistons. Do not soak components for an extended period of time.

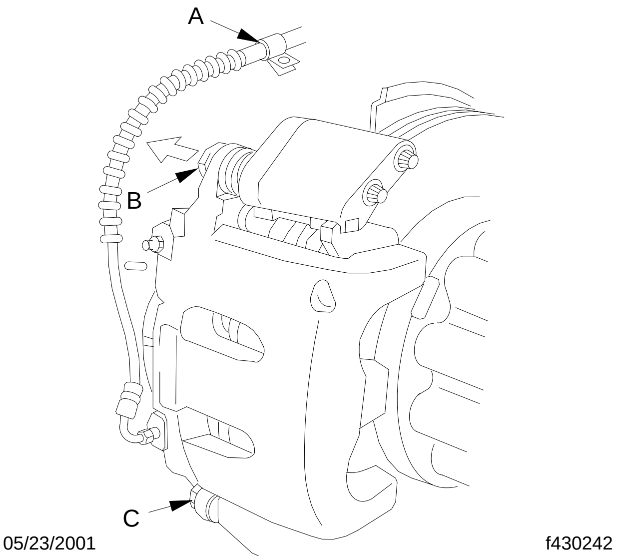
1. Clean contamination, dirt, and debris from the exterior of the caliper, machined faces, and around the caliper piston boots.



A. Fill level for brake fluid.

Fig. 1, Master Cylinder Reservoir

Brake Caliper Removal and Installation



A. Make sure this clip is detached from the support bracket.
B. Remove the upper guide pin bolt.
C. Do not loosen the lower guide pin bolt.

Fig. 2, Upper Guide Pin Mounting Bolt Removal

2. Inspect the caliper for brake fluid leakage or damage to pistons or piston boots. If there is leakage or damage, the caliper should be repaired or replaced. For repair instructions, see **Subject 130**.
3. Make sure the pistons are fully retracted into the caliper. Piston boots must be fully seated in the piston boot groove and the boot grooves in the caliper face.
4. Position the caliper on the anchor plate with the caliper lower guide pin boss hole aligned with the threaded hole in the lower guide pin head. Hand-thread the guide pin bolt through the caliper and into the anchor plate.

IMPORTANT: Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

5. Carefully rotate the caliper closed about the lower guide pin and bolt. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 5**.

IMPORTANT: Always tighten caliper guide pin bolts in the proper sequence. Do not overtighten caliper guide pin bolts. Increased brake drag may result from incorrect tightening. See **Fig. 6** and **Fig. 7** before tightening either the upper or lower bolt.

6. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand-thread the upper guide pin bolt. Then tighten the upper and lower guide pin bolts 93 to 107 lbf·ft (126 to 145 N·m) in the order shown in **Fig. 6** and **Fig. 7**.
7. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
8. If the brake supply hose was disconnected, connect it, as follows.

   8.1 Tighten the brake supply hose fitting 15 lbf·ft (20 N·m).

   8.2 Bleed the brake supply line to the caliper, following the instructions in **Subject 160**. If you have removed more than one brake caliper, bleed the entire brake system.
9. Install the tires, remove the jackstands, and lower the vehicle.
10. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.
11. Close and latch the hood.
12. Remove the chocks from the tires.

WARNING

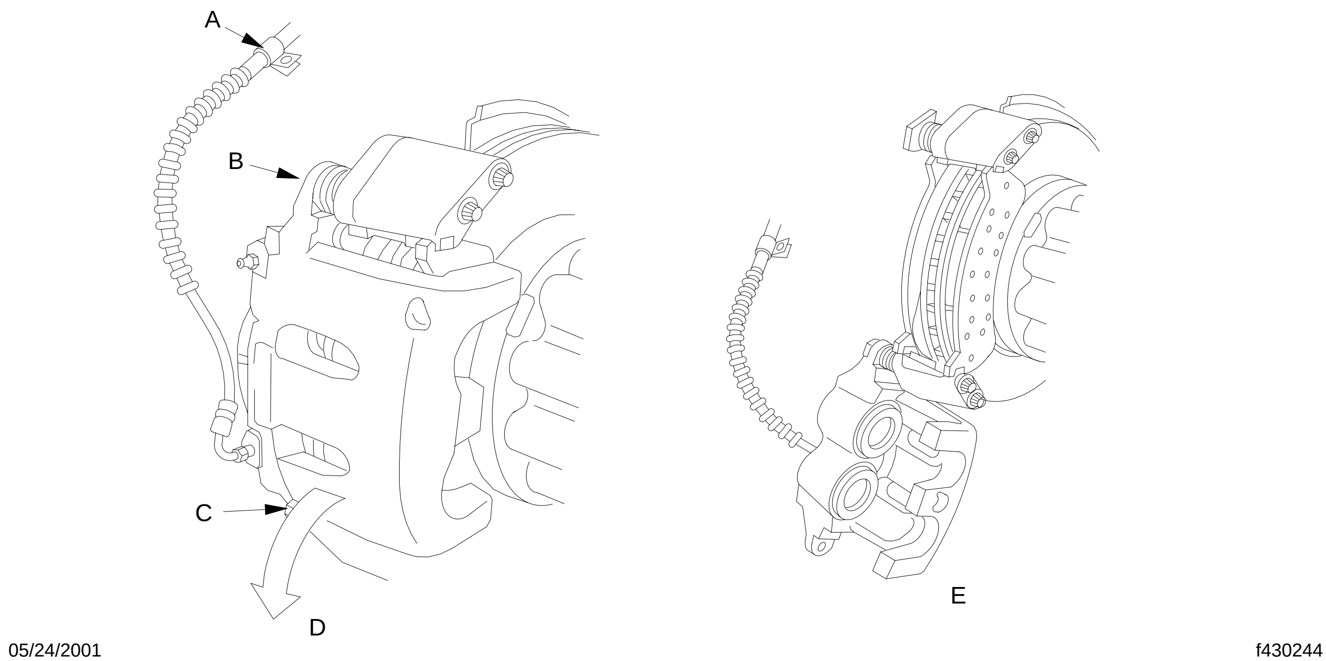
Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

13. Seat the brake pads by pressing firmly on the brake pedal several times.

    If new brake pads were installed, road test the vehicle to seat the brake pads, as follows.

    13.1 Accelerate the vehicle to 30 mph (48 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

Brake Caliper Removal and Installation

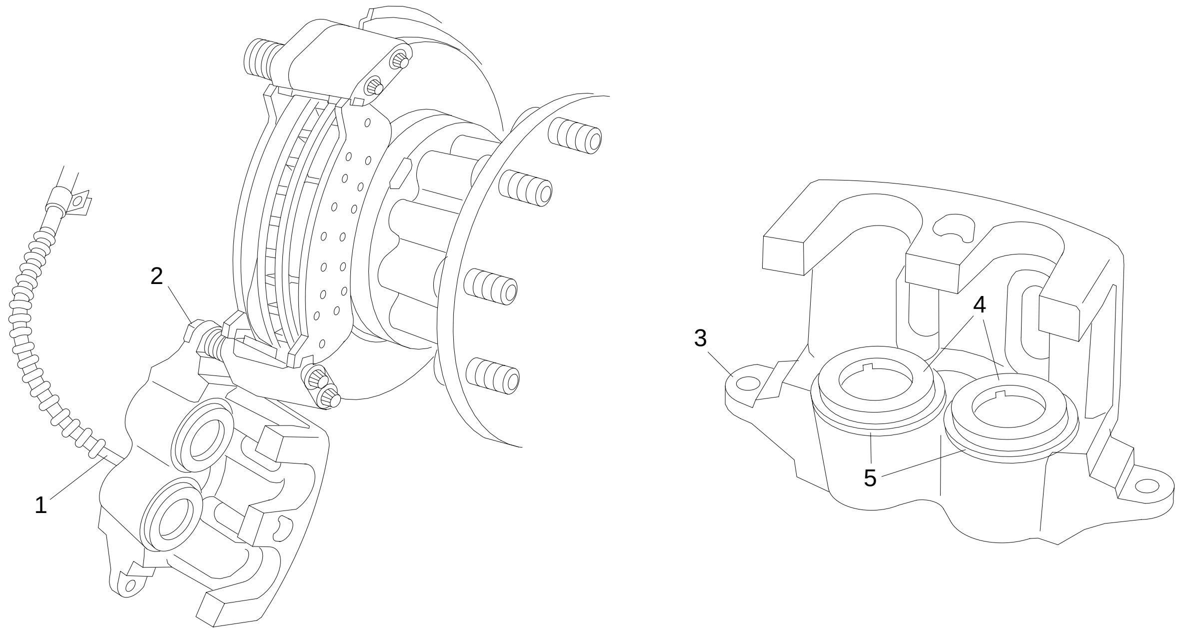


A. Make sure this clip is detached from the support bracket.
B. Upper guide pin bolt has been removed.
C. Lower Guide Pin Bolt (remove after caliper is lowered).
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 3, Swinging the Caliper Down (Open)

13.2 Repeat this step four or five times, allowing a one-minute interval between brake applications.

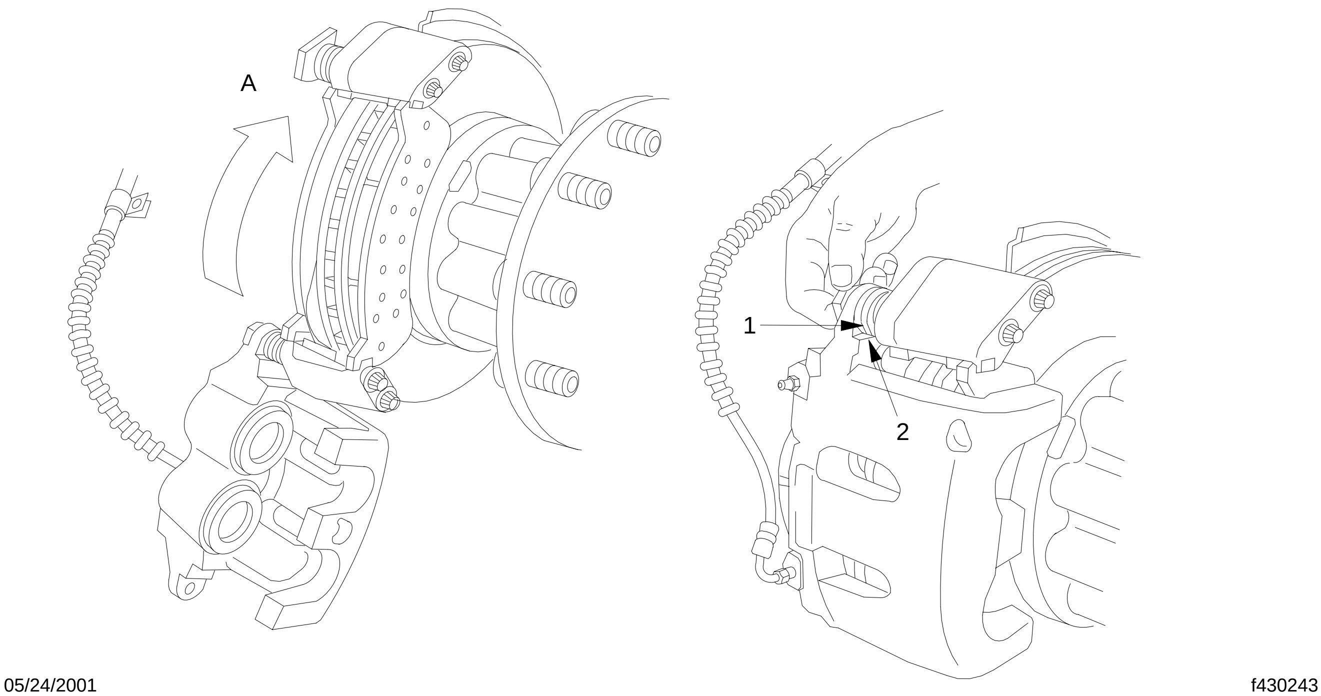
Brake Caliper Removal and Installation



1. Brake Line
2. Lower Guide Pin Bolt
3. Machined Face
4. Pistons
5. Piston Boots

Fig. 4, Removing the Caliper from the Anchor Plate

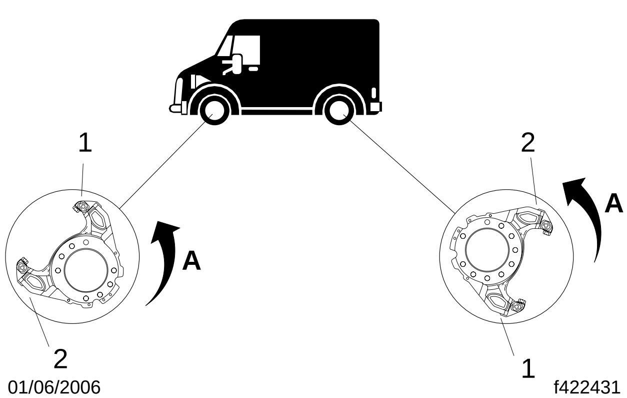
Brake Caliper Removal and Installation



A. Swing the caliper up into position.

1. Flat on Guide Pin
2. Flat on Caliper

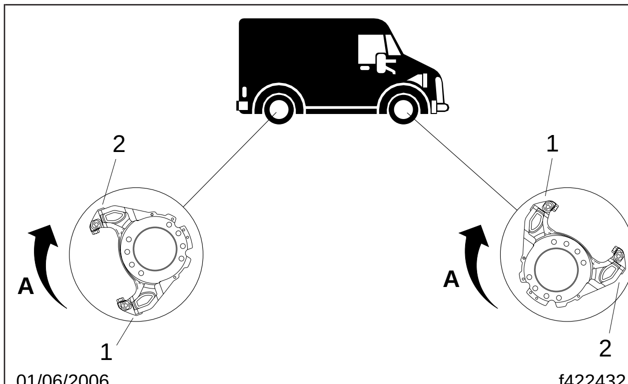
Fig. 5, Closing the Caliper Over the Brake Pads and Rotor



A. Direction of Rotation (forward motion)

1. Tighten First
2. Tighten Second

Fig. 6, Tightening Sequence for Caliper Mounting Bolts, Left Side



A. Direction of Rotation (forward motion)

1. Tighten First
2. Tighten Second

Fig. 7, Tightening Sequence for Caliper Mounting Bolts, Right Side

Brake Rotor Removal and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Remove the brake caliper from the rotor, following the instructions in **Subject 120**.
3. Remove the hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle. Put the hub on the floor so the rotor is facing up.
4. Remove the brake rotor from the wheel hub. Remove the hexbolts and washers that attach the rotor to the hub. See **Fig. 1**. Lift the brake rotor off the hub.

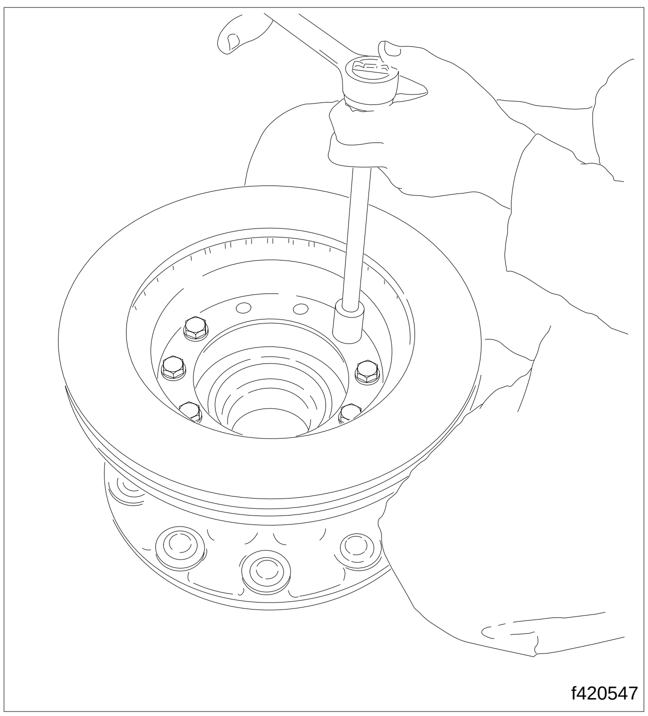
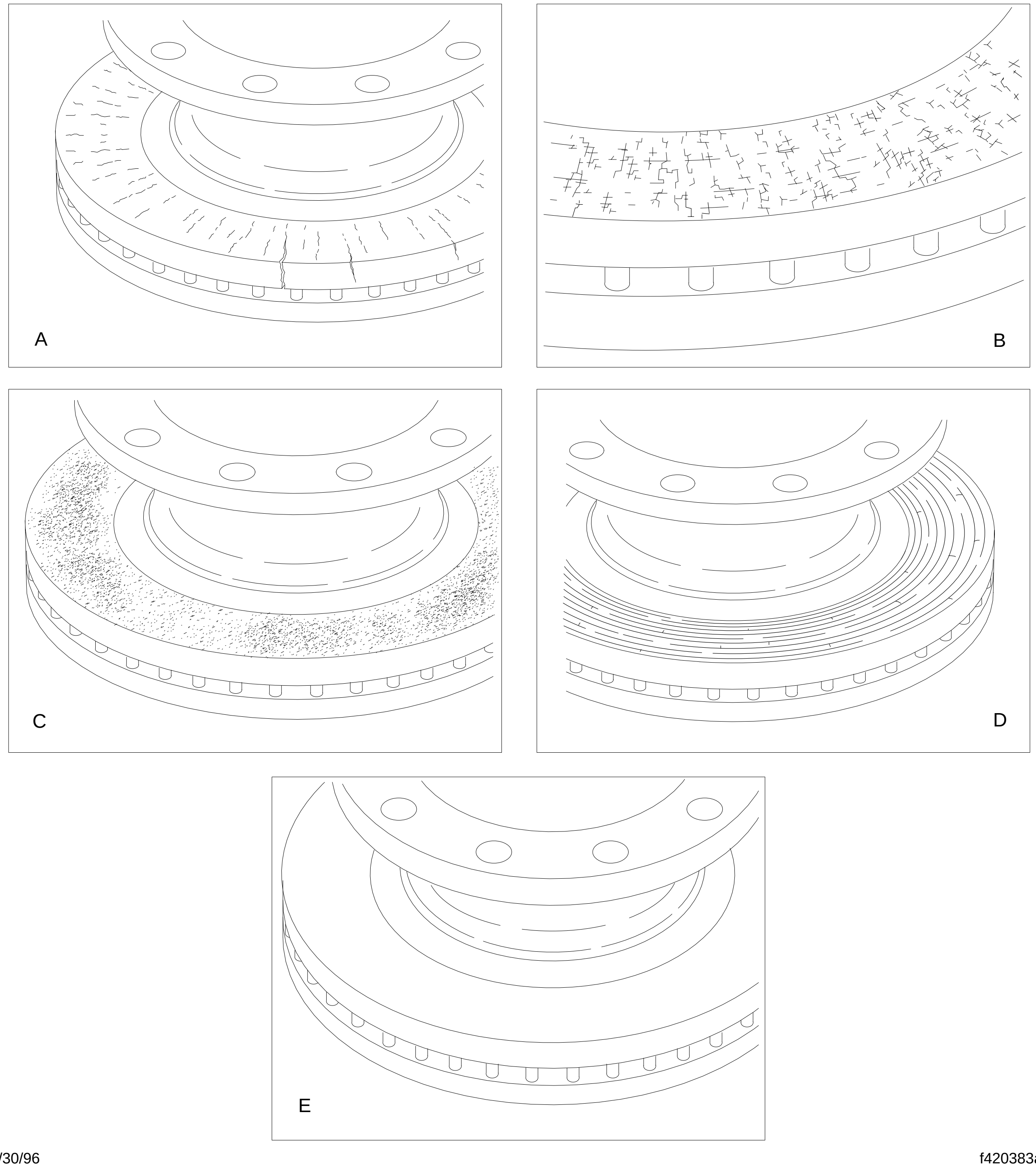


Fig. 1, Rotor-to-Hub Fasteners

Installation

1. Inspect the rotors for scoring, warping, cracks, bluing or heat spots, or other damage. See **Fig. 2**. If signs of damage are found, the rotor should be resurfaced or replaced.
2. Install the rotor on the wheel hub, as follows.
   - 2.1 Position the rotor on the hub as shown in **Fig. 3**. Make sure the holes in the rotor are lined up with those of the hub.
   - 2.2 Install the mounting hexbolts and washers. Using a star pattern, tighten the hexbolts 130 lbf·ft (175 N·m). See **Fig. 4**.
3. Install the hub and rotor assembly on the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
4. Check rotor runout and parallelism. For instructions, see **Subject 140**.
5. Install the brake caliper on the rotor, following the instructions in **Subject 120**.

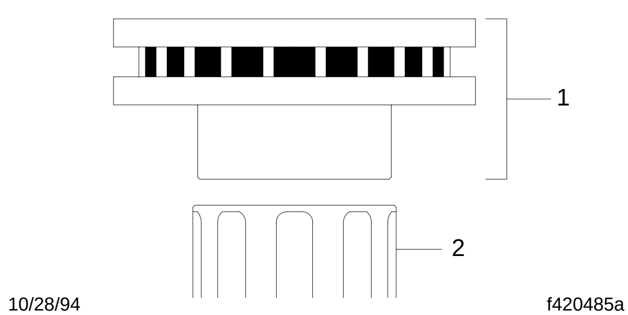
Brake Rotor Removal and Installation



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 2, Rotor Surface Check

Brake Rotor Removal and Installation



1. Rotor
2. Wheel Hub

Fig. 3, Rotor-to-Hub Position

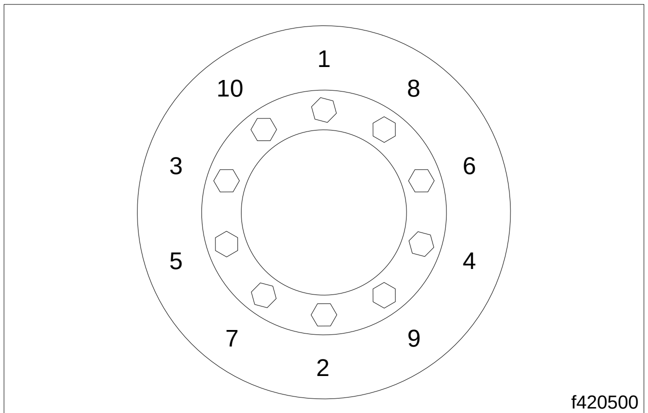
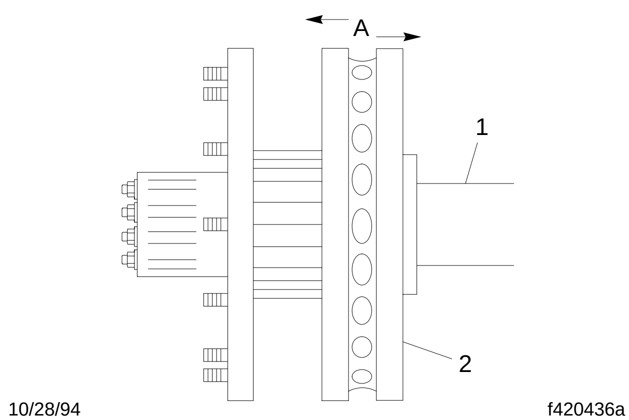


Fig. 4, Tightening Pattern

Runout Check

Brake rotor runout refers to the amount of lateral wobble the rotor has when it is turning, with the wheel bearings correctly adjusted. See **Fig. 1**. Check the rotor runout whenever you replace the brake pads.



A. Runout

1. Axle
2. Rotor

Fig. 1, Brake Rotor Runout

1. If not already done, chock the tires, jack up the axle you are working on and support it with jackstands. Remove the wheels and tires.
2. If working on the rear axle, put the transmission in neutral.
3. Using a dial indicator, measure the amount of runout while spinning the rotor, as shown in **Fig. 2**. Make sure the indicator is centered on the rotor face (between the outer and inner edges).
4. If the runout is more than 0.015 inch (0.38 mm), check that the rotor is securely mounted to the hub. Also check the wheel bearing end-play, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
5. Repeat the runout measurement. If the runout is still more than 0.015 inch (0.38 mm), replace the rotor.

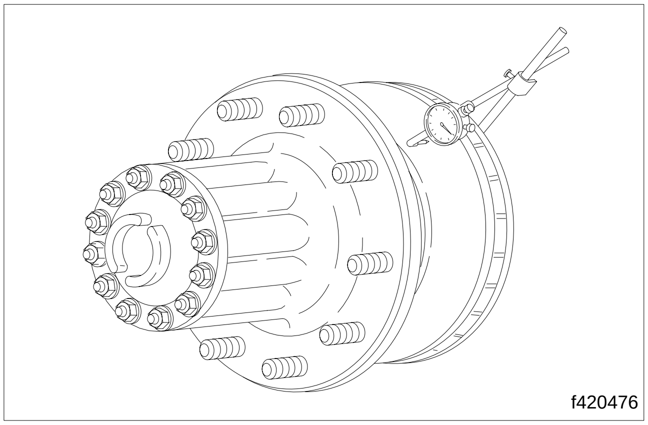
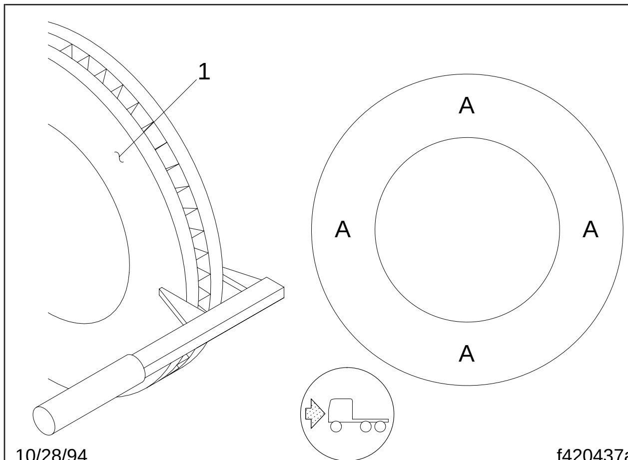


Fig. 2, Measuring Runout

Parallelism Check

Parallelism is the difference in rotor thickness at different points around the rotor. It should be checked whenever the brake pads are replaced.

1. Using a micrometer, measure the thickness of the rotor (between the inboard and outboard faces) at four or more equally spaced points around the rotor. See **Fig. 3**.



A. Measure thickness here.

1. Rotor Face

Fig. 3, Measuring Rotor Thickness

2. If there is a difference of more than 0.005 inch (0.13 mm) between any two measurements, have the rotor resurfaced. If resurfacing will de-

Brake Rotor Runout and Parallelism Check

crease the overall thickness of the rotor to 1.32 inches (33.5 mm) or less, replace the rotor.

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly

WARNING

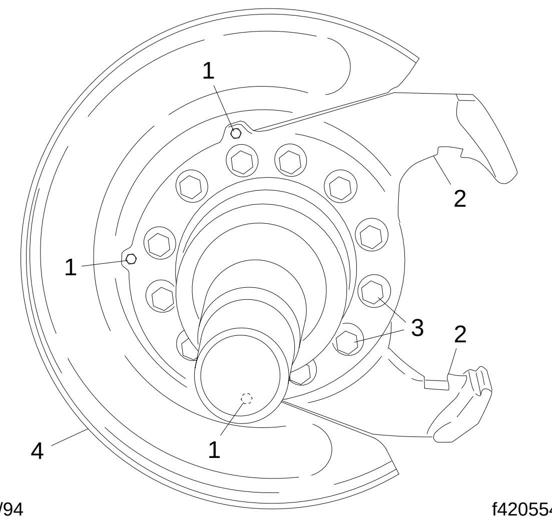
Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Disassembly

1. Park the vehicle on a level surface. Chock the rear or front tires, as required.
2. Jack up the vehicle. Support the axle with jackstands.
3. Remove the tire.
4. Remove the brake caliper from the anchor plate following the instructions in **Subject 120**.
5. Remove the tie bar from the anchor plate on 73 mm brakes, or remove the plugs from the anchor plate on 66 mm brakes.
6. Remove the brake pads from the anchor plate. For instructions, see **Subject 110**.
7. Remove the wheel hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
8. Remove the anchor plate from the axle, as follows.

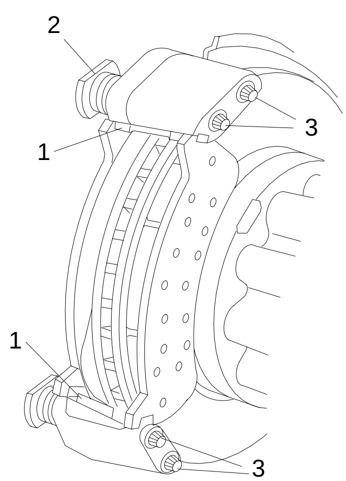
   8.1 Remove the three screws that hold the dust shield to the anchor plate; remove the dust shield.

   8.2 Remove the hexbolts, washers, and nuts that attach the anchor plate to the axle. Remove the anchor plate from the axle. See **Fig. 1**.
9. Remove contamination, dirt, and debris from the exterior of the anchor plate.
10. Remove the brake pad abutment slipper, using a blunt-nose drift pin or screwdriver and a light hammer. Avoid marring the anchor plate abutment surfaces. See **Fig. 2**.
11. Remove the guide pins and guide pin boots by pulling out the guide pin with a slight twisting motion.
12. Remove the splash shield and antilock braking system sensor bracket from the anchor plate. See **Fig. 3**.



1. Dust Shield Screw
2. Anchor Plate
3. Hexbolts
4. Dust Shield

Fig. 1, Axle End (typical)



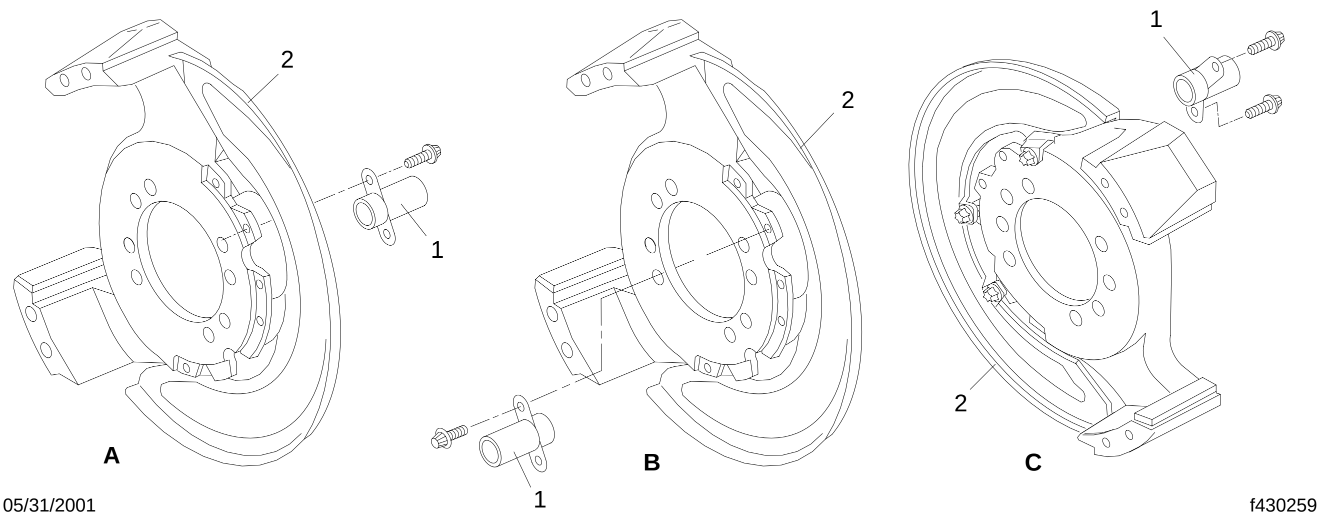
1. Pad Abutment Slipper
2. Guide Pin and Pin Boot
3. Plugs (66 mm brakes only)

Fig. 2, Anchor Plate Components

Cleaning and Inspection

1. Clean the anchor plate, using a brush and solvent. Make sure the anchor plate abutments, anchor plate tie bar mounting surfaces, axle flange

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



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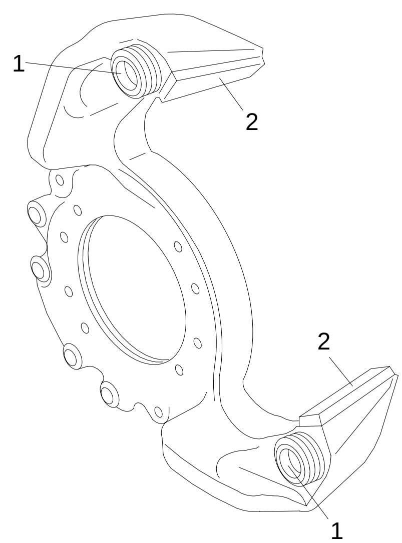
A. Driver Side Front Backing Plate Assembly (66 mm brakes)
B. Driver Side Front Backing Plate Assembly (73 mm brakes)
C. Driver Side Rear Backing Plate Assembly (typical)

1. Sensor Bracket
2. Anchor Plate

Fig. 3, Splash Shield and Sensor Mounting Bracket

mounting surface, and anchor plate boot grooves are clean and free of any rust or corrosion. See Fig. 4. Use a hand-held wire brush to clean these surfaces. It is important to clean these areas of the anchor plate. Also make sure the tie bar bolt hole threads are clean and free of foreign matter.

2. Clean the guide pin bores, using a bore brush and solvent. Use compressed air to clean out and dry guide pin bores. Check the guide pin bores for excessive wear. Replace the anchor plate if necessary.
3. Clean the guide pin boots with isopropyl alcohol. Do not use solvent to clean the boots. Inspect each guide pin boot for cracks, tears, holes, and flexibility. If damage is found, the boot must be replaced. See Fig. 5.
4. Clean the guide pins with isopropyl alcohol. Make sure the guide pins, and the threads in the guide pins, are free of foreign matter and corrosion. Use compressed air to clean out and dry guide pins and bolt threads in the guide pins. Check the guide pins for wear. Replace them if excessive wear is detected.



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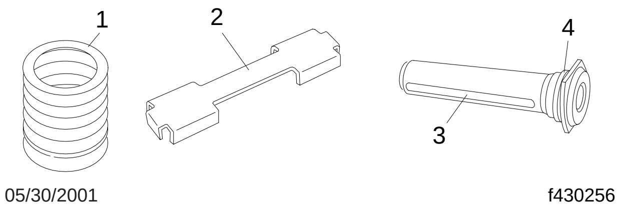
1. Guide Pin Bore and Boot Groove
2. Pad Abutment Slipper Mounting

Fig. 4, Anchor Plate Machined Surfaces

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



1. Guide Pin Boot
2. Pad Abutment Slipper
3. Guide Pin
4. Boot Groove

Fig. 5, Anchor Plate Components

5. Inspect the pad abutment slippers for damage or wear, and clean them with solvent. Replace them if damaged, or if excessive wear is detected.
6. Inspect the anchor plate for worn or damaged slippers, and damaged or dislodged guide pin boots. If signs of wear or damage are found, the anchor plate should be repaired or replaced.

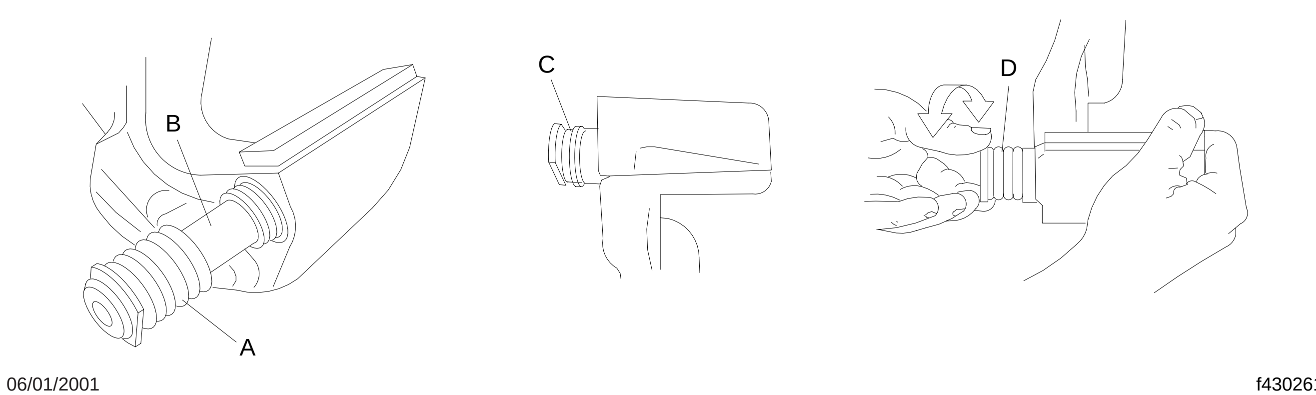
Assembly

NOTE: All brake parts must be clean and completely dry of cleaning fluids before assembly.

1. Uniformly apply Aeroshell Grade 5 grease to the entire guide pin bore and on the guide pin shaft. Use 1/8 ounce (3 grams) of grease to thoroughly lube each guide pin and guide pin bore set. See **Fig. 6**.
2. Apply a thin coat of Aeroshell Grade 5 grease to the inside opening at each end of the boot.
3. Slide the guide pin into the guide pin boot.
4. Insert the guide pin with the boot into the anchor plate guide pin bore until the boot is completely compressed.
5. Rotate the guide pin 1/4 to 1/2 turn back and forth in order to seat the guide pin boot.
6. Inspect the guide pin boot to make sure the boot is fully seated all around the guide pin and the anchor plate retaining grooves.
7. Install an anchor plate pad abutment slipper onto each anchor plate abutment. See **Fig. 7**. Use a soft brass or other light hammer to be sure the slipper is seated on the abutment. Avoid marring anchor plate abutment slipper surfaces.
8. Install the splash shield and antilock braking system sensor bracket on the anchor plate.

   When installing the splash shield and sensor bracket on the anchor plate for 66 mm front and all rear brakes, the splash shield and sensor bracket are mounted on the inboard side of the anchor plate and the five bolts are installed from the inboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).

   For 73 mm front brakes, the splash shield and sensor bracket are mounted on the outboard side of the anchor plate and the five bolts are



A. Lube the inside of the boot at both ends.
B. Apply Aeroshell Grade 5 grease to the bore and the pin.
C. Boot and pin in place.
D. Twist to seat in the groove.

Fig. 6, Installing Guide Pins and Boots

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly

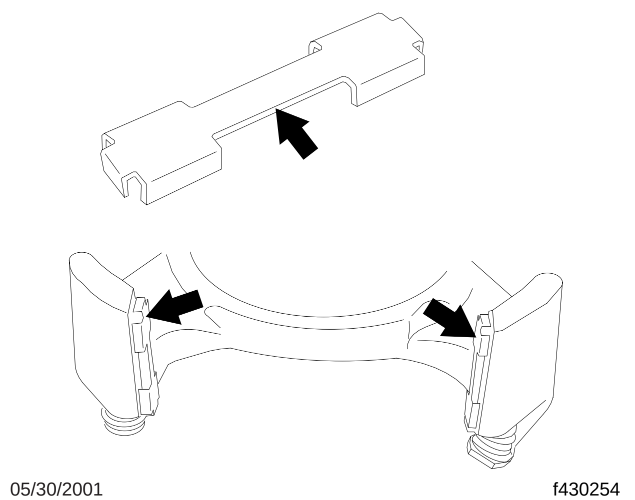
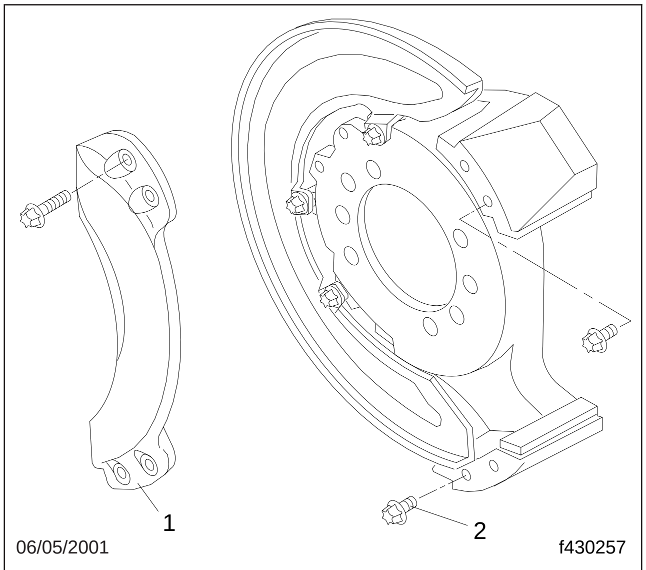


Fig. 7, Pad Abutment Slipper

installed from the outboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).

9. Remove all traces of dirt, grease, and oil from the knuckle and axle brake flange.
10. Install the anchor plate on the axle, as follows.
    - 10.1 Position the anchor plate against the outboard side of the axle flange, making sure the holes in both are lined up.
    - 10.2 From the outboard side of the anchor plate, install the hexbolts and washers. Install the nuts and remaining washers. See **Fig. 1**. Using a star pattern, tighten the hexnuts as follows:
        - Rear Axle; 97 to 123 lbf·ft (132 to 167 N·m)
        - Front Axle Type FC; 70 to 89 lbf·ft (95 to 121 N·m)
        - Front Axle Type FD/FF; 134 to 172 lbf·ft (182 to 233 N·m)
11. Install the dust shield on the anchor plate. See **Fig. 1**.
12. Install the wheel hub and rotor assembly on the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
13. On 66 mm brakes, install the four bolt plugs into the anchor plate face. Tighten the plugs 16 to 27 lbf·ft (22 to 37 N·m). See **Fig. 8**.

On 73 mm brakes, install the anchor plate tie bar using the four tie bar bolts to the anchor plate face. Tighten the bolts 40 to 50 lbf·ft (54 to 68 N·m).



1. Tie Bar (73 mm brakes only)
2. Plug (66 mm brakes only)

Fig. 8, Plugs and Tie Bar

14. Install the brake caliper on the anchor plate, following the instructions in **Subject 120**.
15. Install the brake pads in the anchor plate. For instructions, see **Subject 110**.
16. Install the tire.
17. Remove the jackstands. Lower the vehicle.
18. Remove the chocks.

Bleeding

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Whenever any hydraulic system fitting is loosened or disconnected, the entire system must be bled to remove any air that may have entered it.

CAUTION

Power steering fluid and brake fluid are incompatible. Never mix these two fluids or serious damage to both hydraulic systems will result. Use only brake fluid for the master cylinder and brake lines. Use only power steering fluid for the power booster.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid and do not use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let it get on brake pads or rotors.

Pressure Bleeding

NOTE: Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing, and adapter. These are available from a number of manufacturers and include instructions for use. See **Fig. 1**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Using the manufacturer's instructions, connect the brake master cylinder reservoir, as follows.

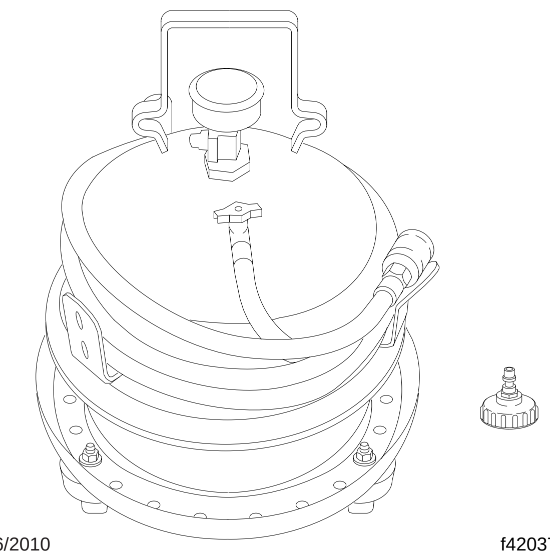


Fig. 1, Pressure Bleeder Kit

   3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.

   3.2 Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.

4. Bleed the hydraulic connections at the rear wheel calipers starting on the right side, as follows.

   4.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

   4.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

   4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

5. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir. Connect it to the front compartment of the reservoir.
6. Bleed the front wheel brake calipers starting at the right side, as follows.

System Bleeding

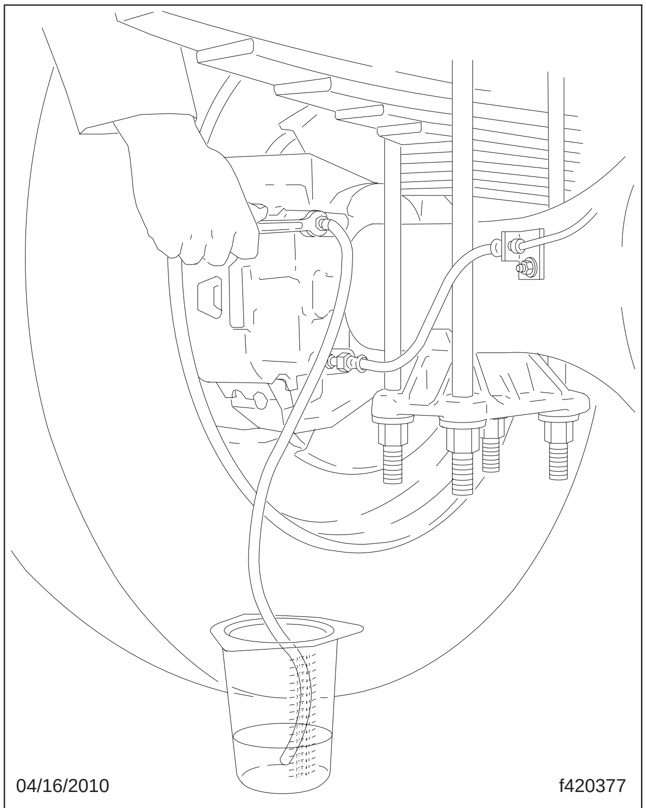


Fig. 2, Bleeding the Hydraulic Connection

6.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

6.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
8. Check the operation of the brakes by depressing the brake pedal several times, until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting, 300** and find the problem.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

Manual Bleeding

NOTE: If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

WARNING

Read over the information in Subject 100 before starting the procedure below. Failure to do so may result in either serious injury to yourself, or damage to the brake system, resulting in an accident causing serious personal injury or property damage.

IMPORTANT: Do not let the brake master cylinder run dry during manual bleeding operations. Keep the master cylinder reservoir filled with new, DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Bleed the master cylinder, as follows.

3.1 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.

3.2 Have someone push the brake pedal down slowly by hand to the floor. Brake fluid, and any air in the master cylinder, will squirt from the fitting.

3.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

3.4 Release the brake pedal.

3.5 Loosen the fitting again, and repeat steps for bleeding as required until no air es-

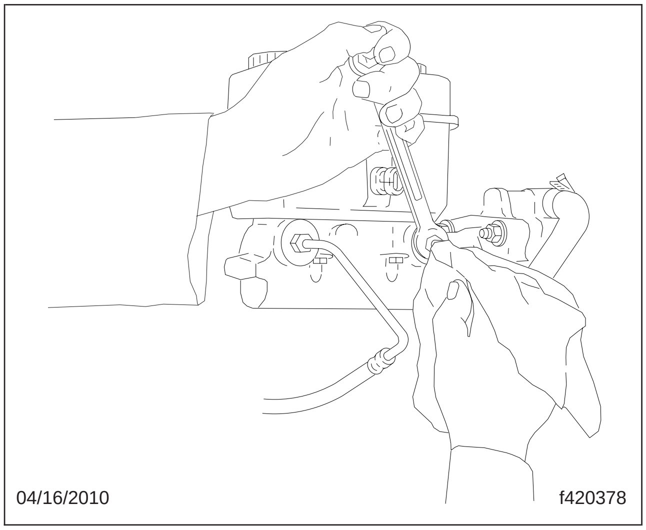


Fig. 3, Rear Outlet Port

capes from the fitting, and the brake pedal feels firm.

3.6 Check the level of the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.

3.7 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

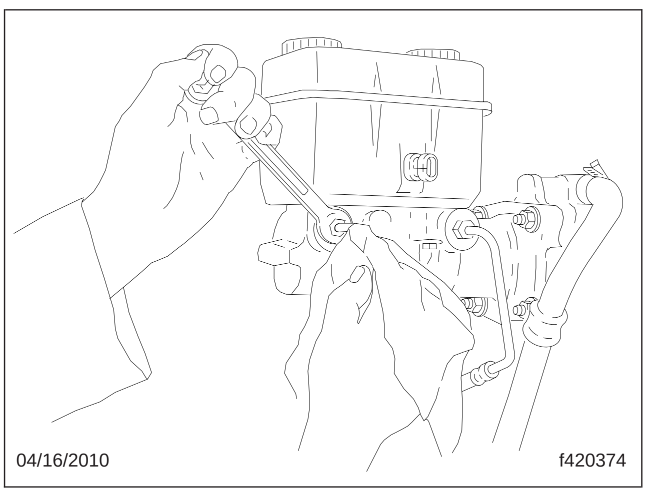


Fig. 4, Front Outlet Port

3.8 Repeat steps as required for the front outlet port.

3.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

4. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper, as follows.

4.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

4.2 Loosen the bleeder fitting about 3/4 turn.

4.3 Have someone slowly push the brake pedal to the floor. *With the brake pedal depressed*, tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

4.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat the steps as required until the fluid in the tube is completely free of air bubbles.

4.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

4.6 Repeat the steps for bleeding the connections for the left rear caliper, the right front caliper, and the left front caliper.

5. Close and latch the hood.

6. Remove the chocks from the rear tires.

Troubleshooting Tables

IMPORTANT: See **Section 42.12** for detailed hydraulic brake system troubleshooting procedures.

Problem—Noise and Chatter

Problem—Noise and Chatter	
Possible Cause	**Remedy**
Bent, damaged, or incorrect pads.	Replace with the correct pads in axle sets.
Worn out lining plates (plates rubbing rotor).	Resurface or replace the rotor. Replace the pads in axle set.
Rotor polished or linings glazed.	Remove the polish or glaze.
Foreign material embedded in linings.	Replace the pads in axle sets.
Excessive rotor thickness variations or runout.	Resurface or replace the rotor. See **Subject 140**.

Problem—Brakes Grab

Problem—Brakes Grab	
Possible Cause	**Remedy**
Incorrect pads or pads loose on plate.	Replace with the correct pads in axle sets.
Grease or brake fluid on linings.	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper at anchor plate pins.	Tighten to specifications.
Excessive rotor runout.	Check the bearing adjustment. See **Subject 140**.

Problem—Vehicle Pulls to One Side

Problem—Vehicle Pulls to One Side	
Possible Cause	**Remedy**
Incorrect pads or loose lining on plates.	Replace with the correct pads in axle sets.
Grease or brake fluid on linings.	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper or anchor plate.	Tighten to specifications.
Caliper piston sticking.	Repair or replace the piston or replace the caliper.
Caliper guide pins sticking.	Repair or replace the guide pins and boots. Clean the pin bores and lubricate.
Excessive rotor runout.	Check the bearing adjustment. See **Subject 140**.

Problem—Pulsating Brake Pedal

Problem—Pulsating Brake Pedal	
Possible Cause	**Remedy**
Worn or damaged front wheel bearings.	Replace the wheel bearings.
Excessive variation in rotor thickness.	Resurface or replace the rotor. See **Subject 140**.

Troubleshooting

Problem—Springy or Spongy Pedal

Problem—Springy or Spongy Pedal	
Possible Cause	**Remedy**
Excessive rotor runout.	Check the bearing adjustment. See **Subject 140**.
Poor quality brake fluid (low boiling point).	Drain and clean the system. Refill with the approved brake fluid.
Weak brake hoses that expand under pressure.	Replace the hoses.
Air in hydraulic system.	Bleed the system. For instructions, see **Subject 160**.

Problem—All Brakes Drag (or Both Brakes on Same Axle)

Problem—All Brakes Drag (or Both Brakes on Same Axle)	
Possible Cause	**Remedy**
Binding brake pedal.	Free-up and lubricate the pedal.
Soft or swollen rubber parts caused by incorrect or contaminated brake fluid.	Replace rubber parts. Flush the system and refill with approved brake fluid. For instructions, see **Subject 160**.
Trapped pressure in brake lines caused by master cylinder and/or booster not fully releasing.	Repair or replace the master cylinder and/or booster as necessary.

Problem—One Brake Drags

Problem—One Brake Drags	
Possible Cause	**Remedy**
Loose or worn front wheel bearings.	Adjust to specifications or replace.
Defective brake hose or hydraulic tube (preventing return of fluid).	Replace the hose or tube.
Sticking caliper piston.	Repair or replace the caliper.
Swollen caliper piston seal.	Replace the seal. Drain and flush the system. Refill with the approved brake fluid.
Sticking caliper guide pin(s).	Repair or replace the pin(s). Lubricate the pins and boots.

Problem—Low Pedal

Problem—Low Pedal	
Possible Cause	**Remedy**
Leak in hydraulic brake system.	Check the master cylinder, calipers, hoses, and tubes. Replace as necessary.
Air in hydraulic brake system.	Bleed the system. For instructions, see **Subject 160**.
Poor quality brake fluid (low boiling point).	Drain the system. Flush and refill with approved brake fluid.
Weak brake hoses that expand under pressure.	Replace the defective hoses.
Pad and piston knockback caused by loose wheel bearings.	Adjust or tighten parts or replace faulty parts as necessary.

Specifications

Kent-Moore Tools	
Kent-Moore Part Number	**Tool**
ZTSE4417	Seating Tool for 66 mm Caliper Pistons
ZTSE4418	Seating Tool for 73 mm Caliper Pistons

Table 1, Kent-Moore Tools

Fastener Torque Values			
Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Caliper Pin Mounting Bolts	M12 x 1.25	—	93–107 (126–145)
Brake Supply Hose Fitting	—	—	15 (20)
Tie Bar-to-Anchor Plate Mounting Bolt (73 mm only)	M10 x 1.5	—	40–50 (54–68)
Tie Bar-to-Anchor Plate Hole Plug (66 mm only)	M10 x 1.5	—	16–27 (22–37)
Splash Shield, ABS Sensor Mounting Bracket, and Brake Line Clip Screw	5/16–18	—	12–16 (17–22)
Anchor Plate Mounting Hexnuts	—	—	Rear Axle: 97–123 (132–167) Front Axle Type FC: 70–89 (95–121) Front Axle Type FD/FF: 134–172 (182–233)
Caliper Bleed Screw	7/16–24	—	8–15 (10–20)
Rotor Mounting Hexbolts	9/16–12	8	130 (175)

Table 2, Fastener Torque Values

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluids**
DOT 3	Wagner-Premium Plus Super HD
	Delco Supreme II
	Dow HD 50-4

Table 3, Approved Brake Fluid for Brake System

Approved Brake System Grease	
Component	**Recommended Grease**
Anchor Plate Guide Pins, Guide Pin Boots, Guide Pin Bores	Aeroshell Grade 5 (ES-1246)
Caliper Piston Bores	Dow Corning DC-4

Table 4, Approved Brake System Grease

Rotor Specifications	
Outside Diameter	15.0 inch (381 mm)
Thickness, New	1.435 inch (36.45 mm)
Thickness, Discard	1.320 inch (33.53 mm)
Surface Finish	40–120 micro inch 40–100 micro inch (preferred)

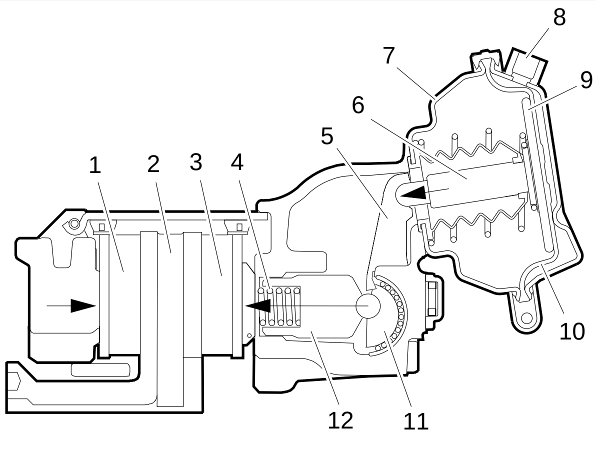
Table 5, Rotor Specifications

General Information

Bendix® Air Disc Brakes use a floating caliper design to provide foundation braking on all axles.

Principles of Operation

Bendix Air Disc Brakes convert air pressure into braking force. When the vehicle brakes are applied, air enters the service brake chamber through the supply port, applying pressure within the diaphragm. The pressure expands the diaphragm, applying force to and moving the pressure plate and pushrod forward. See **Fig. 1**.



1. Outer Brake Pad
2. Rotor
3. Inner Brake Pad
4. Return Spring
5. Lever
6. Pushrod
7. Service Brake Chamber
8. Supply Port
9. Pressure Plate
10. Diaphragm
11. Eccentric Bearing
12. Bridge

Fig. 1, Bendix Air Disc Brake

The pushrod acts against a cup in the internal lever that pivots on an eccentric bearing, moving the bridge. Moving against a return spring, the bridge transfers the motion of two threaded tubes and tappets, which move the inner brake pad. The inner brake pad (from its normal position of having a running clearance between it and the rotor) moves into contact with the brake rotor. Further movement of the bridge forces the caliper, sliding on two stationary guide pins, away from the inner side of the rotor, which pulls the outer brake pad into the rotor. The clamping action of the brake pads on the rotor applies braking force to the wheel.

When the vehicle brakes are released, the air pressure in the service brake chamber is exhausted and the return springs in the chamber and the bridge return the air disc brake to a neutral, non-brakes position. To maintain the running clearance gap between the rotor and the brake pads over time, the non-braked position is mechanically adjusted by a mechanism in the caliper.

The adjustment mechanism operates automatically whenever the brakes are activated, to compensate for rotor and brake pad wear and to keep the running clearance constant. During pad or rotor maintenance, the technician manually sets the system's initial non-braked position. The total running clearance (sum of clearances on both sides of the rotor) should be between 0.024 to 0.043 in (0.6 to 1.1 mm).

General Safety Precautions

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake calipers, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Brake Pad Removal, Inspection, and Installation

Removal

1. Shut down the engine. Chock the tires on the axle that is not being repaired.

WARNING

Before jacking on the vehicle, ensure that the rear tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

2. Raise the vehicle as follows:

   2.1 Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.

   2.2 *For vehicles equipped with IFS suspensions*, raise the front or rear axle by jacking underneath the front suspension subframe until the weight is off of the front suspension. and place safety stands (jackstands) under the frame rails, close to the front of the vehicle. Remove the jack. Be sure the jackstands will support the weight of the vehicle.

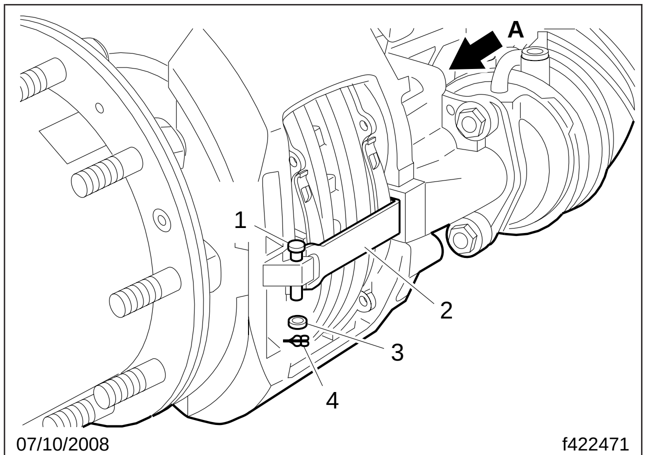
3. Remove the wheel(s).

IMPORTANT: Before removing the brake pads, it is strongly recommended that the adjuster mechanism be checked for proper operation.

4. Remove the pad retainer clip and washer. See **Fig. 1**. Depress the pad retainer and remove the pad retainer pin. Discard all components that have been removed.
5. Using the tab, pull off the adjuster cap, being sure to keep the shear adapter in position on the adjuster. See **Fig. 2** and **Fig. 3**.
6. Using a box-end wrench or socket, fully retract the tappet and boot assemblies by rotating the shear adapter counterclockwise. See **Fig. 4**.

NOTE: Do not use an open-ended wrench, as this may damage the adapter.

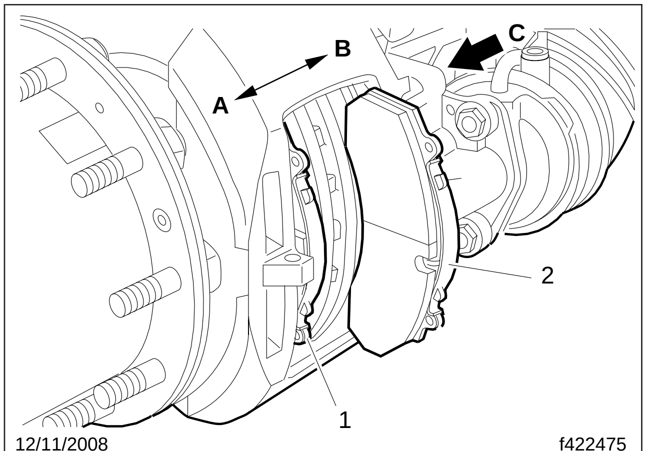
IMPORTANT: Never turn the adjuster without the shear adapter installed. The shear adapter is a safety feature and is designed to prevent an excess of torque being applied to the adjuster. The shear adapter will come loose if too much torque is applied. If the shear adapter fails, try



A. Shear Adjuster Location

1. Pad Retainer Pin
2. Pad Retainer
3. Washer
4. Clip

Fig. 1, Caliper Assembly

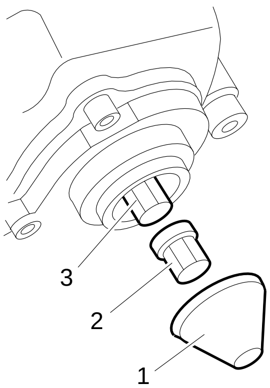


A. Outboard
B. Inboard
C. Area of Shear Adapter

1. Outboard Brake Pad
2. Inboard Brake Pad

Fig. 2, Brake Pad Removal

Brake Pad Removal, Inspection, and Installation



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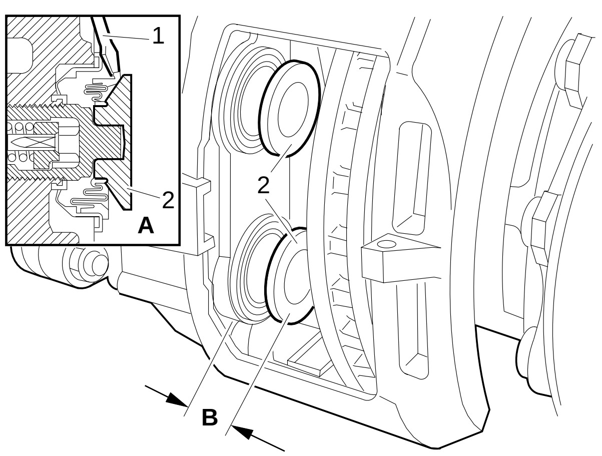
1. Adjuster Cap
2. Shear Adapter
3. Adapter

Fig. 3, Shear Adapter



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A. Boot Location Ring
B. Extend less than 1.18 in (30 mm)

1. Boot Location Ring
2. Tappet and Boot Assembly

Fig. 4, Tappet and Boot Assembly

again with a new adapter. A second failure confirms that the adjustment mechanism is seized and the caliper/carrier assembly must be replaced.

7. Slide the caliper to the outboard position. Remove the outer pad.
8. Slide the caliper to the inboard position. remove the inner pad.

Inspection

Brake Pads

1. Measure the thickness of the friction material on the brake pad.

   If the thickness of the friction material is less than 0.079 in (2 mm) the pads must be replaced. See **Fig. 5**, Ref. E.

   Most Bendix Air Disc Brakes use 0.35 in (9 mm) backing plates. On a used brake pad, the combined pad and backing plate thickness should be no less than 0.43 in (11 mm). If equipped, some Bendix SK7® type air disc brakes, use a 0.28 in (7mm) backing plate, so the minimum thickness should be no less than 0.35 in (9 mm).
2. If the pad thickness is within the acceptable range, inspect the pad surface.

   Minor damage (small amount of brake material chipped) at the edges is permitted, but replace the pads if major damage (section damaged or missing) is found on the surface.

Rotors

1. Examine the rotor and measure the thickenss at the thinnest point. Avoid measuring near the edge of the rotor as minor burrs may be present.

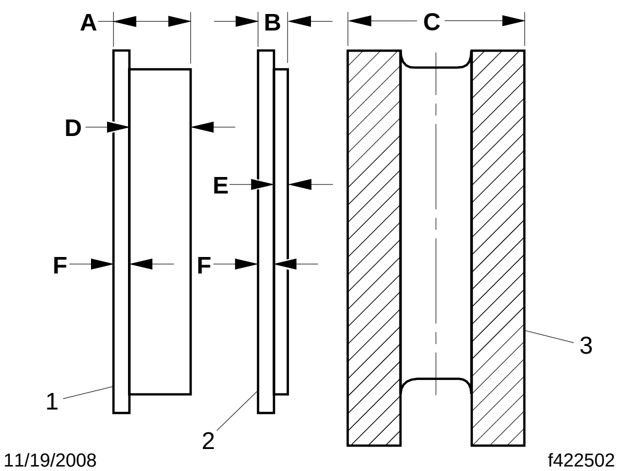
   Replace the rotors when the minimum thickness is 1.46 in (37 mm).

NOTE: It is recommended to use Bendix brake rotors and to replace the brake pads at the same time.

2. Inspect the rotor for grooves and cracks.

   Conventional rotors may be turned when changing pads, but is not normally necessary. In the case of severe grooving of the entire friction surface, turning could be useful and may increase the load-bearing surface of the pads. To meet Bendix recommendations, the minimum rotor thickness after turning must be greater than 1.53 in (39 mm).

IMPORTANT: Always maintain air disc brake pads and rotors within specifications. Excessive



1. New Pad
2. Used Pad
3. Rotor

A. New Pad Thickness 1.18 in (30 mm)
B. Used Pad Thickness 0.43 in (11 mm)
C. Rotor Thickness 1.77 (45 mm) to 1.46 (37 mm)
D. New Pad Friction Material Thickness
E. Used Pad Friction Material Thickness 0.079 in (2 mm) minimum
F. Backing Plate Thickness 0.35 in (9 mm) to 0.43 in (11 mm)

Fig. 5, Brake Pad Inspection

pad or rotor wear will degrade optimum performance. When replacing rotors, be sure to adhere to Freightliner Custom Chassis recommended bolt tightening torques.

Installation

NOTE: When replacing brake pads, replace them as an axle set.

If equipped, new wear indicators are normally installed whenever brake pads are replaced. The wear indicator is installed after the new brake pads are installed, but before the retainer hardware.

1. Install the outboard brake pad by sliding the caliper to the outboard position (be sure the brake lining material is facing the rotor).
2. Install the inboard pad by sliding the caliper to the inboard position.
3. Install a new in-pad wear indicator. See **Subject 120**.
4. Using a box-end wrench or socket, turn the shear adapter clockwise until the pads come into contact with the rotor. Then turn the shear adapter counterclockwise two clicks, to set the initial running clearance.

NOTE: Only use pads that have the same backing plate thickness as originally specified.

5. Install the pad retainer into the groove of the caliper. Depress the pad retainer, and install the pad retainer pin so that it is pointing downward.
6. Install the washer and spring clip to secure the pad retainer pin. See **Fig. 1**.

NOTE: The adjustment mechanism operates automatically whenever the brakes are activated, to compensate for rotor and brake pad wear and to keep the running clearance constant. During pad or rotor maintenance the technician is to manually set the system's initial nonbraked position.

7. Set the total running clearance (sum of clearances on both sides of the rotor), between 0.024 to 0.043 in (0.6 to 1.1 mm).
8. Apply and release the brake, then check that the hub turns easily by hand.
9. Using white lithium-based grease, lightly grease and install a new adjuster cap. Position the adjuster cap tab as shown in **Fig. 3** for ease of access.
10. Install the wheel(s).

WARNING

Before jacking on the vehicle, ensure that the rear tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

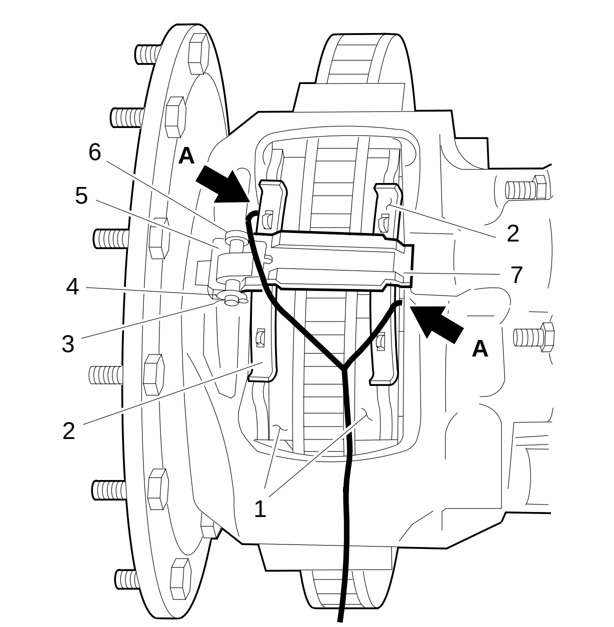
11. Raise the vehicle by jacking under the subframe. Remove the safety stands (jackstands) and lower the vehicle.

General Information

New wear indicators are normally installed whenever brake pads are replaced. If equipped, the wear indicator is installed after the new brake pads are installed, but before the retainer hardware.

Replacement

1. Apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. If not already done, raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. If not already done, remove the wheel(s).
4. Remove the pad holder springs, and set them aside. See **Fig. 1**.



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A. Wear Indicator Sensors

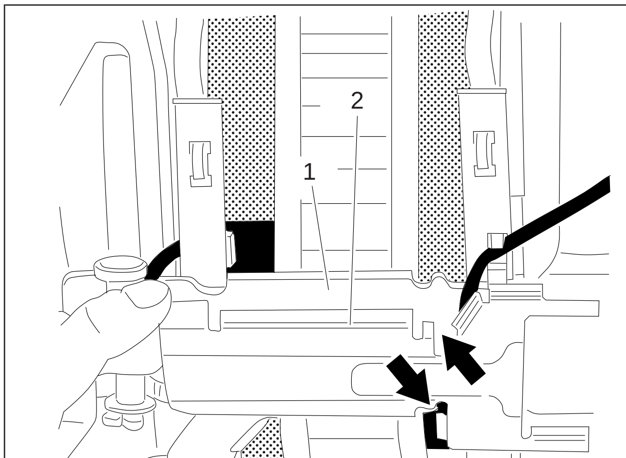
1. Pads
2. Pad Holder Springs
3. Spring Clip
4. Washer
5. Pad Retainer
6. Pad Retainer Pin
7. Cable Guide

Fig. 1, Electronic Wear Indicator

5. Insert the longer branch of the wear indicator cable into the pre-cut slot in the outboard pad. The wear indicator will snap into place.
6. Insert the wear indicator sensors into the pads.
7. Install the pad holder springs on the pads with the wear indicator.
8. Install the pad retainer, pad retainer pin, washer, and spring clip with the wear indicator cable.
9. Install the cable guide on the pad retainer. By pressing lightly on the pad retainer, the cable guide will snap into place.
10. Press the wear indicator cable into the locating tabs of the cable guide.
11. Install the cable that leads to the electrical supply of the vehicle, in one of the two locating tabs.
12. Install the cable that routes to the electrical supply of the vehicle in one of the wire loops.

NOTE: Do not secure the short end of the wear indicator cable with the wire loop of the cable guide.

13. Carefully install the cable protection plate with attention to the correct position of the cable protection plate's catch. The cable protection plate should snap into place. See **Fig. 2**.



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1. Pad Retainer
2. Cable Protection Plate

Fig. 2, Electronic Wear Indicator

Tappet and Boot Assemblies Removal and Installation

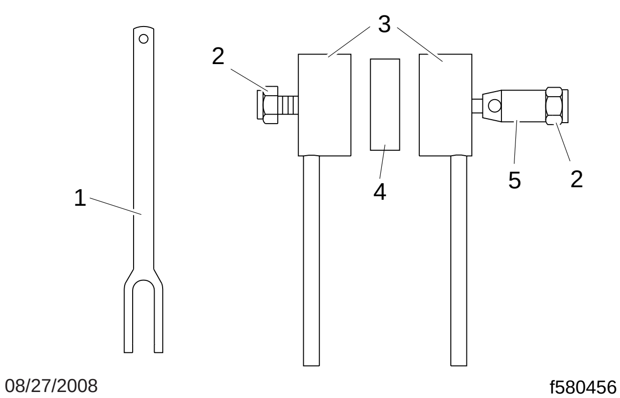
Removal

1. Remove the brake pads. See **Subject 110** for instructions.

IMPORTANT: Never turn the adjuster without the shear adapter installed. The shear adapter is a safety feautre and is designed to prevent applying excess torque to the adjuster. The shear adapter will fail (by breaking loose) if too much torque is applied.

IMPORTANT: Never extend the tappet more than 1.18 in (30 mm). Overextending the tappet will result in the tappet losing engagement with the threads of the synchronizing mechanism. Since the mechanism can only be set by the manufacturer, the caliper assembly must be replaced if this occurs.

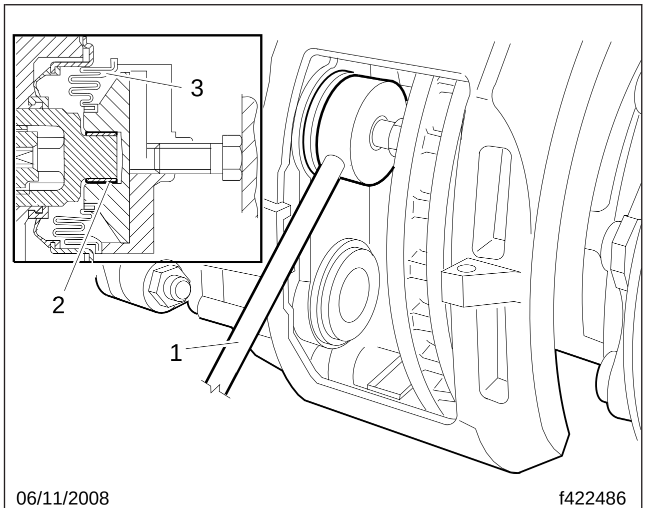
2. Using the wedged fork tool, (**Fig. 1**, Item 1), remove the tappet and boot assembly. See **Fig. 2**.



1. Wedged Fork (use when caliper is fitted on the vehicle)
2. Short Press-In Extension Tool
3. Tappet Removal Tool
4. Supplemental Ring
5. Long Press-In Tool Extension (use when caliper installation is off the vehicle)

Fig. 1, Tappet Removal Tools

3. Remove the old tappet bushings, and inspect the inner sealing face for damage. See **Fig. 2**. If the inner seal is damaged, replace the caliper/carrier assembly.



1. Press-In Tool
2. Tappet Bushing on Threaded Tube
3. Sealing Seat in Caliper for Tappet and Boot Assembly

Fig. 2, Caliper On-Vehicle Installation

Installation

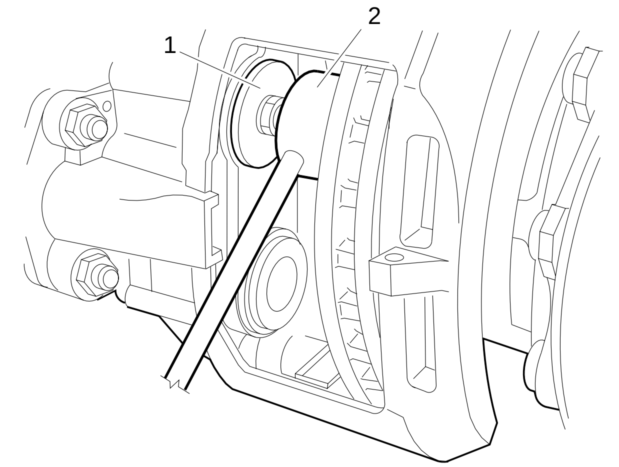
NOTE: When installing the tappet, use the supplemental ring, inserted into the tappet removal tool. The caliper back plate is too thin to use only the press-in tool to achieve the correct position.

1. Using white grease, lubricate the threads on the tappet bushing.
2. Turn the shear adapter counterclockwise.
3. The sealing seat in the caliper must be free of grease. See **Fig. 2**.

With Caliper On Vehicle

1. Using the press-in tool, install the boots. See **Fig. 1**, Item 1. Position and press into place.
2. Position a tappet assembly on each of the tappet bushings. See **Fig. 2**. Using the press-in tool, in a reverse orientation with the press-in extension pointing towards the threaded tube, install each tappet on its bushing. See **Fig. 3**.
3. Install the brake pads.
4. Install the wheels.

Tappet and Boot Assemblies Removal and Installation



1. Tappet Assembly
2. Press-In Tool

Fig. 3, On-Vehicle Installation of Tappet

5. Remove the safety stands and lower the vehicle.

With Caliper Off Vehicle

1. Using the long press-in extension tool, install the boots.
2. Position a tappet on each of the tappet bushings. Using the press-in tool, in a reverse orientation with the press in-tool pointing towards the threaded tube, install each tappet on its tappet bushing.
3. Install the brake pads.
4. Install the wheels.
5. Remove the safety stands and lower the vehicle.

Replacement

1. Chock the front and rear tires. Shut down the engine.

WARNING

Before jacking on the vehicle, ensure that the rear tires are securely chocked. Exercise caution when jacking and do not rely on jacks alone to support the vehicle. Place jackstands securely in position. If the vehicle or components should fall, severe injury, death, and substantial property damage could result.

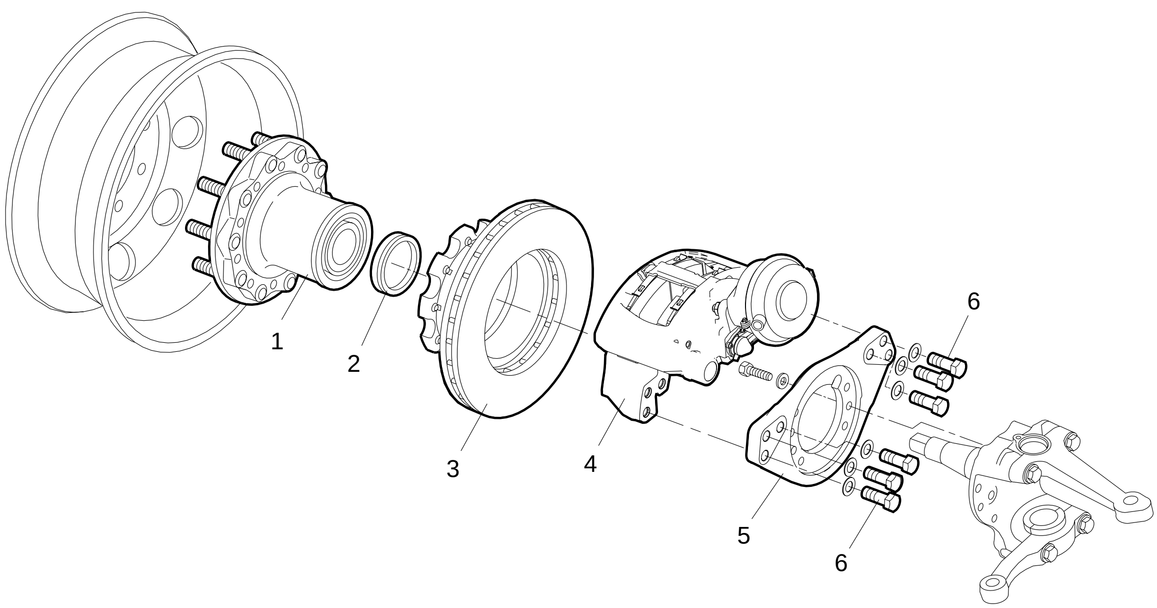
2. Jack up the vehicle, and support it with jack stands.
3. Securely support the caliper/carrier assembly.
4. Remove the capscrews that attach the caliper/carrier to the axle. Remove the caliper/carrier assembly. See **Fig. 1**.

IMPORTANT: Do not attempt to use the pad retainer to attach any lifting device to the brake. The pad retainer is not suitable for this purpose. Damage to the brake and/or unsafe conditions may result.

5. Clean and inspect the axle contact area.

NOTE: Replacement caliper/carrier assemblies may be equipped with a plastic cap, adhesive tape, or a breakthrough diaphragm in the area of the actuator attachment. Remove the cap or tape only after installing the replacement caliper on the vehicle. If the replacement caliper has the breakthrough diaphragm, it should be left in place. If the new caliper/carrier assembly is equipped with a potentiometer for wear indcation, then the connection must be made using the appropriate mating plug.

6. Position the new caliper/carrier assembly. Install and tighten the six capscrews (with washers).



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1. Hub
2. Hub Seal
3. Rotor
4. Caliper/Carrier Assembly
5. Anchor Plate
6. Capscrews (with washers)

Fig. 1, Wheel End Assembly (exploded view)

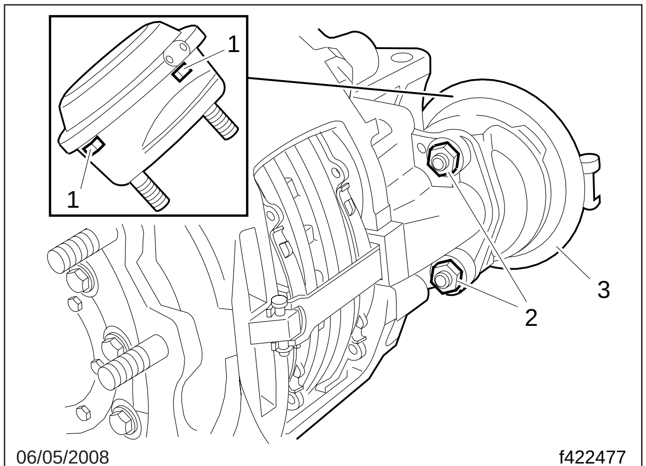
Service Brake Chamber Replacement

Replacement

WARNING

Drain the air system before disconnecting the air hoses. Do not disconnect pressurized hoses because they will whip as air escapes from the line, which could result in personal injury.

1. Shut down the engine. Chock the tires.
2. Remove the tires.
3. Drain the air pressure from the air brake system.
4. Disconnect the air hose from the brake chamber. See **Fig. 1**.

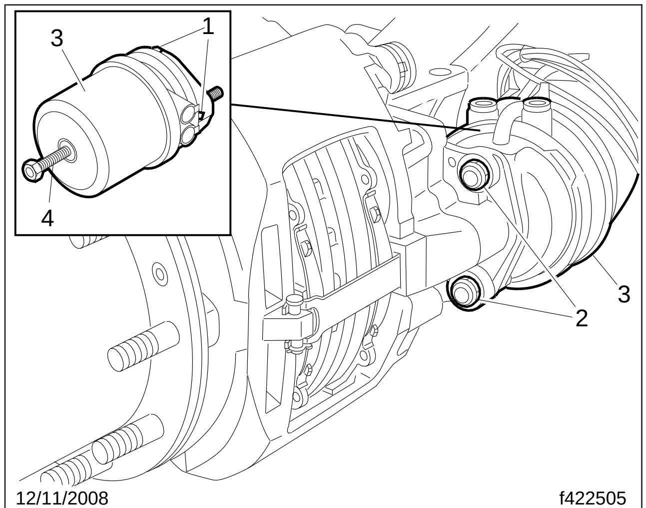


1. Drain Plugs
2. Brake Chamber Mounting Nuts
3. Brake Chamber

Fig. 1, Service Brake Chamber Installation

NOTE: New service (spring) brake chambers have drain plugs installed. After installation, remove the plug at the lowest position. Be sure that all other drain holes remain plugged (the drain hole must be aligned downwards or within ±30°) when installed on the vehicle.

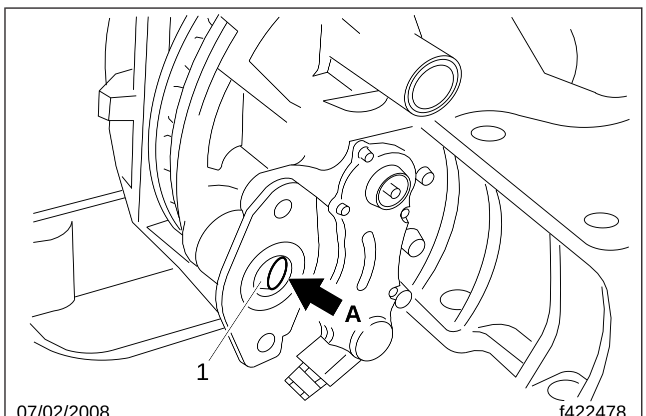
5. Using a maximum torque of 26 lbf·ft (35 N·m), back out the release bolt to release spring force on the pushrod. See **Fig. 2**. In some cases it may be permissable to cage the spring brake while the spring is engaged. While supporting the service brake in position, remove and discard the brake chamber mounting nuts. Remove the service (spring) brake chamber.



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 2, Service Brake Chamber

6. Before installing the new service (spring) brake chamber, the actuator flange must be cleaned and inspected. See **Fig. 3**.



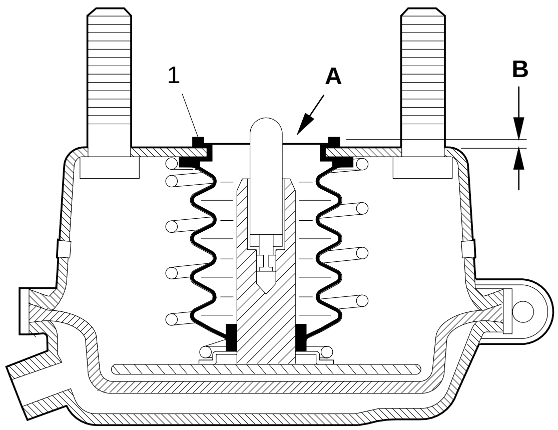
A. Actuator Flange

1. Spherical Cup in Lever

Fig. 3, Actuator Flange

Service Brake Chamber Replacement

7. Using white grease, lubricate the spherical cup. See **Fig. 3**. The seal and pushrod area must be clean and dry. See **Fig. 4**.



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A. Pushrod Area
B. Do Not Use if Thickness is Less than 0.12 in (3 mm)

1. Seal

Fig. 4, Pushrod Area

IMPORTANT: Do not use grease containing molybdenum disulfate.

IMPORTANT: Do not use brake chambers with seals that have a thickness less than 0.12 in (3 mm). Use brake actuators that are recommended by the manufacturer.

8. Install the brake chamber using new self-locking nuts (EN ISO 10513). Alternately tighten both nuts in increments to a final torque of 126 to 140 lbf·ft (170 to 190 N·m).
9. Connect the air hose, and be sure that the hose is not twisted or in contact with moving vehicle components. The air hose routing must allow for full caliper travel.
10. Test for leakage and check the brake operation and effectiveness before returning the vehicle to service.

Troubleshooting Flowchart

See **Fig. 1** for a troubleshooting procedure flowchart.

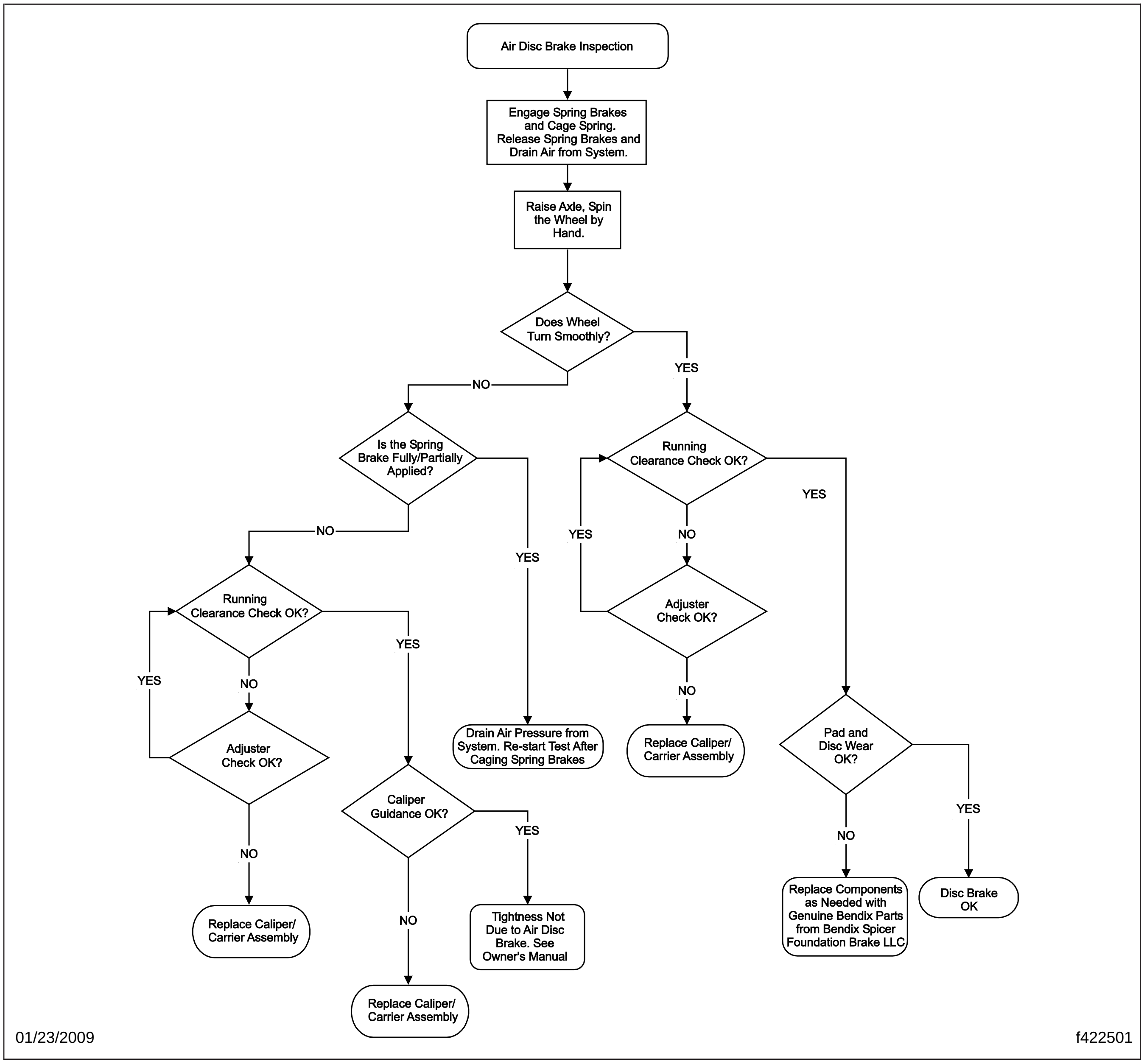


Fig. 1, Bendix Air Disc Brakes Troubleshooting Flowchart

General Description

Pneumatic-brake-equipped Recreational Vehicle chassis use the Meritor WABCO E-Version Antilock Braking System (ABS) with a frame-mounted electronic control unit (ECU).

The ABS is an electronic wheel speed monitoring and control system that works with the standard air brakes. It passively monitors vehicle wheel speed at all times, then controls braking force during emergency stops. As a result, the driver has full control of braking until the ECU senses that a wheel is about to skid, when the ABS will ease braking only on the wheels that are threatening to lock. By controlling individual wheel braking, the ABS gives drivers more vehicle control when wheels might otherwise lock up and cause a skid or loss of control.

The ABS reads individual wheel speed with signal-generating sensors activated by tone rings located on the hubs of the monitored road wheels. See **Fig. 1**. The sensors transmit vehicle wheel speed information to the ECU. The control unit follows programmed specifications, and signals the appropriate modulator valves to regulate air pressure in the brake chambers. This prevents wheel lockup and enhances steering control during emergency braking situations. During normal braking conditions, only the standard air brake system is in effect.

NOTE: Tone rings are also referred to as tooth wheels, ABS exciters, ABS rings, and variations of those names. They all refer to toothed or slotted rings turning with the wheel hubs of ABS-equipped vehicles. Stationary ABS sensors count the passing teeth or slots to tell the ECU how fast that wheel is turning.

Recreational Vehicle chassis have the standard four-channel ABS with four wheel speed sensors and four modulator valves (4S/4M).

Principles of Operation

The ABS is controlled by the ECU, mounted inside the left frame rail toward the rear of the vehicle. The ECU is a computer that receives, processes, and compares wheel speed information from each wheel sensor. During emergency brake applications or braking on slick surfaces, the control unit regulates the braking force applied to each wheel by sending control signals to the individual wheel modulator valves.

Major components of the ABS are:

- Wheel speed sensors
- An electronic control unit (ECU)
- Modulator valves (solenoid-controlled valves)
- ABS warning and wheel-spin indicator lamps

NOTICE

Before any electric welding on an ABS-equipped vehicle, disconnect the battery power, ground cables, and the electrical harness connectors at the ABS ECU. Electric currents produced during electric welding can damage various electronic components on the vehicle.

Wheel Speed Sensors

The wheel speed sensor assembly is a signal-generating device. The assembly includes a sensor (a coil wrapped around a magnet to generate an electrical field), a tone ring, and a sensor clip that holds the sensor in position near the tone ring. See **Fig. 1** and **Fig. 2**.

Each ABS-controlled wheel has a stationary wheel speed sensor assembly, mounted very close to, or touching, a tone ring mounted on the hub. When the wheel is rolling, the teeth or slots on the tone ring cause interruptions in the magnetic field created by the sensor. The interruptions create electrical pulses that are sent to the ECU which counts them to determine wheel speed.

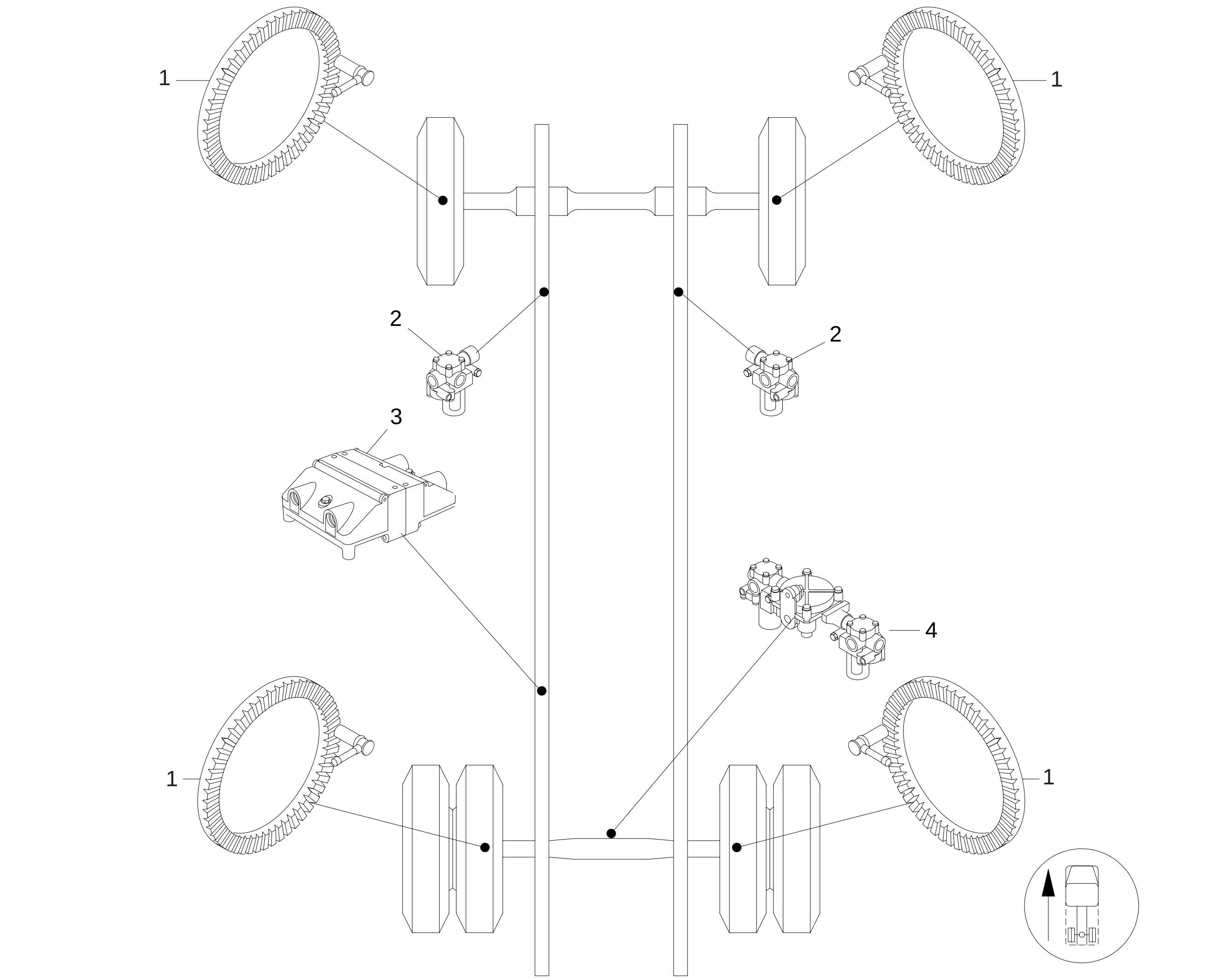
Electronic Control Unit (ECU)

The ECU is mounted on the left-hand frame rail. See **Fig. 1** and **Fig. 3**.

The wheel speed sensors tell the ECU how fast each wheel is turning. The ECU compares those speeds to determine whether any wheel is beginning to skid. If the ECU senses that a wheel is beginning to skid, the wheel control circuit of the locking wheel or wheels signals their modulator valve to release, hold, or reapply braking pressure.

The ECU also shuts off the engine brake and the exhaust brake, if they are installed, when it senses that a wheel is beginning to skid. It automatically re-

General Information



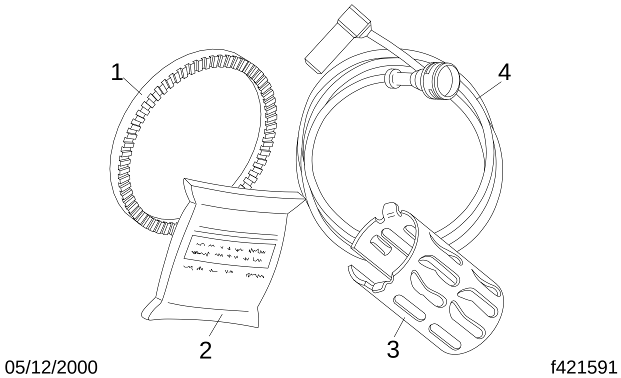
1. Tone Ring and Sensor
2. Front Modulator Valve Assembly
3. Electronic Control Unit (ECU)
4. Rear Modulator Valve Assembly

Fig. 1, ABS Component Location (4-channel, 4S/4M system)

activates the engine and exhaust brakes when there is no more danger of wheel skidding. The ABS does this by communicating with the engine ECM through the J1939 datalink.

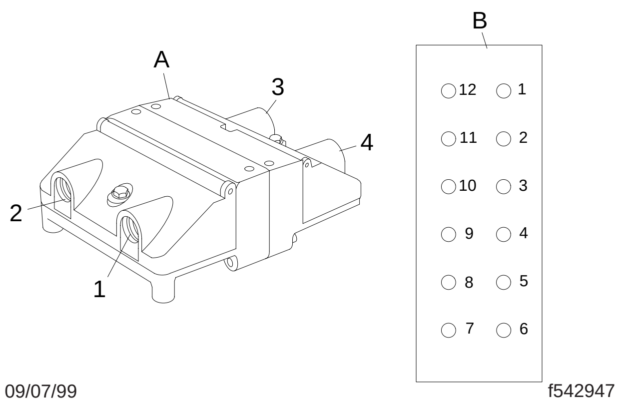
The ECU constantly monitors the wheel sensors, modulator valves, and the electrical circuitry. After the ignition switch is turned on, the ABS warning lamp on the dash illuminates for about 3 seconds. See **Fig. 4** for a typical instrument cluster.

During the self-test, the modulator valves cycle on and off, creating clicking noises that may be heard inside the vehicle. These clicking noises are normal and do not indicate an ABS problem. If all of the ABS components are functioning correctly, the lamp will go off after about 3 seconds.



1. Tone Ring
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 2, Wheel Speed Sensor Components



A. Frame-mounted ECU.
B. ECU connector pin locations.

1. X1 Connector (gray)
2. X2 Connector (black)
3. X3 Connector (green)
4. X4 Connector (brown—6S/4M, 6S/6M only)

Fig. 3, ECU Module, and Pin Locations in the Connector

IMPORTANT: If the ABS warning lamp does not work as described above, locate and repair the problem immediately. See **Troubleshooting, 300** for fault diagnosis.

If the safety circuit senses a failure in any part of the ABS system while the vehicle is running, the ABS warning lamp comes on. Then, a fault code is stored in ECU memory. The ABS works on a diagonal (RF/LR and LF/RR). If a fault occurs, ABS is disabled in the diagonal in which the fault occurred. However, normal braking is still functional in both diagonals.

Fault codes can be retrieved using Meritor TOOLBOX software (the recommended software), ServiceLink, or the ICU if it is equipped with a mode/reset switch.

IMPORTANT: Do not open the ECU. Opening the ECU will void the warranty.

Modulator Valves

Modulator valves control the air pressure in each affected brake chamber during an ABS operation. Responding to the signal received from the ECU, modulator valves prevent wheel lockup by regulating brake pressure. During normal braking applications, the ABS system is inactive, and compressed air flows freely through the modulator valves to the brake chambers.

Each ABS-monitored wheel has its own modulator valve, mounted on the left or right frame rail near the wheel. The rear modulator valve assembly is mounted on a crossmember near the brake chambers. See **Fig. 1**. The rear assembly includes two modulator valves, one mounted on each side of a service relay valve.

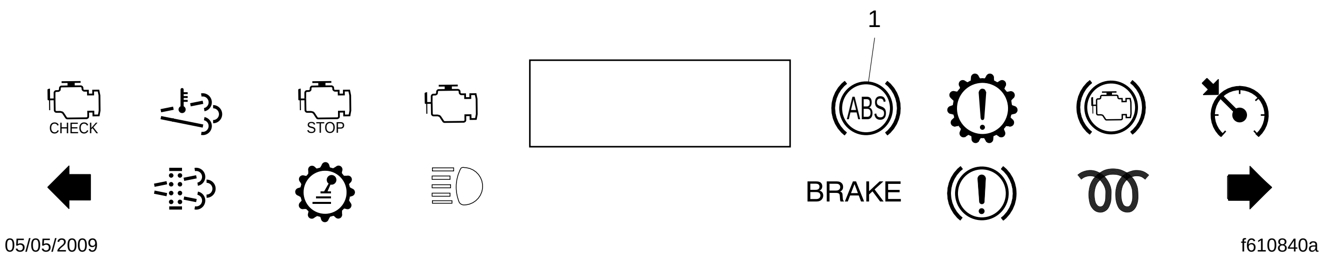
The front modulator valves are mounted on the frame rails near the front wheels.

Each modulator valve assembly includes two solenoid control valves (one supply and one exhaust) and two diaphragms. See **Fig. 5**.

- The supply diaphragm opens and closes an air passage between the supply port and delivery port. It is controlled by the supply solenoid valve.
- The exhaust solenoid valve controls the exhaust diaphragm, which opens and closes an air passage between the exhaust port and the delivery port.

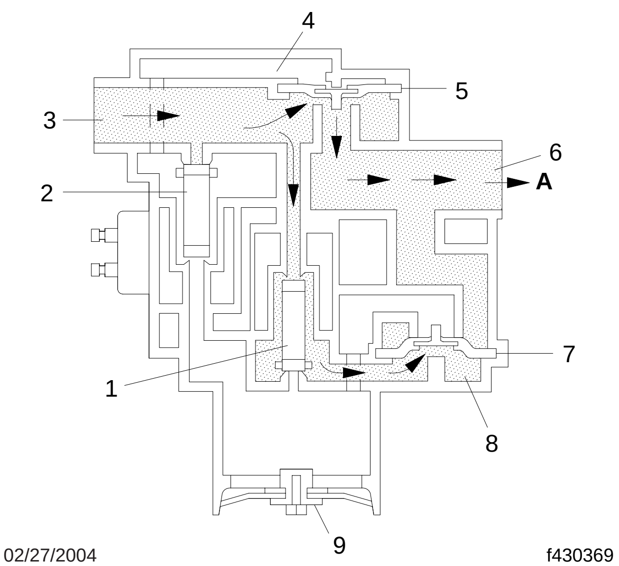
The ECU energizes different combinations of these solenoid valves to perform four functions: normal braking (without ABS control), ABS brake release, ABS brake hold, and normal brake reapplication.

General Information



1. ABS Warning Lamp

Fig. 4, ABS Lamp (Lightbar Control Unit [LBCU] instrument panel shown)



A. Air to Brake Chamber

1. Exhaust Solenoid
2. Supply Solenoid
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (unseated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Port

Fig. 5, Pressure Increase (without Antilock)

Normal (Without Antilock) Brake Application—Supply

During normal braking, both solenoids in the ABS modulator valve are de-energized and inactive. See **Fig. 5**.

The supply diaphragm control chamber of the inlet valve is open to the atmosphere. Air pressure entering the supply port unseats the supply diaphragm. This opens the passage to the delivery port and allows air pressure to flow through the valve, into the brake chamber. Simultaneously, air pressure flows past the solenoid and puts pressure on the exhaust diaphragm. This pressure combines with spring force to keep the exhaust diaphragm seated and close the path from the delivery port to the exhaust port.

The ABS valve maintains this balanced (or pressure increase) position until a wheel starts to lock. Then the ECU activates one or both of the solenoids.

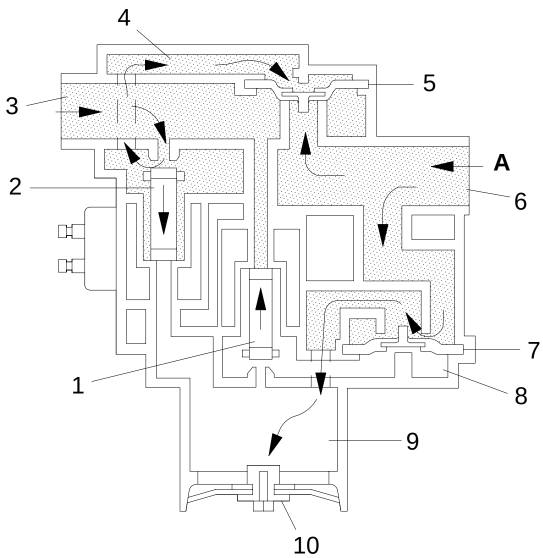
Normal (Without Antilock) Brake Application—Exhaust

Air pressure at the supply port decreases when the brake pedal valve is released. This reverses the direction of airflow through the valve and exhausts air pressure from the brake chamber. Air can also be released from the ABS valve exhaust port during brake release.

Antilock Brake Control—Exhaust

When it senses a wheel is locking, the ECU energizes and opens both ABS valve solenoids. The energized supply solenoid allows air pressure to enter the supply diaphragm control chamber, where it holds the supply diaphragm in the seated position. This stops any more air from entering the brake chamber. See **Fig. 6**.

Energizing the exhaust solenoid cuts off the supply of air pressure entering the exhaust diaphragm and exhausts that air to the atmosphere. Then, pressure from the brake chamber enters through the delivery port and unseats the exhaust diaphragm. This opens the passage between the delivery port and the exhaust port, which releases air pressure from the brake chamber.



A. Air From Brake Chamber

1. Exhaust Solenoid (open)
2. Supply Solenoid (open)
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Port Diaphragm (unseated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Chamber
10. Exhaust Port

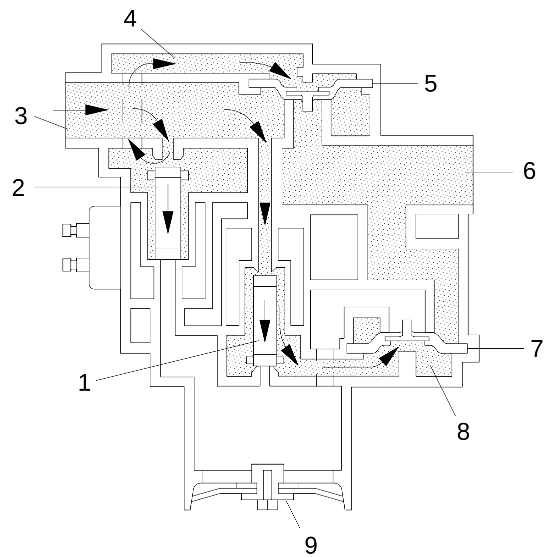
Fig. 6, Pressure Decrease (Antilock)

Antilock Brake Control—Hold

When enough air is released through the exhaust port to prevent the wheel from locking, the exhaust solenoid is de-energized. This seats the exhaust diaphragm and stops any more air leaving the brake chamber. The supply solenoid remains energized to prevent air pressure from passing through the ABS valve. The remaining air pressure in the brake chamber is held and remains constant. See **Fig. 7**.

Antilock Brake Control—Reapply

To achieve proper braking, the ECU monitors wheel speed and determines when to reapply brake pressure. When necessary, both ABS valve solenoids are de-energized, returning the system to the normal brake-application supply state. See **Fig. 8**.



1. Exhaust Solenoid
2. Supply Solenoid
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Port

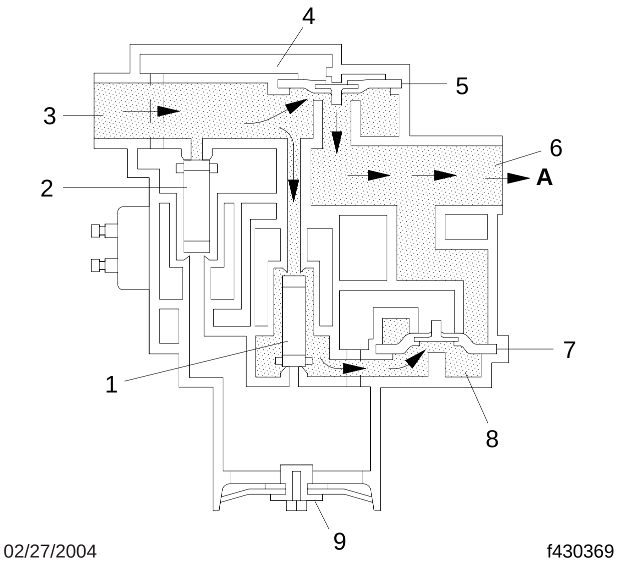
Fig. 7, Pressure Constant

The ECU cycles through the different valve states (pressure increase, pressure decrease, and pressure hold) very rapidly in order to control wheel speed. The Meritor WABCO ABS achieves efficient braking by independently controlling individual wheels.

ABS Warning Lamp

The ABS warning lamp receives power whenever the ignition switch is turned on. The ground path for this indicator is through the ABS lamp relay, which is controlled by the ABS ECU. During the self-test and whenever a malfunction occurs, the ECU completes the ground path and the ABS indicator on the dash comes on. See **Fig. 4**.

The warning lamp tells the driver that either the self-test is working, or an ABS system malfunction exists.



A. Air To Brake Chamber

1. Exhaust Solenoid
2. Supply Solenoid
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (unseated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Port

Fig. 8, Pressure Increase (Antilock)

After a wheel-sensor-related fault has been repaired, if the stored faults are cleared, the ABS warning lamp remains on until the vehicle is driven above a speed of 4 mph (6 km/h).

Tire Size

WARNING

The size of the tires installed at the factory is programmed into the ECU. Installing different size tires could result in reduced braking, leading to longer stopping distances, and could possibly lead to an accident with personal injury or property damage.

For proper ABS operation with the standard ECU, the front and rear tire sizes must be within 20 percent of each other. When the tire-size range is exceeded, system performance can be affected and the warning lamp may come on. Do not continue driving with the ABS lamp illuminated.

Call Meritor WABCO at 1-800-535-5560 for a consultation if you plan a tire-size difference greater than 14 percent.

Calculate the percentage difference of the tire sizes with the following equation:

Percentage Difference = {(steer-axle tire RPM ÷ drive-axle tire RPM) – 1} x 100, where RPM equals tire revolutions per mile.

Safety Precautions

WARNING

Follow the manufacturer's procedures while working on any air device. Some parts are subject to mechanical (spring) or pneumatic propulsion and may cause personal injury or property damage when released. Failure to take all necessary precautions during servicing of the air brake system can result in personal injury or property damage.

Compression and storage of air in the air brake system is comparable to the energy in a coiled spring: when released, it may present a hazard. Because of this, certain precautions are required.

1. Chock the tires. This will prevent accidental rolling of the vehicle when air is released from the brake system.
2. Don't disconnect pressurized hoses because they will whip as air escapes from the line. Drain the air system before disconnecting the air hoses.
3. When draining the air system, do not look into the air jets or direct them toward another person: dirt particles or sludge may be carried in the air stream.
4. As air pressure is drained and the parking/emergency brakes apply, keep your hands away from the brake chamber push rods and parking brake chambers, which will activate automatically with the loss of pressure.

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

Front Axle

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the sensor bracket. See **Fig. 1**.

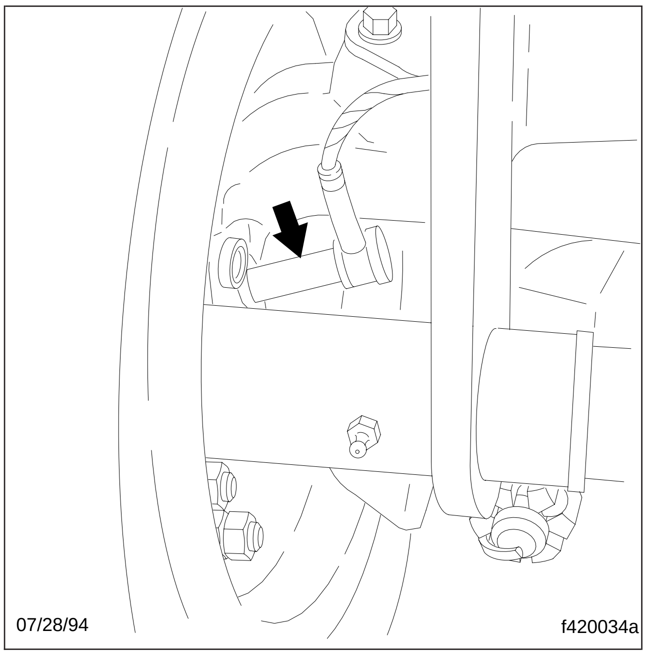


Fig. 1, Removing the Wheel Speed Sensor

3. Remove the sensor cable clip from the top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the sensor spring clip from the sensor bracket.
6. Connect the new sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Coat the sensor spring clip and the sensor with Mobil HP, Valvoline EP 633, Penzoil 707L, or an equivalent.
9. Press the sensor spring clip into the sensor bracket at the brake spider hole until it stops. Make sure the spring clip tabs are on the inboard side of the vehicle.
10. Press the sensor into the sensor spring clip until it is stopped by the tone wheel.
11. Remove the chocks from the rear tires.

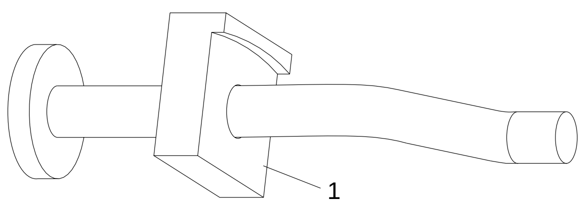
Rear Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the mounting block in the axle housing.
3. Remove the sensor spring clip.
4. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
5. Disconnect the sensor cable from the chassis harness.
6. Connect the new sensor cable to the chassis harness.
7. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
8. Press the sensor spring clip into the mounting block until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP633, Penzoil 707L, or an equivalent. Using your hand, push the sensor into the sensor spring clip until it is stopped by the tone wheel.
10. Remove the chocks from the front tires.

Adjustment

NOTE: The following adjustment procedure requires the use of special tool T11-17556-000. Use of this tool, available through the Parts Distribution Centers (PDCs), eliminates the time-consuming task of removing the wheel and tire assembly, and the brake drum. See **Fig. 1**.

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



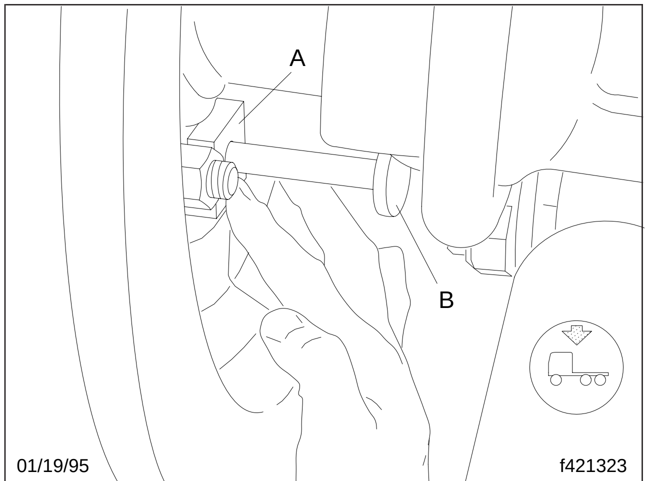
1. Adjustment Tool Slide

Fig. 1, ABS Sensor Adjustment Tool

2. Find the sensor access hole in the rear-axle flange, as follows.
   - 2.1 View the inboard side of the brake drum and axle from the rear. The ABS sensor wiring harness should be visible through a hole at the 12 o'clock position.
   - 2.2 Find the S-cam at either the 3 or 9 o'clock position.
   - 2.3 The sensor access hole is opposite the S-cam. The hole is approximately 3/4 inch (19 mm) in diameter.

IMPORTANT: Do not pry or push the sensor with sharp objects.

3. Insert service tool T11-17556-000 in the sensor access hole.
4. Place the slide of the tool on the axle flange to align the tool. See **Fig. 2**.
5. Tap the tool handle lightly with the palm of your hand. This ensures that the sensor is touching the tone wheel.
6. Remove the tool from the wheel and repeat the procedure on the other rear-axle speed sensor.



A. Place the slide against the axle flange.
B. Tap the handle with your hand.

Fig. 2, Positioning the Tool

7. Remove the chocks from the tires.

Removal

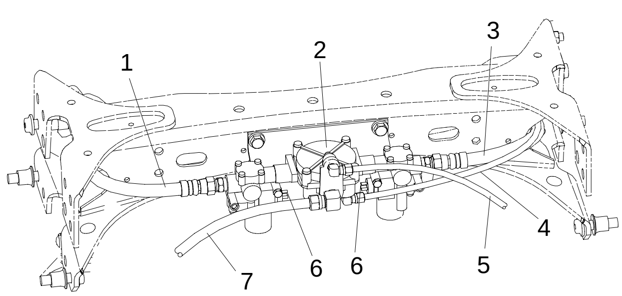
NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Section 54.00** for information on special terminals and connectors, and on ordering tools for them.

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

WARNING

Release all the compressed air from the air reservoirs before disconnecting any air hose. Disconnecting air hoses from the modulator valves without first releasing the pressure in the air reservoirs can cause the hoses to thrash around dangerously, possibly resulting in personal injury or property damage. Before starting work on the brake system, read Safety Precautions, 100 in this section.

2. Release the pressure from the air reservoirs.
3. Mark the electrical connectors for ease of installation. Disconnect the wiring from the modulator valve or modulator valve assembly. The rear assembly includes two modulator valves and a service relay valve. See **Fig. 1**.



1. Delivery Air Line (to RH brake chamber)
2. Service Relay Valve
3. Delivery Air Line (to LH brake chamber)
4. Anti-Compounding Line (black, to park brake quick-release/relay valve)
5. Control Air Line (green, from foot pedal valve)
6. Modulator Valve Electrical Connection
7. Supply Air Line (green, from primary air reservoir)

Fig. 1, Modulator Valve Assembly

4. Mark the air lines for ease of installation. Disconnect the air lines.
5. Remove the fasteners that attach the front modulator valve or rear modulator valve assembly to the mounting bracket. Remove the valve or assembly.

NOTE: The modulator valve assemblies can be disassembled if replacement of the service relay valve, or one of the modulator valves is needed. For disassembly and assembly instructions, see **Subject 140**.

Installation

1. Install the new front modulator valve or rear modulator valve assembly on the mounting bracket. Tighten the fasteners 18 lbf·ft (24 N·m).
2. Connect the air lines to the valves, as marked during removal.
3. Connect the electrical cable connectors to the valves. Tighten only hand-tight.

Installation Checkout

1. Apply the brakes, turn the ignition switch on, and wait for the ABS indicator light to come on.
2. Listen to the modulator valves cycle one by one, then together diagonally as follows:
   - 4-Channel valve cycle: 1, 2, 3, 4; then 1 and 2 together, followed by 3 and 4.
3. If a valve fails to cycle, turn the ignition switch off and make sure the electrical connections are tight. Then, turn the ignition switch on and listen to the valve cycle again.

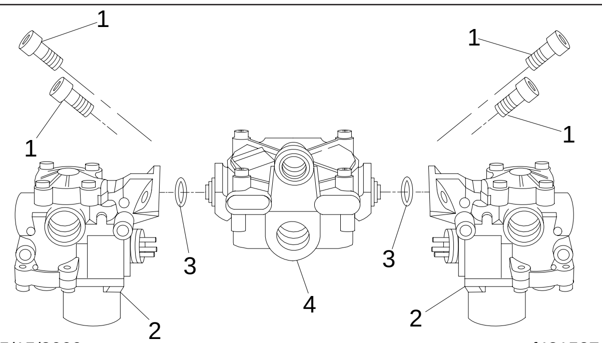
   If a valve still fails to cycle, check for fault codes. See **Troubleshooting, 300** for fault-code identification.
4. Apply the brakes and check the modulator valve fittings for leaks. No air leakage is permitted.
5. Remove the chocks from the tires.
6. Test drive the vehicle to verify that the ABS warning light is functioning correctly.

Modulator Valve Disassembly and Assembly

Disassembly

1. Remove the modulator valve assembly from the crossmember. See **Subject 130** for instructions.
2. Remove the modulator valves from the service relay valve, as follows.

   2.1 Using a 6-mm Allen wrench, remove two Allen-head capscrews that attach each modulator valve to the service relay valve. See **Fig. 1**.



1. Capscrew, Allen-Head, M8
2. Modulator Valve
3. O-Ring
4. Service Relay Valve

Fig. 1, Modulator Valve Assembly

   2.2 Carefully separate the modulator valves from the service relay valve.

   2.3 Remove and discard the O-rings.

Assembly

1. Install the modulator valves on the service relay valve, as follows.

   1.1 Plug any unused ports on the replacement modulator valves.

   1.2 Clean the O-ring surfaces on the modulator and service relay valves. Lubricate the replacement O-rings and place them in the applicable grooves in the valves.

   1.3 Install each modulator valve on the service relay valve with two M8 Allen-head capscrews. Tighten the capscrews 13 to 15 lbf·ft (18 to 20 N·m).

2. Install the modulator valve assembly on the bracket on the crossmember. For instructions, see **Subject 130**.

Tone Ring Installation

NOTE: Tone rings are also referred to as tooth wheels, ABS exciters, ABS rings, and variations of those names. They all refer to toothed or slotted rings on ABS-equipped vehicle wheel hubs, turning with the wheel. Stationary ABS sensors count the passing teeth or slots to tell the ECU how fast that wheel is turning.

IMPORTANT: Some ABS hubs do not have a tone ring installed or machined on the hub. On those hubs, the tone ring must be ordered separately and installed on the hub before installation of the hub onto the axle. Some tone rings are made of special material and require a specific procedure for proper installation. Doing the procedure incorrectly can damage or destroy the tone ring or cause the ABS to work improperly. The procedure below is used for many stamped steel or powdered metal tone rings such as those manufactured by Gunite. ConMet aluminum hub tone rings are installed at room temperature with special drivers. Check the tone ring and hub manufacturer's literature or website for specific procedures.

WARNING

If the teeth of a cast-in tone ring are damaged, that hub must be replaced immediately. If a removeable tone ring is badly corroded, bent, or damaged, it must be replaced immediately. The ABS may not work correctly with damaged tone rings. This could lead to decreased vehicle control, increased braking distances, and an accident with personal injury or property damage.

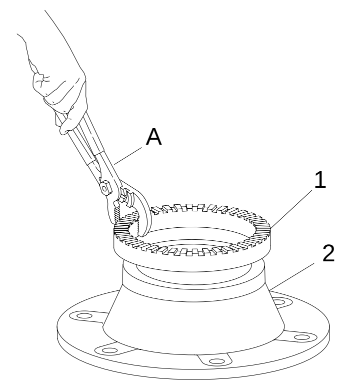
The following procedure is typical for Gunite hubs and similar ones.

1. Submerge the tone ring in boiling water or place it in an oven at 250°F (121°C) for approximately 15 minutes.

NOTICE

Do not attempt to heat the tone ring with a torch as this can damage the ring.

2. Using pliers, remove the tone ring from the boiling water or oven and center it on the machined area of the hub bore. See **Fig. 1**.



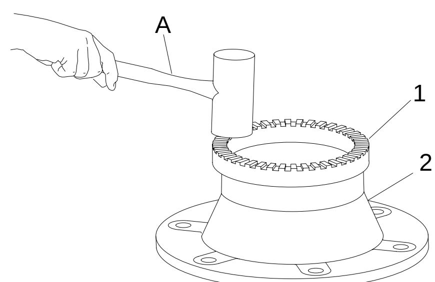
12/23/97 f421664

A. Use pliers to apply the ring.

1. Tone Ring 2. Hub

Fig. 1, Installing the Ring on the Hub

3. While the tone ring is still hot, make sure it is properly centered on the machined surface. Using a rubber mallet, tap the tone ring until it bottoms out around the machined surface on the hub. See **Fig. 2**.



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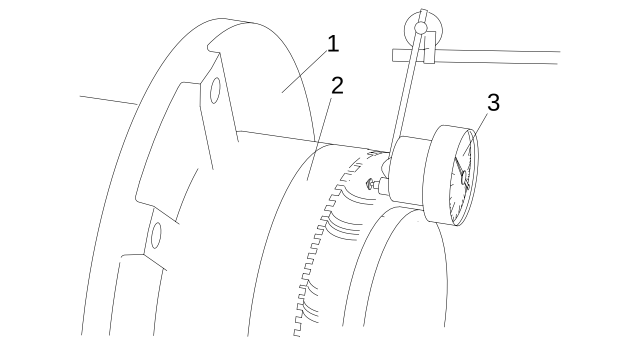
A. Use a rubber mallet.

1. Tone Ring 2. Hub

Fig. 2, Tapping the Tone Ring

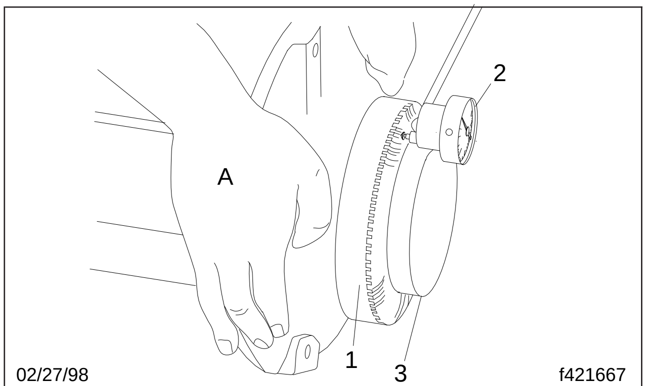
4. Install the hub on the axle. Place a dial indicator with a magnetic base so the dial indicator is against the tone-ring teeth. See **Fig. 3**.
5. Rotate the hub and check the ring for runout. The runout should be less than 0.005 inch (0.13 mm). See **Fig. 4**.

ABS Tone Ring Installation on Service Hubs



1. Hub
2. Tone Ring
3. Dial Indicator

Fig. 3, Positioning the Dial Indicator



A. Rotate the hub.

1. Tone Ring
2. Dial Indicator
3. Axle

Fig. 4, Checking Tone-Ring Runout

6. Install the wheel. For instructions, see **Group 40**.

General Information

This subject contains information for diagnosing problems in the WABCO E-Version pneumatic ABS system under the following headings:

- Troubleshooting Tables
- Component Specific Tests
- ABS Circuit Pin Wire Numbers
- Using Meritor TOOLBOX software to reconfigure the ECU

NOTE: Use Meritor TOOLBOX or ServiceLink for the preferred method of J1587 fault code diagnosis. Meritor WABCO also provides technical assistance through its website and the ArvinMeritor Customer Service Center phone: 1-800-535-5560.

NOTE: For wiring, see module 330 BOM in PartsPro for the correct schematic specific to the vehicle being serviced.

Troubleshooting Tables

Use the following tables to troubleshoot the ABS by MID-SID.

J1587 Fault Code Cross-Reference		
MID-SID	Description	Troubleshooting Table
	Wheel Sensor	
136-001	Left Front	Table 2
136-002	Right Front	Table 3
136-003	Left Rear	Table 4
136-004	Right Rear	Table 5
	Modulator Valve	
136-007	Left Front	Table 6
136-008	Right Front	Table 7
136-009	Left Rear	Table 8
136-010	Right Rear	Table 9
136-014	Ground Faults	Table 10
136-015		Table 11
136-019	Auxiliary Output	Table 12
136-231	J1939 Datalink	Table 13
136-251	Voltage	Table 14
136-253	Configuration Errors	Table 15
136-254	Miscellaneous Faults	Table 16

Table 1, J1587 Fault Code Cross Reference

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 7 and 8 of the X2 (black) ECU connector while rotating the LF wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	001	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.

WABCO E-Version ABS Troubleshooting

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	03	Sensor shorted to power	2. Measure the voltage across pin 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor harness, replace the sensor.
					No voltage at any pin.	Repeat the test and check for intermittent short to power in circuits 377LF– and 377LF+. If the problem persists, suspect that the ECU is faulty.
136	001	04	Short to ground	3. Measure the resistance between pin 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377LF– and 377LF+. If the problem persists, suspect that the ECU is faulty.
136	001	05	Open circuit	4. Measure the resistance between pins 7 and 8 of the X2 (black) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377LF– and 377LF+. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms.	Repair open or short in circuits 377LF– and 377LF+ in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	001	06	Short circuit			Perform tests 4 and 5.
136	001	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure the correct tone ring is installed (100-tooth is the normal application). Repair as needed.
136	001	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	001	09	Wire mismatch	6. Check for mixed sensor connections. While using Meritor TOOLBOX software, spin each wheel individually. Confirm that the output is from the correct sensor.		Correct wiring connections, as needed.
136	001	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK.	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	001	11	Erratic signal			Perform test 7.
136	001	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 2, Left Front Wheel Sensor Troubleshooting (SID 001)

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	002	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pin 5 and 6 of the X2 (black) ECU connector while rotating the RF wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	002	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on the tone wheel. Correct as needed.
136	002	03	Sensor shorted to power	2. Measure the voltage across pin 5 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 6 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor cable, replace the sensor.
					No voltage at any pin.	Repeat the test and check for intermittent short to power in circuits 377RF+ and 377RF–. If the problem persists, suspect that the ECU is faulty.

WABCO E-Version ABS Troubleshooting

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	002	04	Short to ground	3. Measure the resistance between pin 5 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 6 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor cable, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377RF+ and 377RF–. If the problem persists, suspect that the ECU is faulty.
136	002	05	Open circuit	4. Measure the resistance between pin 5 and 6 of the X2 (black) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377RF+ and 377RF–. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohm.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms.	Repair open or short in circuit(s) 377RF+ and 377RF– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	002	06	Short circuit			Perform tests 4 and 5.
136	002	07	Damaged tone ring			Inspect the tone ring for damage and missing teeth. Make sure the correct tone ring is installed (100-tooth is normal application). Repair as needed.
136	002	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	002	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor TOOLBOX software, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	002	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK.	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	002	11	Erratic signal			Perform test 7.
136	002	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 3, Right Front Wheel Sensor Troubleshooting (SID 002)

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	003	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 1 and 2 of the X3 (green) ECU connector while rotating the LR wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	003	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.
136	003	03	Sensor shorted to power	2. Measure the voltage across pin 1 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 2 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor cable, replace the sensor.
					No voltage at any pin.	If the problem persists, suspect that the ECU is faulty.
136	003	04	Short to ground	3. Measure the resistance between pin 1 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 2 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If the short is in the sensor cable, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377LR+ and 377LR–. If the problem persists, suspect that the ECU is faulty.

WABCO E-Version ABS Troubleshooting

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	003	05	Open circuit	4. Measure the resistance between pins 1 and 2 of the X3 (green) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377LR+ and 377LR–. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms.	Repair open or short in circuit(s) 377LR+ and 377LR– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	003	06	Short circuit			Perform tests 4 and 5.
136	003	07	Damaged tone ring			Inspect the tone ring for damage and missing teeth. Make sure the correct tone ring is installed (100-tooth is normal application). Repair as needed.
136	003	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	003	09	Wire mismatch	6. Check for mixed sensor connection. While using Meritor TOOLBOX software, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.
136	003	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK.	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	003	11	Erratic signal			Perform test 7.
136	003	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 4, Left Rear Wheel Sensor Troubleshooting (SID 003)

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	004	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 3 and 4 of the X3 (green) ECU connector while rotating the RR wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	004	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on the tone wheel. Correct as needed.
136	004	03	Sensor shorted to power	2. Measure the voltage across pin 3 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 4 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If the problem is in the sensor harness, replace the sensor.
					No voltage at any pin.	If the problem persists, suspect that the ECU is faulty.
136	004	04	Short to ground	3. Measure the resistance between pin 3 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 4 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If the problem is in the sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377RR+ and 377RR–. If the problem persists, suspect that the ECU is faulty.
136	004	05	Open circuit	4. Measure the resistance between pins 3 and 4 of the X3 (green) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377RR+ and 377RR–. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms.	Repair open or short in circuit(s) 377RR+ and 377RR– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	004	06	Short circuit			Perform tests 4 and 5.

WABCO E-Version ABS Troubleshooting

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	004	07	Damaged tone ring			Inspect the tone ring for damage and missing teeth. Make sure the correct tone ring is installed (100-tooth is normal application). Repair as needed.
136	004	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	004	09	Wire mismatch	6. Check for mixed sensor connections. While using Meritor TOOLBOX software, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.
136	004	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK.	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	004	11	Erratic signal			Perform test 7.
136	004	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 5, Right Rear Wheel Sensor Troubleshooting (SID 004)

Left Front Modulator Valve Troubleshooting (SID 007)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	007	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 2, 10, and 11 of the X2 (black) connector and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378LFI, 378LFO, and 378LF– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378LFI, 378LFO, or 378LF–.

Left Front Modulator Valve Troubleshooting (SID 007)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	007	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LFI, 378LFO, or 378LF– for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.
136	007	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LFI and 378LFO for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 6, Left Front Modulator Valve Troubleshooting (SID 007)

Right Front Modulator Valve Troubleshooting (SID 008)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	008	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 3, 4, and 9 of the X2 (black) connector, and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378RFO, 378RFI, and 378RF– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378RFO, 378RFI, or 378RF–.
136	008	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RFO, 378RFI, or 378RF– for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.
136	008	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RFO and 378RFI for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 7, Right Front Modulator Valve Troubleshooting (SID 008)

WABCO E-Version ABS Troubleshooting

Left Rear Modulator Valve Troubleshooting (SID 009)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	009	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pin 10, 11, and 12 of the X3 (green) connector and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378LRI, 378LRO, and 378LR– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378LRI, 378LRO, or 378LR–.
136	009	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LRI, 378LRO, and 378LR– for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.
136	009	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LRI and 378LRO for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 8, Left Rear Modulator Valve Troubleshooting (SID 009)

Right Rear Modulator Valve Troubleshooting (SID 010)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	010	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pin 7, 8, and 9 of the X3 (green) connector and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378RRO, 378RR–, and 378RRI for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378RRO, 378RR–, or 378RRI.
136	010	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RRO, 378RR–, and 378RRI for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Right Rear Modulator Valve Troubleshooting (SID 010)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	010	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RRO and 378RRI for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 9, Right Rear Modulator Valve Troubleshooting (SID 010)

Ground Faults Troubleshooting (SID 014)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	014	04	Low voltage or open circuit	1. Disconnect the X1 (gray) connector at the ABS ECU. With the ignition ON, measure the voltage between pins 1 and 12.	Voltage is 9.5 to 14 volts.	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.
					Voltage is less than 9.5 volts.	Check vehicle batteries and charging system. Check ABS ECU power and ground circuits for open or high resistance. Repair as necessary.
136	014	05	Central ground open or high resistance	2. Disconnect the X1 (gray) connector at the ABS ECU. Check the ground circuit (pin 11) for high resistance or open circuit.	Ground is okay.	Verify the fault. Check the ground circuits intermittent open circuit. Repair as necessary.
					Ground is open or has high resistance.	Repair ground circuit as necessary.
136	014	07	Internal relay does not open			If the fault repeats, replace the ABS ECU.

Table 10, Ground Faults Troubleshooting (SID 014)

Ground Faults Troubleshooting (SID 015)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	015	04	Low voltage or open circuit	2. Disconnect the X1 (gray) connector at the ABS ECU. With the ignition ON, measure the voltage between pin 2 and a good ground.	Voltage is 9.5 to 14 volts.	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.
					Voltage is less than 9.5 volts.	Repair voltage supply to ECU.
136	015	07	Internal relay fault			If the fault repeats, replace the ABS ECU.

Table 11, Ground Faults Troubleshooting (SID 015)

WABCO E-Version ABS Troubleshooting

Auxiliary Output Troubleshooting (Not fitted, but possible to encounter error code) (SID 019)				
MID	**SID**	**FMI**	**Problem**	**Action**
136	019	03	Short to power	This fault should not appear. Re-configure the ECU. If fault continues to appear, check the wiring in the X2 (black) ABS ECU connector. Pins 1 and 12 should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor WABCO.
136	019	05	Open circuit	Verify fault. Contact Meritor WABCO if fault persists.
136	019	06	Short to ground	This fault should not appear. Reconfigure the ECU. If fault continues to appear, check the wiring in the X2 (black) ABS ECU connector. Pins 1 and 12 should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor WABCO.

Table 12, Auxiliary Output Troubleshooting (SID 019)

J1939 Datalink Troubleshooting (SID 231)					
MID	**SID**	**FMI**	**Problem**	**Test**	**Action**
136	231	02	J1939 speed plausibility error. NOTE: This fault indicates a discrepancy between vehicle speed reported on J1939 and ABS sensed vehicle speed.		Check the speedometer calibration. Check for the tire size mismatch. The vehicle speed reported on the J1939 datalink does not agree with the wheel sensor speeds.
136	231	05	J1939 open/short		Repair J1939 datalink as necessary.
136	231	06	J1939 open/short Code 136s231 05 may be active as well.		Repair J1939 datalink as necessary.
136	231	07	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check the engine retarder, ECU, and wires.	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	08	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check engine ECU and wires. Check J1939 datalink.	Check J1939 datalink and engine ECU. Repair as necessary.

J1939 Datalink Troubleshooting (SID 231)					
MID	SID	FMI	Problem	Test	Action
136	231	09	J1939 time out NOTE: Fault occurs if engine or transmission sends message incorrectly.	Check engine and transmission ECUs and wires. Check J1939 datalink.	Check J1939 datalink, engine ECU, transmission ECU, and wiring. Repair as necessary.
136	231	10	J1939 time out NOTE: Fault occurs if the exhaust retarder sends a message incorrectly.	Check the engine ECU and wires. Check the J1939 datalink.	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	12	J1939 internal error		Verify fault. Clear code from the ECU memory. If fault persists, replace the ABS ECU.

Table 13, J1939 Datalink Troubleshooting (SID 231)

Voltage Troubleshooting (SID 251)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	251	03	Overvoltage Voltage to ECU was too high for more than 5 seconds.	Set the engine at governed speed. Using Meritor TOOLBOX software, measure the diagonal voltages.	Voltage is 9.5 to 14 volts	Check for intermittent sources of high voltage. Check condition of charging system and batteries. Verify fault.
					Voltage is greater than 14 volts.	Check charging system. Repair as necessary.

Table 14, Voltage Troubleshooting (SID 251)

Configuration Errors Troubleshooting (SID 253)				
MID	SID	FMI	Problem	Action
136	253	02	ABS configuration/wheel parameter incorrect.	Reconfigure ECU. If the fault repeats, then the wrong ECU is installed. Replace with the correct ECU.
136	253	12	Check sum error.	Check parameter setting. Check if diagnostic device was disconnected during active diagnosis.

Table 15, Configuration Errors Troubleshooting (SID 253)

Miscellaneous Faults Troubleshooting (SID 254)				
MID	SID	FMI	Problem	Action
136	254	05	ABS ECU, no loads.	No modulator valve connected. Fault may have resulted from end-of-line test at factory.
136	254	08	Excessive wheel slip.	Check wheel speed sensor air gaps. One wheel was much faster than the other. May have been caused by testing vehicle on a dynamometer.

WABCO E-Version ABS Troubleshooting

Miscellaneous Faults Troubleshooting (SID 254)				
MID	SID	FMI	Problem	Action
136	254	09	Modulator valve actuated too long.	Modulator valve was activated too long (more than 75% of 5 minutes). After a delay, function will return to normal.
136	254	12	Internal error.	If the fault persists, replace the ABS ECU.
136	254	13	Accelerometer out of range.	If the fault persists, replace the ABS ECU.
136	254	14	ECU Mounting.	Check ECU mounting. Replace the ECU if the fault persists.
			Extreme banked road (measured acceleration not plausible).	No correction required. This fault is for reporting only.
			Accelerometer linearity (measured acceleration not plausible).	

Table 16, Miscellaneous Faults Troubleshooting (SID 254)

Wheel Speed Sensor Tests

Wheel Speed Sensor and Circuit Resistance

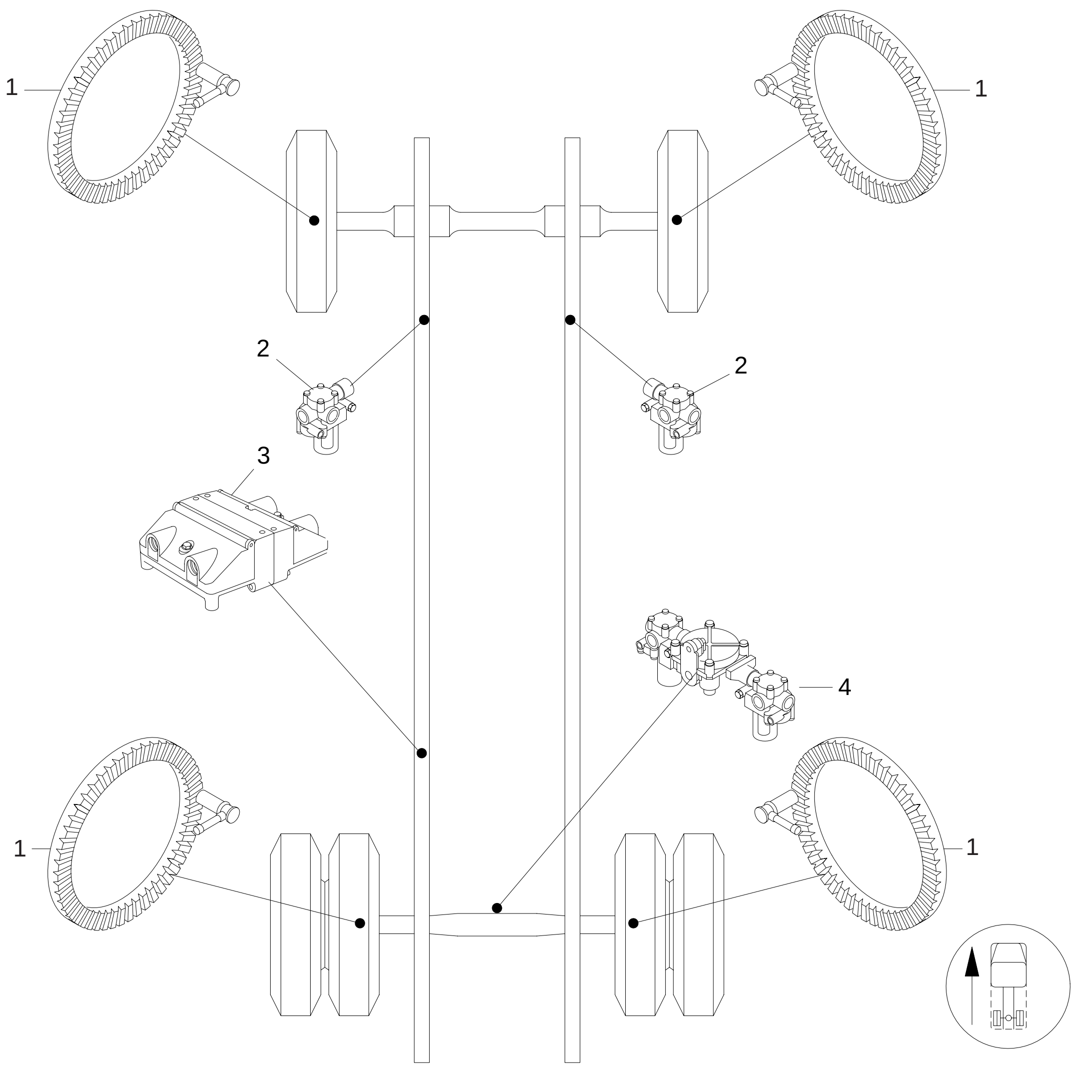
To check the resistance in a wheel speed sensor and its circuit, refer to **Fig. 1** and perform the following test.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect from the ECU the connector that contains the circuit for the sensor being tested. See **Table 17** for detailed pinout information.
3. Connect ohmmeter probes to the connector terminals and measure the resistance.
    - If the resistance is 900 to 2000 ohms, the sensor and its circuit are good. Proceed to the "Wheel Speed Sensor Voltage" test.
    - If the resistance is less than 900 ohms or greater than 2000 ohms, perform the next test, "Wheel Speed Sensor Resistance."
4. Connect the sensor connector to the ECU.

Wheel Speed Sensor Resistance

To check the resistance in a wheel speed sensor, perform the following test.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the sensor cable from the chassis harness.
3. Connect ohmmeter probes to the pins on the sensor and measure the resistance.
    - If the resistance reading is 900 to 2000 ohms but the resistance noted in the previous test, "Wheel Speed Sensor and Circuit Resistance" was not, repair or replace the chassis harness wiring.
    - If the resistance is less than 900 ohms or greater than 2000 ohms, clean the terminals and check the resistance again. If the resistance reading is still not correct, replace the sensor.
4. Connect the sensor cable to the chassis harness and remove the chocks from the tires.



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1. Tone Rings and Wheel Sensors
2. Front Modulator Valves
3. ABS ECU (Inside Frame Rail)
4. Rear Modulator Valve Assembly

Fig. 1, ABS Main Component Locations

WABCO E-Version ABS Troubleshooting

WABCO E-Version Circuit Pin and Wire Numbers			
Connector	Pin Number	Wire Number	Circuit Description
X1 Gray	1	376A	ECU Battery Supply (+12 volt)
	2	376C	ECU Ignition Supply (+12 volt)
	4	1587+	J1587+
	5	—	—
	6	1939–	J1939–
	7	1939+	J1939+
	8	—	Not used
	9	1587–	J1587–
	10	376L1	ABS Light
	11	GND	ECU Ground
	12	GND	ECU Ground
X2 Black	1	—	Not used
	2	378LFI	Left Front Modulator Valve, In
	3	378RFO	Right Front Modulator Valve, Out
	4	378RFI	Right Front Modulator Valve, In
	5	377RF+	Right Front Sensor, High
	6	377RF–	Right Front Sensor, Low
	7	377LF–	Left Front Sensor, Low
	8	377LF+	Left Front Sensor, High
	9	378RF–	Right Front Modulator Valve, Ground
	10	378LFO	Left Front Modulator Valve, Out
	11	378LF–	Left Front Modulator Valve, Ground
	12	—	Not used
X3 Green	1	377LR–	Left Rear Sensor, Low
	2	377LR+	Left Rear Sensor, High
	3	377RR+	Right Rear Sensor, High
	4	377RR–	Right Rear Sensor, Low
	7	378RRO	Right Rear Modulator Valve, Out
	8	378RR–	Right Rear Modulator Valve, Ground
	9	378RRI	Right Rear Modulator Valve, In
	10	378LRO	Left Rear Modulator Valve, Out
	11	378LR–	Left Rear Modulator Valve, Ground
	12	378LRI	Left Rear Modulator Valve, In

Table 17, WABCO E-Version Circuit Pin and Wire Numbers

Wheel Speed Sensor Voltage

NOTE: Meritor TOOLBOX software can be used for this test to compare speed signal output of all sensors. Low or erratic output indicates a problem.

Check the voltage output of a wheel speed sensor, as follows.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine.
2. Chock the tires of the axle not being tested. Raise the vehicle and put jack stands under the axle to be tested, so the wheels can rotate.
3. Disconnect from the ECU the connector for the sensor being tested. See **Table 17** for detailed pinout information.
4. Set a digital multimeter to the AC voltmeter mode. Connect the probes to the terminals for the sensor being tested.
5. Rotate the wheel by hand at a speed of 30 rpm (one-half revolution per second) and read the voltage output. The wheel speed sensor must generate a minimum of 0.2 volt AC.
    - If the voltage is at least 0.2 volt AC, go to the next step.
    - If the voltage reading is less than 0.2 volt AC, push the sensor into its holder until the sensor touches the tone ring. Repeat the voltage test. If the voltage is still less than 0.2 volt AC, replace the sensor.
6. Install the connector on the ECU. Remove the jack stands, lower the vehicle. Remove the chocks from the tires.

Modulator Valve Tests

Modulator Valve Function Check

NOTE: Valves can be tested using the Meritor WABCO TOOLBOX software or the following procedure.

1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Turn the ignition on.
3. When the ABS warning light comes on, listen for the modulator valves to cycle one by one. The 4-Channel valve cycle is: 1, 2, 3, 4. See **Fig. 2**.

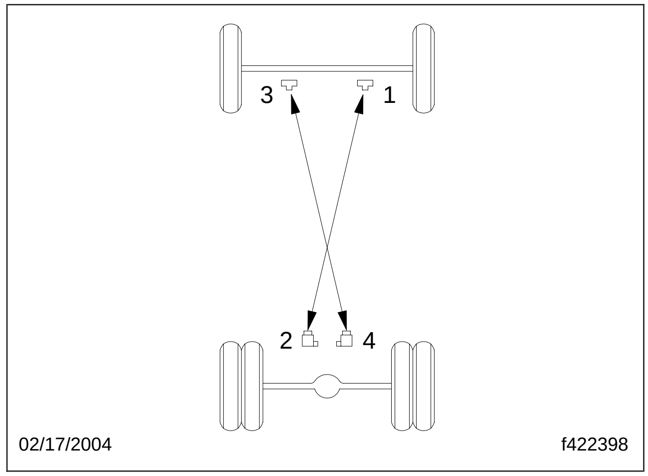


Fig. 2, Modulator Valve Function Test Sequence

4. If the valves do not all cycle correctly, turn the ignition off and check the connectors for tightness. Repeat the self-test.
5. If the valves still do not cycle correctly, start the engine and check the air line connections to the valves for leaks. Shut down the engine and tighten the air line fittings. Repeat the self-test.
6. If the valves still do not cycle correctly, check for fault codes. Perform the next test, "Modulator Valve and Circuit Resistance."

Modulator Valve and Circuit Resistance

To check the resistance in a modulator valve and its circuit, perform the following test.

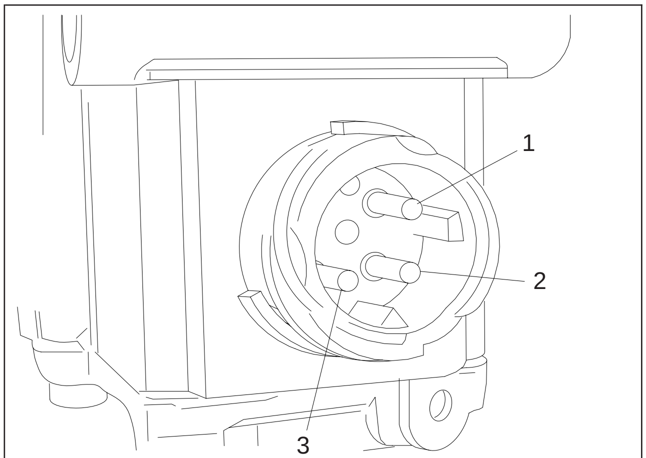
1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect (from the ECU) the connector that contains the circuit for the modulator valve being tested. See **Table 17** for detailed pinout information.
3. Connect ohmmeter probes to the connector pins for the modulator valve "In" and "Ground" terminals. Measure the resistance. Move the probes to the pins for the "Out" and "Ground" terminals and measure the resistance.

4. The resistance in both cases must be 4 to 9 ohms.
   - If the resistance in both cases is 4 to 9 ohms, the modulator valve and its circuit are good. Install the connector on the ECU and remove the chocks from the tires.
   - If the resistance in either is less than 4 ohms or greater than 9 ohms, go to the next test, "Modulator Valve Resistance."

Modulator Valve Resistance

To check the resistance in a modulator valve, perform the following test.

1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the modulator valve being tested.
3. Connect ohmmeter probes to the modulator valve "In" and "Ground" terminals. See **Fig. 3**. Measure the resistance. Move the probes to the "Out" and "Ground" terminals and measure the resistance.



07/03/2001 f430270

1. Ground (Common)
2. Exhaust Solenoid (Out)
3. Supply Solenoid (In)

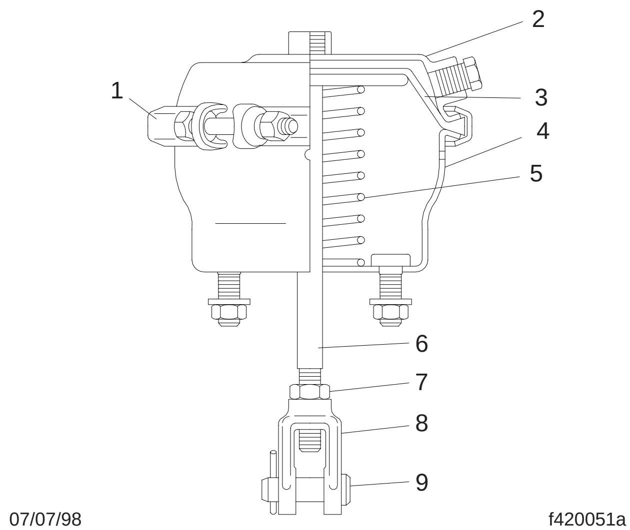
Fig. 3, Modulator Valve Terminals

4. The resistance in both cases must be 4 to 9 ohms.
   - If the resistance in both cases is 4 to 9 ohms but the resistance noted in the previous test, "Modulator Valve and Circuit Resistance" was not, repair or replace the chassis harness.
   - If the resistance is less than 4 ohms or greater than 9 ohms, clean the terminals on the modulator valve and check the resistance again. If the resistance still is not correct, replace the valve.
5. Install the connectors and remove the chocks from the tires.

General Description

Brake chambers convert the energy of compressed air into the mechanical force and motion needed to apply the brakes. Two chambers operate the brakes, one on each side of the axle.

Each brake chamber consists of two dished metal sections: the cover assembly and the body assembly, which are separated by a nylon-neoprene diaphragm. A metal two-segment clamp ring holds the assemblies together. See **Fig. 1**.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

In front of the diaphragm are the body, piston rod assembly, and a piston rod spring. The threaded piston rod assembly extends through the bottom of the body and connects to the clevis. See **Fig. 1**.

Different sized brake chambers are identified by numbers, which specify the effective area of the diaphragm. For example, a type 16 brake chamber has 16 square inches of effective area.

Principles of Operation

The greater the air pressure admitted to the brake chamber, the greater the force applied by the piston rod. Piston rod force is determined by multiplying the delivered air pressure by the effective diaphragm area. For example, if 60 psi (415 kPa) is admitted to a type 16 brake chamber, the force on the end of the piston rod is about 960 lbf (436 kg).

When the brake pedal is depressed, air pressure from the brake valve passes through the port in the brake chamber cover to move the diaphragm and piston rod assembly forward. This compresses the spring, and applies a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

When the brake pedal is released, compressed air behind the diaphragm exhausts through the quick release valve. The spring then allows the piston rod assembly and diaphragm to return to their previous positions.

NOTE: For both of these tests, the air system must be pressurized to at least 80 psi (550 kPa).

Operating Test

1. Chock the tires.
2. Apply the brakes. Check that each piston rod moves out promptly, without binding.
3. Release the brakes. Check that each piston rod returns to the released position promptly, without binding.
4. Check the brake chamber stroke. It should be as short as possible without causing the brakes to drag. If needed, adjust the travel of the piston rod at the slack adjuster. For instructions, refer to the foundation brake section in this manual.

Leakage Test

1. Apply the brakes and hold them on full line pressure of at least 80 psi (550 kPa).
2. Using a soap solution, coat the clamp ring. Leakage is excessive if it produces a 1-inch (25-mm) bubble within five seconds.

NOTICE

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

3. If the leakage is excessive, tighten the clamp ring flange nuts evenly until the leakage is reduced. For acceptable torque ranges, see **Specifications 400**.
4. Using a soap solution, coat the area around the piston-rod hole. No leakage is permitted. If there is leakage, replace the diaphragm. For instructions, see **Subject 110**.

Diaphragm Replacement

Replacement

NOTE: This procedure is for service of a leaking brake chamber *diaphragm only*. If there are any other problems, refer to the applicable subjects elsewhere in this section.

1. Chock the tires.

WARNING

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

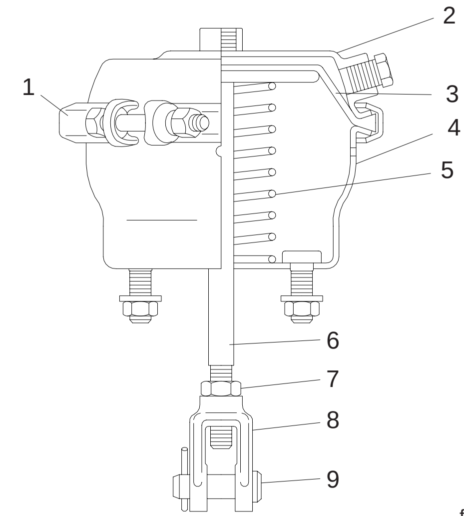
Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Back off the slack adjuster; for instructions, refer to the applicable slack adjuster section in this manual. Pull out the piston rod. See **Fig. 1**. Clamp the rod at the chamber body to protect it from damage.
4. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
5. Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
6. Remove the cover assembly, and replace the diaphragm.

NOTICE

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

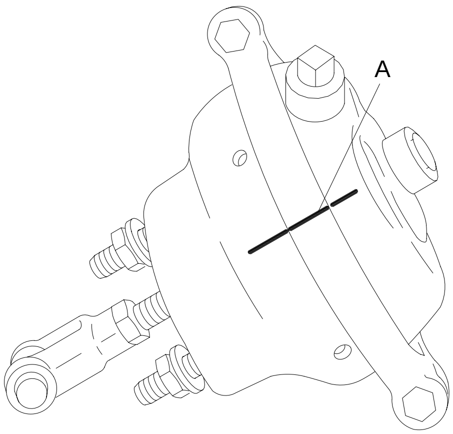
7. Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications 400**.
8. Release the clamp on the piston rod.
9. Do both of the tests in **Subject 100**.
10. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
11. Remove the chocks from the tires.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

Diaphragm Replacement



A. Reference Line

Fig. 2, Marking a Reference Line

Brake Chamber Removal and Installation

Removal

1. Chock the tires.

WARNING

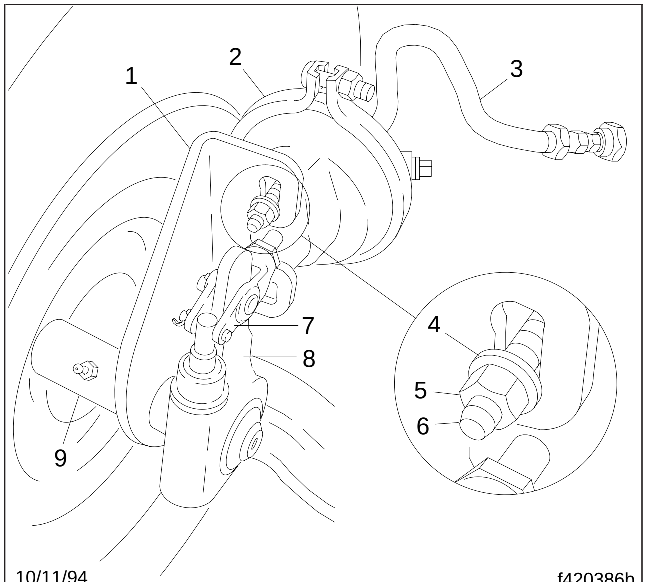
Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Do not direct the airstreams at other people. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in severe personal injury.

Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Carefully disconnect the air line from the brake chamber.
4. Remove the cotter pins from the clevis pins. See **Fig. 1**.

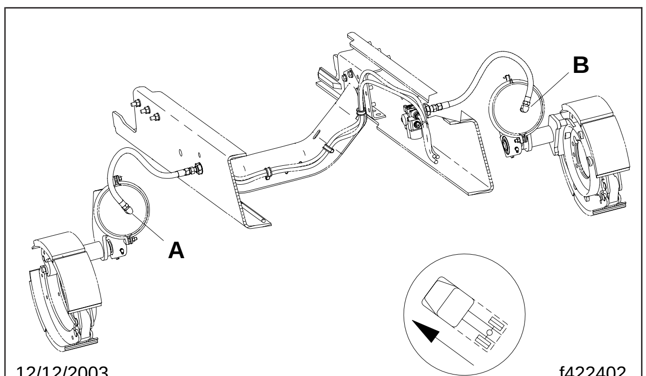
NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

5. Remove the clevis pins from the slack adjuster.
6. From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.



1. Chamber Mounting Bracket
2. Brake Chamber
3. Air Line
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Chamber Mounting Stud
7. Clevis Assembly
8. Slack Adjuster
9. Camshaft Tube

Fig. 1, Brake Chamber Mounting



A. Fitting Located at 11 o'clock Position, Left Hand Brake Chamber
B. Fitting Located at 1 o'clock Position, Right Hand Brake Chamber

Fig. 2, Brake Chamber Fitting Position

Installation

1. Before installing a new chamber, be sure it is the same size and make as the brake chamber on the other side of the axle. To ensure the proper supply of compressed air to the chamber, the left-hand brake chamber air fitting should be positioned at the 11 o'clock position and the right-hand brake chamber air fitting should be positioned at the 1 o'clock position. See **Fig. 2**.

WARNING

Ensure the air fittings on the brake chamber are in the 11 o'clock and 1 o'clock positions or the flow of compressed air to the brake chamber may

Brake Chamber Removal and Installation

be restricted, resulting in loss of control of the vehicle and personal injury or property damage.

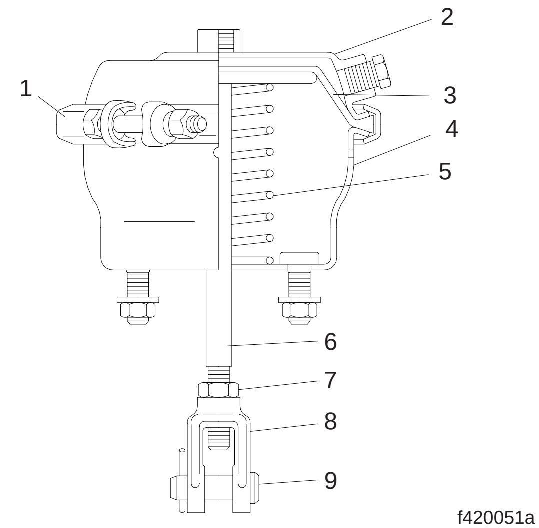
2. Attach the brake chamber to the mounting bracket using a hardened flatwasher and prevailing torque locknut. Install the flatwasher between the locknut and the mounting bracket. See **Fig. 1**.
3. Tighten the locknuts. See **Specifications 400** for the correct torque value.
4. Connect the clevis pins to the slack adjuster.
5. Install and lock new cotter pins to secure the clevis pins.

NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

6. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
7. Check that the hoses are properly supported and, if needed, clamped to provide good clearance.
8. Before connecting the air line, make sure the fittings are clean and free of debris.
9. 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.
10. Do both of the tests in **Subject 100**.
11. Remove the chocks from the tires.

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

Refer to **Fig. 1** during chamber disassembly and assembly.



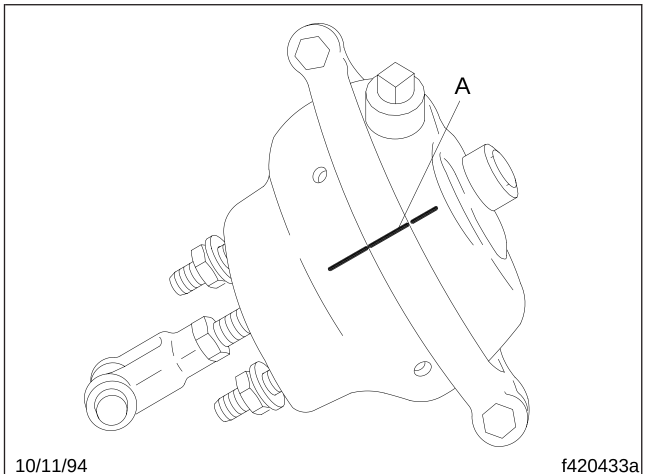
1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

Disassembly

NOTE: If the brake chamber is to be disassembled without removing the body assembly from the vehicle, first back off the slack adjuster. For instructions, refer to the applicable slack adjuster section in this manual.

1. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.
3. Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
4. Remove the cover assembly and the diaphragm.
5. Remove the clevis locknut and clevis from the piston rod, and release the clamp on the piston rod, being careful to contain the piston rod assembly and body until the return spring is relaxed.



A. Reference Line

Fig. 2, Marking a Reference Line

6. Remove the piston rod assembly and spring.

Inspection and Cleaning

1. Clean all metal parts with cleaning solvent.
2. Check the cover and the body for dents. If any are too deep to be pounded out, replace as needed.
3. Check the diaphragm for wear or deterioration and replace it if necessary. Haldex recommends replacement of the diaphragm whenever the service brake chamber is opened for inspection.
4. Inspect all other parts not considered serviceable. Replace if necessary.

Assembly

1. Stand the piston rod assembly upright on a flat surface (if the chamber was removed from the vehicle).
2. Place the return spring on the piston rod.
3. Place the body on the piston rod assembly, and press the body down, working against the tension of the spring, until the body bottoms out on the flat surface. Clamp the body rod at the body,

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

making sure to protect the rod from damage. Insert the piston rod assembly through the body and clamp the rod (if the body wasn't removed from the vehicle).

4. Place the diaphragm in the body.

NOTICE

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

5. Install the clevis locknut and clevis, and release the clamp on the piston rod.
6. If the brake chamber was removed from the vehicle, install it. For instructions, see **Subject 120**.
7. Do both of the tests found in **Subject 100**.

Specifications

Fastener Torque Specifications		
Fastener Description	**Chamber Size: in^2**	**Torque: lbf·ft (N·m)**
Brake Chamber Mounting-Stud Locknuts	12	30 (41)
	16 (5/8-inch stud)	100 (136)
	20	100 (136)
	24	100 (136)
Clamp Ring Flange Nuts	12	17–21 (22–28)
	16	17–21 (22–28)
	20	9–19 (12–26)
	24	13–19 (17–26)
Piston Rod Nuts	12	20–30 (27–41)
	16 (5/8-inch stud)	33–90 (45–122)
	20	33–90 (45–122)
	24	33–90 (45–122)

Table 1, Fastener Torque Specifications

General Information

The Meritor automatic slack adjuster has two main functions:

- As a lever, it converts the straight-line force of the brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the brake drum.
- As an automatic adjuster, it automatically maintains brake chamber pushrod stroke, which controls lining-to-drum clearance during operation.

Meritor automatic slack adjusters automatically adjust the clearance between the brake lining and the brake drum. When linings wear, this clearance increases and causes the chamber pushrod to move a greater distance to apply the brakes.

During operation, if the chamber stroke exceeds the design limit, the automatic slack adjuster will automatically adjust the pushrod's return stroke to control clearance between the lining and the drum and reset the stroke to the correct length. See **Fig. 1**.

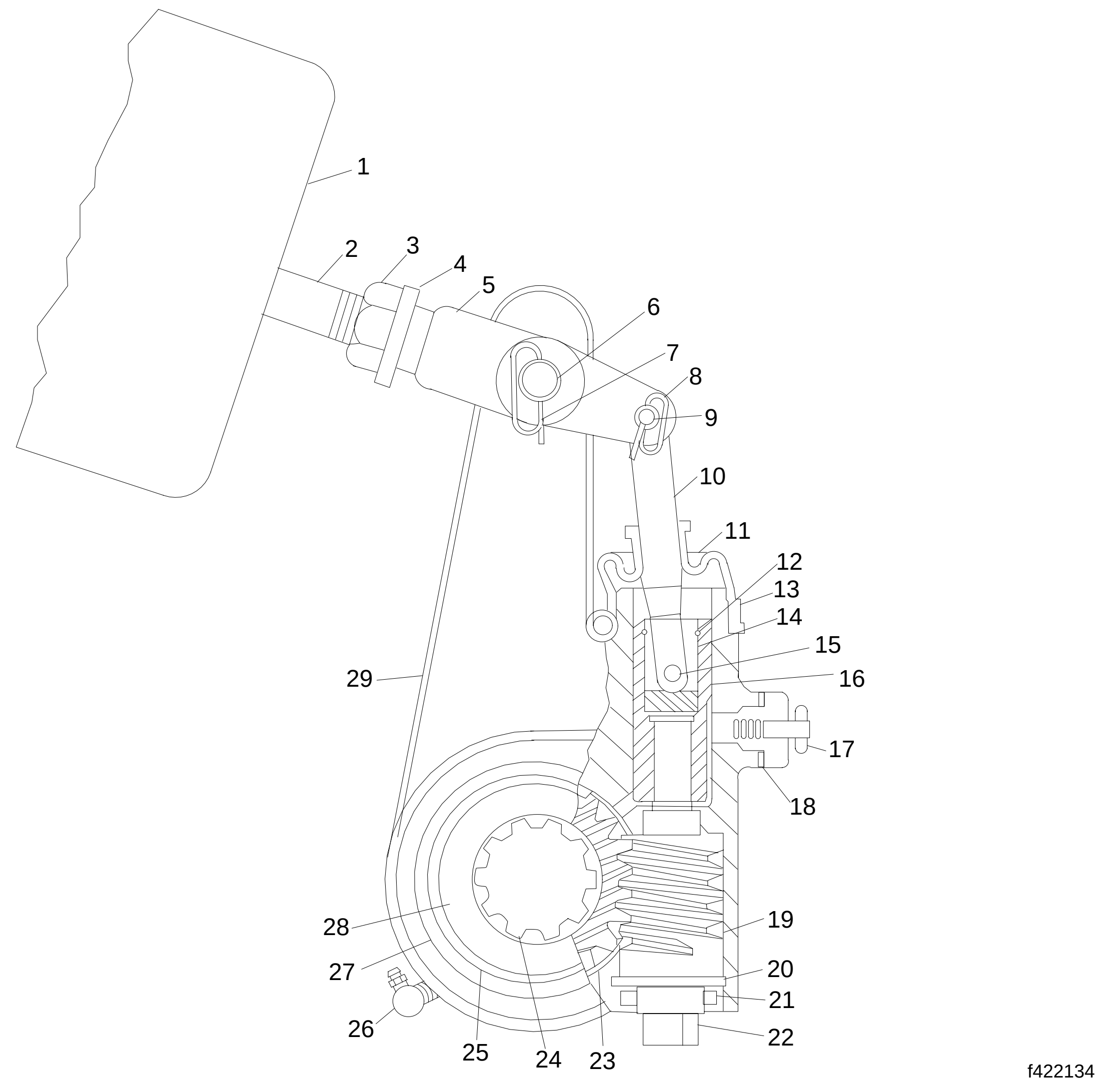
A pressed-in, sealed actuator boot is standard equipment on Meritor slack adjusters. The boot features a metal retaining ring with additional material that extends beyond the base of the retainer. The boot forms a seal once it is pressed into the slack adjuster body.

Meritor automatic slack adjusters, including the factory-installed slack adjusters on the Q Plus cam brakes, have a one-piece threaded clevis. See **Fig. 2**.

The one-piece threaded clevis:

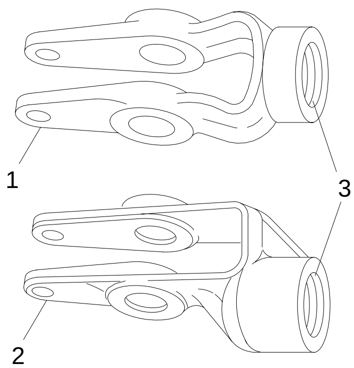
- has a threaded hole for the pushrod;
- can be straight or offset;
- is used on all service replacement automatic slack adjusters.

General Information



1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Clevis Pin Retainer Clip (large)
8. Clevis Pin Retainer Clip (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Sleeve)
17. Pull-Pawl Assembly (shown 90 degrees out of position)
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual (Worm) Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retainer/Seal
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Arm

Fig. 1, Automatic Slack Adjuster (sectional view)



1. Straight Clevis
2. Offset Clevis
3. Threads

Fig. 2, One-Piece Threaded Clevis Configurations

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface, apply the parking brake, shut down the engine, and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting the air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Slack Adjuster Removal and Installation

Removal

1. With the vehicle parked on a level surface, set the parking brake, shut down the engine, and chock the tires.

WARNING

Manually cage each parking brake chamber power spring in the release (no application) position before continuing. Loss of brake chamber air pressure will cause sudden application of the parking brakes, which could result in personal injury.

2. If the rear slack adjusters will be removed, release the parking brakes, then cage the power spring of the parking brake chamber.
3. Remove the retainer clips from the large and small clevis pins. Remove the clevis pins. See **Fig. 1**.

NOTICE

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

4. Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**.

   Wedge the tool in place. Pull-pawls are spring-loaded; when the tool is removed, the pull-pawl will engage the teeth automatically.
5. Using a wrench, manually turn the square adjusting nut clockwise to move the slack adjuster away from the clevis. See **Fig. 3**.
6. Remove the snap ring, washer(s), and seal (if equipped) that secure the slack adjuster in place on the brake camshaft; save them for later installation.
7. Remove the slack adjuster from the camshaft.
8. Note the location and number of any remaining spacing washers on the camshaft. Remove the spacers and seal (LX500 and MX500 series only), and save them for later installation.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Inspect the parts and prepare the slack adjuster for installation.
2. Check the brake camshaft splines for wear or corrosion.

IMPORTANT: The following lubricants provide corrosion protection. Do not mix them with other types of lubricants.

3. Coat the camshaft splines and the splines of the slack adjuster gear with Meritor 0-637, Meritor 0-695 (LX500 and MX500 only), Southwest SA 8249496, or an equivalent.
4. Apply the service brake several times. Make sure the return spring retracts the pushrod quickly and completely. Replace the return spring or brake chamber, if needed.
5. Slide the spacing washer(s) on the camshaft.

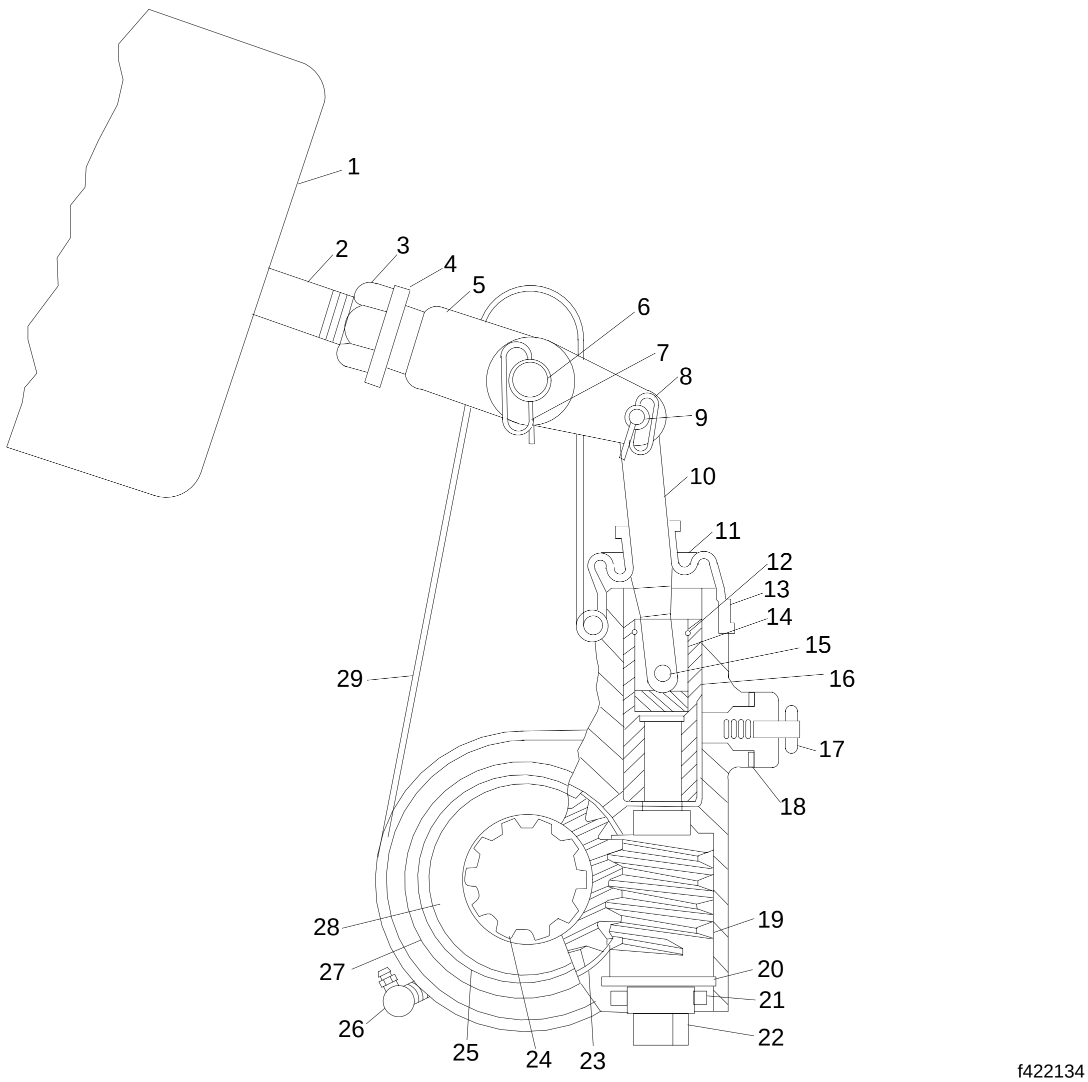
   On LX500 and MX500, install the slack adjuster seal with the lip facing the brake spider.
6. If reinstalling the same slack adjuster:

   6.1 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.

   6.2 On LX500 and MX500, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.

   6.3 Install the outer washer(s) and snap ring on the camshaft.

Slack Adjuster Removal and Installation



1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Retainer Clip (large)
8. Retainer Clip (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Sleeve)
17. Pull-Pawl Assembly (shown 90 degrees out of position)
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
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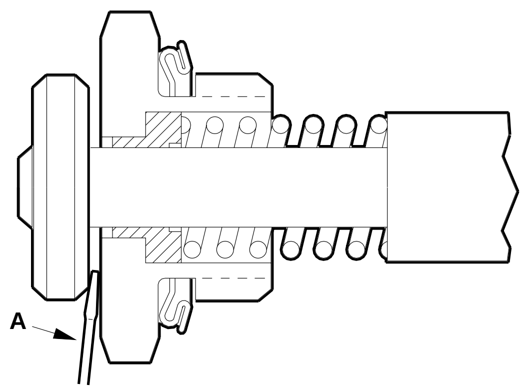
22. Manual (Worm) Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retainer/Seal
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Arm

Fig. 1, Automatic Slack Adjuster (sectional view)



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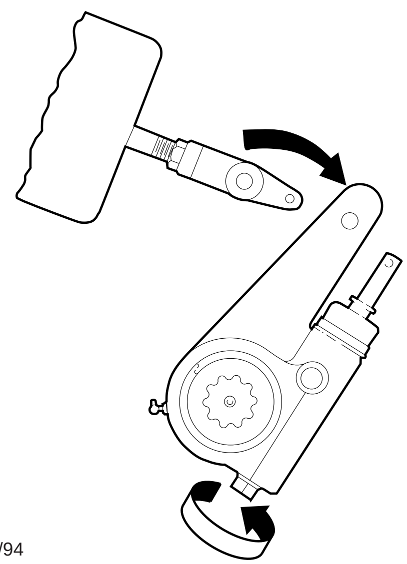
A. Insert a screwdriver here to pry the pull-pawl button out about 1/32 inch (0.8 mm).

Fig. 2, Pull-Pawl Assembly



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Turn the manual adjusting nut clockwise.

Fig. 3, Slack Adjuster Removal

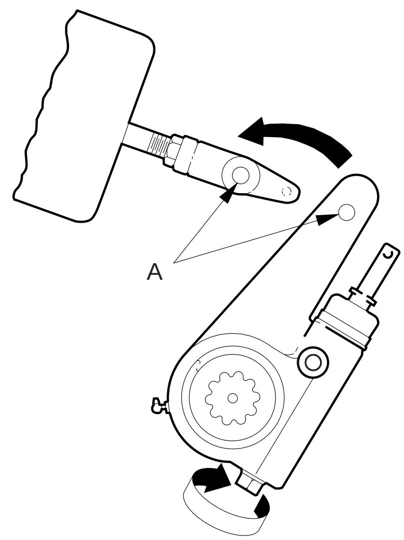
NOTICE

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

6.4 Using a screwdriver or an equivalent tool, pry the pawl button out at least 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

6.5 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.



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A. Turning the adjusting nut counterclockwise, align the large holes in the slack adjuster and clevis.

Fig. 4, Slack Adjuster Installation

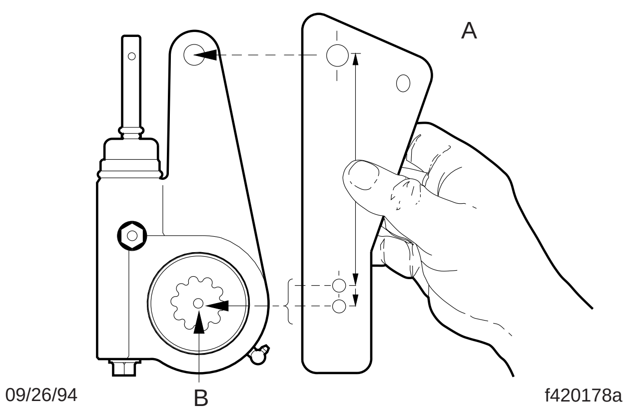
7. If installing a new slack adjuster:

   7.1 Using an installation template, measure the old and new slack adjusters. Measure from the center of the large clevis-pin hole to the center of the camshaft opening. See **Fig. 5**.

   Make sure the old and new slack adjusters are the same length.

   7.2 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.

Slack Adjuster Removal and Installation



A. Using a template, measure the slack adjuster arm length.
B. Camshaft Center

Fig. 5, Slack Adjuster Measurement

7.3 On LX500 and MX500 series, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.

7.4 Install the outer washer(s) and snap ring on the camshaft.

7.5 Using a dial indicator, measure the in-and-out (axial) end play of the camshaft. If necessary, add the appropriate number of spacing washers to achieve the correct axial end play.

- For all Cam-Master brakes, except LX500 and MX500 series, there should be no more than 0.060 inch (1.52 mm) movement.
- For LX500 and MX500, the axial end play should be no more than 0.020 inch (0.51 mm).

NOTICE

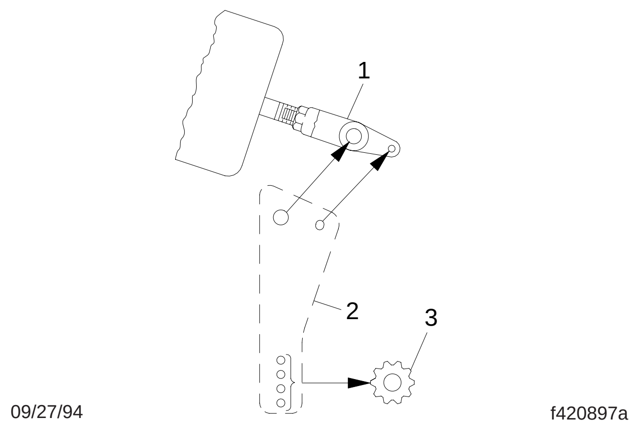
Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

7.6 Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

7.7 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.

7.8 With the brakes fully released, place the installation template over the clevis and camshaft end. See **Fig. 6**.



Place the template over the clevis and camshaft end.

1. Clevis
2. Template
3. Camshaft End

Fig. 6, Template Placement

7.9 Temporarily insert the large clevis pin through the large holes in the template and the clevis.

7.10 Select the hole in the lower part of the template that matches the length of the slack adjuster. Hold the template in place on the center of the camshaft with a pencil.

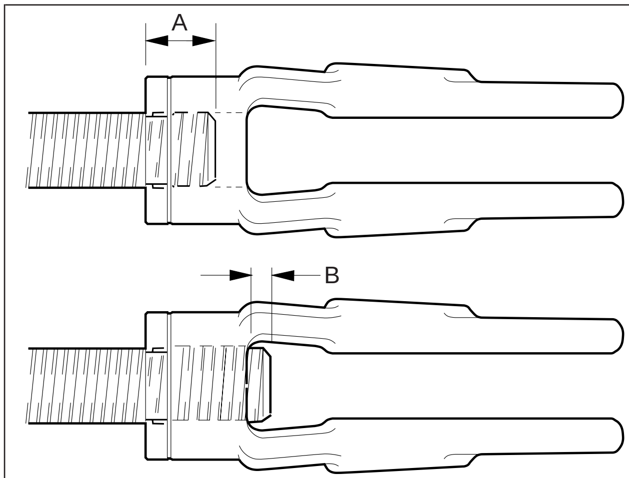
7.11 Make sure the small hole in the clevis is completely visible through the 1/8-inch hole at the top of the template.

If it is not, loosen the clevis jam nut, and turn the clevis adjusting nut to adjust the position of the clevis on the pushrod until the small clevis hole is completely visible.

IMPORTANT: The pushrod must be installed in the clevis at least 1/2 inch (13 mm) and not extend beyond it more than 1/8-inch (3-mm).

7.12 Make sure there is at least 1/2 inch (13 mm) of thread engagement between the clevis and the pushrod. Also, check that the pushrod does not extend through the clevis more than 1/8-inch (3-mm). See **Fig. 7**.

If necessary, cut the pushrod, install a new pushrod, or install a new brake chamber.



A. Minimum 1/2 inch (13 mm).
B. Maximum 1/8 inch (3 mm).

Fig. 7, Check Pushrod Engagement

7.13 Temporarily insert the small clevis pin through the template, clevis, and actuator rod to make sure the alignment is correct. Repeat the adjustment, if necessary. When the alignment is correct, remove both clevis pins and the template.

8. Apply antiseize compound to the two clevis pins.
9. Insert both clevis pins with their pinheads on the inboard side of the slack adjuster. Be sure the small clevis pin is inserted through the hole in the actuator rod. Install new retaining clips to secure the clevis pins.
10. If it was loosened, tighten the clevis jam nut to the following values.
    - For 1/2–20 threads, tighten the clevis jam nut 20 to 30 lbf·ft (27 to 41 N·m).
    - For 5/8–18 threads, tighten the jam nut 25 to 50 lbf·ft (34 to 68 N·m).
11. Lube the slack adjuster through the grease fitting until the lubricant is forced out through the pawl slot or through the gear splines around the inboard snap ring.
12. Adjust the brakes. See "Brake Adjustment" below.

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

1. If a rear axle slack adjuster was installed, manually uncage the parking brake.
2. Fully release the brakes (the air chamber pushrod must be fully retracted).

NOTICE

Before turning the manual adjusting nut on the slack adjuster, disengage the pull-pawl. Failure to do so could damage the pull-pawl teeth. A damaged pull-pawl will not allow the slack adjuster to automatically adjust the brake clearance.

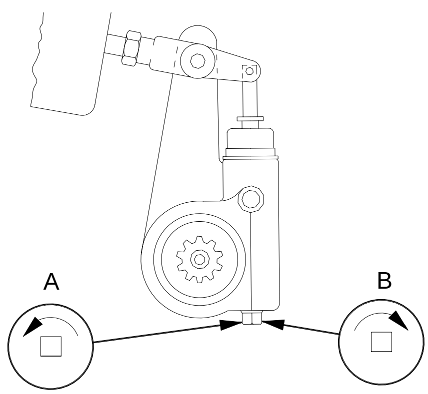
3. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 2**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.

NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

Slack Adjuster Removal and Installation

4. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment), as follows. See **Fig. 8**.

   4.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.



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A. Shorten stroke. B. Lengthen stroke.

Fig. 8, Adjusting the Stroke

   4.2 Then, turn the adjusting nut clockwise 1/2 turn.

5. Measure and adjust the free-stroke, as follows.

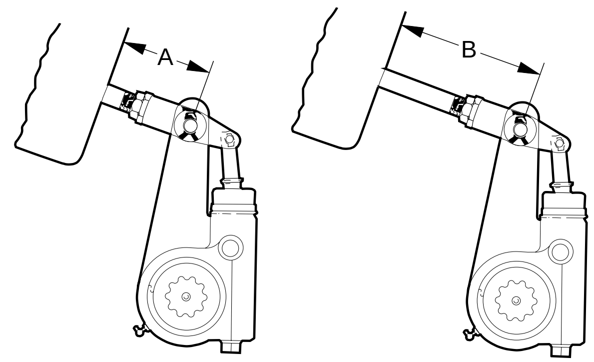
   5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

   5.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.

   Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension B. See **Fig. 9**.

   5.3 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

   5.4 The free-stroke for a new brake installation should be 5/8 to 3/4 inch (16 to 19 mm). For a brake that is in service, the free-stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not, turn the adjusting nut 1/8 turn, as shown in **Fig. 8**. Then, measure the free-stroke again; readjust it until it is correct.



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NOTE: For either free-stroke or applied chamber stroke, subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied by manual lever (free-stroke) or pressurized brake application (applied chamber stroke).

Fig. 9, Measuring the Stroke

6. Measure and adjust the applied chamber stroke (fine adjustment), as follows.

   6.1 If system pressure is not already at 100 psi (689 kPa), start the engine and build air pressure, then shut down the engine.

   6.2 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

   6.3 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 9**, Ref. B. Record this measurement as dimension B.

   6.4 Subtract dimension A from dimension B. The difference between these measurements is the true applied chamber stroke.

NOTICE

The adjusted applied chamber stroke should be as short as possible but not so short that the free-stroke is too short and the linings drag. If the linings drag, the brakes could be damaged.

6.5 The applied chamber stroke must not exceed the maximum value specified in **Table 1**.

If the applied chamber stroke is incorrect, turn the adjusting nut 1/8-turn counterclockwise to shorten the stroke, or 1/8-turn clockwise to lengthen it. See **Fig. 8**. Measure the applied stroke again and readjust it until it is correct.

6.6 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Section 42.13, Subject 150**.

7. Remove the screwdriver from the pull-pawl assembly. This will engage the pull-pawl with the actuator.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation before you put the vehicle in service, as follows.

8.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

8.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others show a lack of braking effort on those wheels.

Brake Chamber Stroke Specifications			
Chamber Type (Size)	Maximum Applied Stroke*: inch (mm)	Free-Stroke: inch (mm)	
		New Brake Installation	In-Service Brake
Long Stroke†			
16 and 20	2-1/2 (64)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (550–620 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

Specifications

Specified Lubricant	
Lubricant Type	**Temperature**
Amoco Super Permalube No. 2	–40°F (–40°C) or Above
Aralub 3837	
Citco Premium Lithium EP No. 2	
Exxon Ronex MP No. 2	
Kendall L–427 Super Blu No. 2	
Mobilith AW No. 1	
Meritor 0–616–A	
Meritor 0–692	
Shell Darina No. 1	
Sohio Factran EP No. 2	
Texaco Hytherm EP No. 1	
Texaco Thermotex EP No. 1	
Tribolube 12, Grade 1	
Mobil 28	Below –40°F (–40°C)
Meritor 0–645	

Table 1, Specified Lubricant

Slack Adjuster Arm Length	
Arm Length: inch (mm)	**Chamber Size**
5 (127)	9, 12, 16, 20, 24, 30
5-1/2 (140)	9, 12, 16, 20, 24, 30
6 (152)	24, 30
6-1/2 (165)	30

Table 2, Slack Adjuster Arm Length

Maximum Adjusted Brake Chamber Stroke	
Chamber Size	**Stroke: inch (mm)**
9	Less than 1-1/2 (38)
12	Less than 1-1/2 (38)
16	Less than 1-3/4 (44)
20	Less than 1-3/4 (44)
24	Less than 1-7/8 (48)
24 Long Stroke	Less than 2 (51)
30	Less than 2 (51)

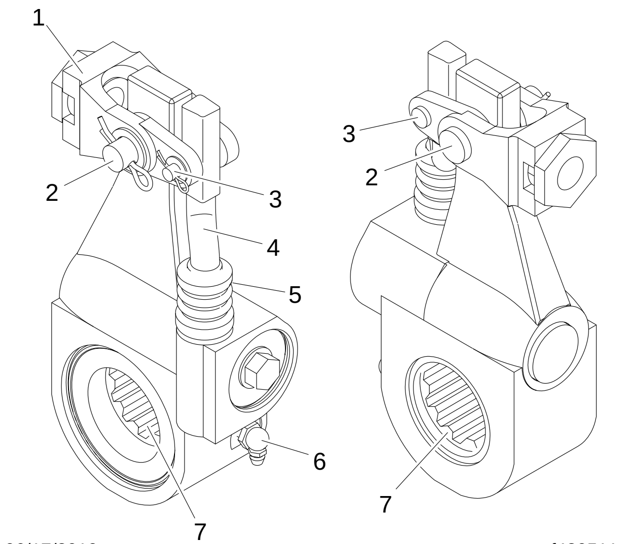
Table 3, Maximum Adjusted Brake Chamber Stroke

Chamber Pushrod Thread Size	
Chamber Size	**Pushrod Thread Size**
9, 12, 16	1/2–20
20, 24, 30, 36	5/8–18

Table 4, Chamber Pushrod Thread Size

General Description[1]

The Bendix® ASA-5® automatic slack adjuster is designed for use on cam actuated drum brakes of the type in use on most highway vehicles. See **Fig. 1**. Like a manual slack adjuster, the ASA-5 slack adjuster multiplies and transforms the linear force of the air actuator into a rotational force or torque, which is used to apply to foundation brake. Additionally, the automatic slack adjuster adjusts the clearance between the brake lining and drum to compensate for wear.



1. Yoke
2. Yoke Pin
3. Link Pin
4. Link
5. Boot
6. Lube Fitting
7. Worm Gear

Fig. 1, ASA-5 Automatic Slack Adjuster

A variety of ASA-5 slack adjuster configurations are offered, including both straight arm and 5/8-inch yoke offset models.

IMPORTANT: The manual hex adjuster is **only** intended for use during installation.

WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

Either of two yoke designs (easy-on and quick-connect) in combination with an external manual hex adjuster provides easy installation and maintenance of the ASA-5 slack adjuster.

Operation

The automatic adjustment provided by the ASA-5 slack adjuster results in consistent brake lining to drum clearance and brake actuator stroke. The key to its operation is the ability to complete the brake adjustment during the early part of each brake application and to cease adjusting as resistance to brake cam rotation begins to build. This aspect of the adjuster mechanism's operation prevents over-adjustment caused by lining compression, actuator bracket deflection, drum and foundation brake component distortion, or brake component wear.

The ASA-5 slack adjuster incorporates a clutch-type adjuster mechanism that continuously adjusts in very small increments as lining and drum wear occurs. Therefore, the adjustments made by the ASA-5 slack adjuster are not in specific increments relative to actuator stroke.

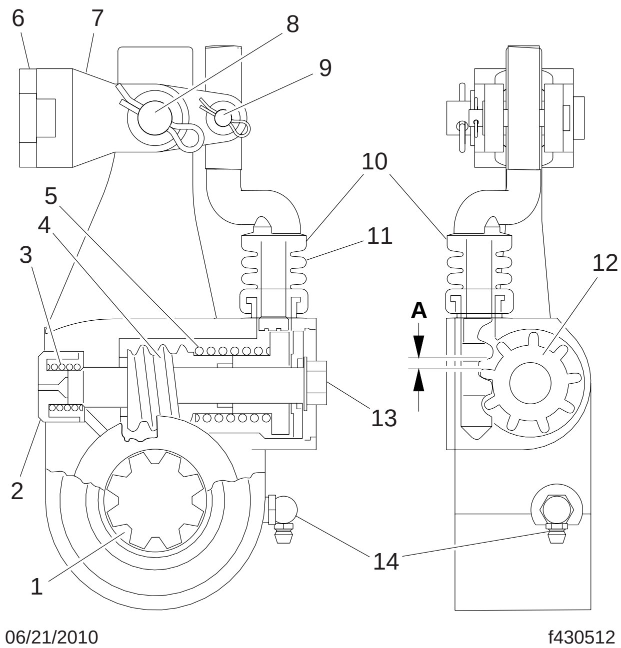
Brake Application

When the brakes are applied, the linear travel of the brake actuator's pushrod causes the ASA-5 slack adjuster to rotate the foundation brake camshaft, which in turn begins to force the brake shoes into contact with the drum. When the ASA-5 slack adjuster rotates, the yoke assembly pivots on the yoke pin causing the link to be pulled upward. See **Fig. 2** for a sectional view of the ASA-5 slack adjuster.

The teeth on the link mesh with the adjuster mechanism pinion. As the link is pulled, it travels first through its free play and then causes the pinion to rotate. Rotation of the pinion is transmitted through the clutch spring to the worm and shaft. Worm and shaft rotation results in worm gear rotation, which adjusts the brake camshaft.

[1] The instructions and illustrations in this section are provided by Bendix Commercial Vehicle Systems, LLC and are used with permission.

General Information



A. Free-Play

1. Worm Gear
2. Spring Retainer
3. Anti-Reverse Spring
4. Worm
5. Clutch Spring
6. Adaptor Bushing
7. Yoke
8. Yoke Pin
9. Link Pin
10. Boot
11. Lube Relief Opening
12. Pinion
13. Manual Hex Adjuster
14. Lube Fitting

Fig. 2, ASA-5 Automatic Slack Adjuster (sectional view)

When the foundation brake shoes contact the drum, the camshaft begins to resist rotation and friction between the worm gear and worm builds, preventing further rotation of the worm. Brake adjustment ceases at this point and further rotation of the ASA-5 slack adjuster will cause the pinion and clutch spring to slip. The free-play between the link teeth and pinion results in a predetermined lining-to-drum clearance.

Brake Release

When the brake application is released, the brake actuator pushrod returns the ASA-5 slack adjuster to the released position. During release, the ASA-5 slack adjuster rotates back toward the actuator causing the brake camshaft to again rotate, but in the opposite direction, and the brake shoes begin to move away from the drum. As the ASA-5 slack adjuster rotates back to the release position, the yoke again pivots, causing the link to be pushed downward into the slack adjuster body. The free-play between the link teeth and pinion is taken up during the initial part of the release. Continued movement of the ASA-5 slack adjuster toward the released position causes the link to rotate the pinion. The anti-reverse spring prevents counterclockwise rotation of the shaft and worm causing the pinion and clutch spring to slip. The gripping action of the anti-reverse spring and slippage of the clutch spring during release is due to the direction of the coil windings of each.

Yoke Designs

ASA-5 slack adjusters may be equipped with either of two yoke designs. Both are designed to permit installation or removal of the slack adjuster along with its yoke body and its attached adjusting linkage.

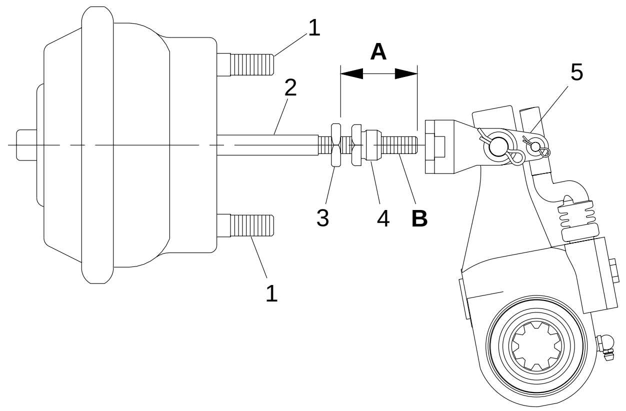
The brake actuator pushrod must thread into the adapter a minimum of 1/2 inch and must not extend more than 7/64 inch beyond the other end of the adaptor. The yoke adaptors, quick-connect and easy-on, have either a 1 or 1-1/4 inch adjuster hex to allow tightening of the brake actuator pushrod jam nut.

Easy-On Yoke

The easy-on yoke assembly, shown in **Fig. 3**, consists of an adaptor which is threaded internally to match the pushrod threads and external to match female threads in the yoke. A special extended yoke adaptor is also available as a separate service item. The extended adaptor is 1/2 inch longer than the standard and it is intended for use when the existing brake actuator pushrod is too short.

Quick-Connect Yoke

For the quick-connect yoke, the adaptor bushing is threaded internally to match the pushrod, but is designed to slide into the yoke. A retainer ring is used to secure the adaptor bushing in the yoke. See **Fig. 4**.



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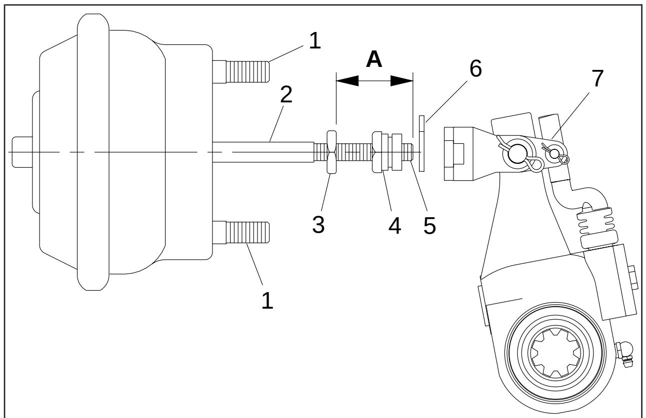
A. 1-5/16"
B. 3/8" Out

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor
5. Yoke

Fig. 3, Easy-On Yoke Assembly



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A. 1"

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor Bushing
5. Flush
6. Retaining Ring
7. Yoke

Fig. 4, Quick-Connect Yoke Assembly

Safety Precautions

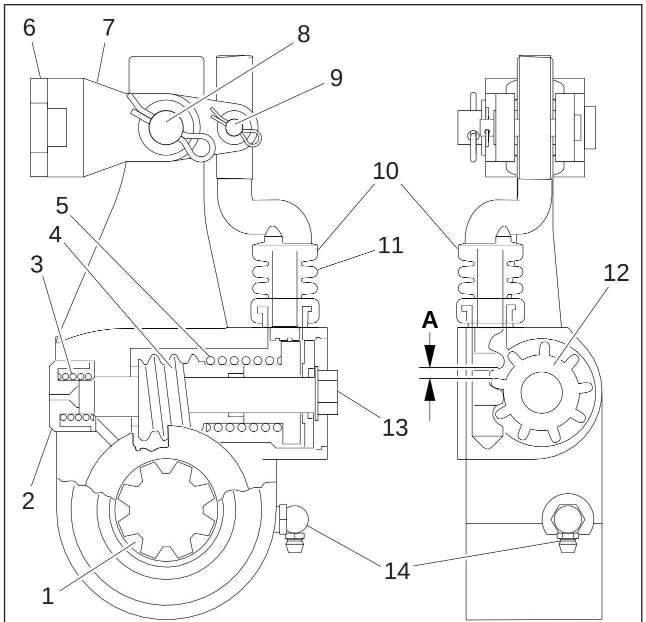
When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface, apply the parking brake, shut down the engine, and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting the air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Slack Adjuster Removal and Installation

Removal

NOTE: Refer to **Fig. 1** for an example of the ASA-5 slack adjuster when completing this procedure.



A. Free-Play

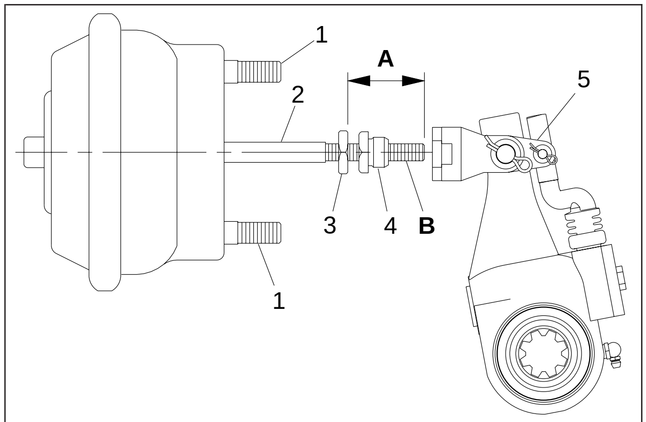
1. Worm Gear
2. Spring Retainer
3. Anti-Reverse Spring
4. Worm
5. Clutch Spring
6. Adaptor Bushing
7. Yoke
8. Yoke Pin
9. Link Pin
10. Boot
11. Lube Relief Opening
12. Pinion
13. Manual Hex Adjuster
14. Lube Fitting

Fig. 1, ASA-5 Automatic Slack Adjuster (sectional view)

ASA-5 Slack Adjuster with Easy-On Yoke Assembly

1. Loosen the brake actuator pushrod jam nut and run it back on the brake actuator pushrod approximately 5/8 inch. See **Fig. 2**.
2. Loosen the easy-on yoke adaptor and run it back on the brake actuator pushrod until it is free of the yoke.

NOTE: Considerably more torque is required to rotate the manual hex adjustment counterclockwise than is necessary to rotate it clockwise. The torque may be as high as 70 lbf·ft (95 N·m).



A. 1-5/16"
B. 3/8" Out

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor
5. Yoke

Fig. 2, Easy-On Yoke Assembly

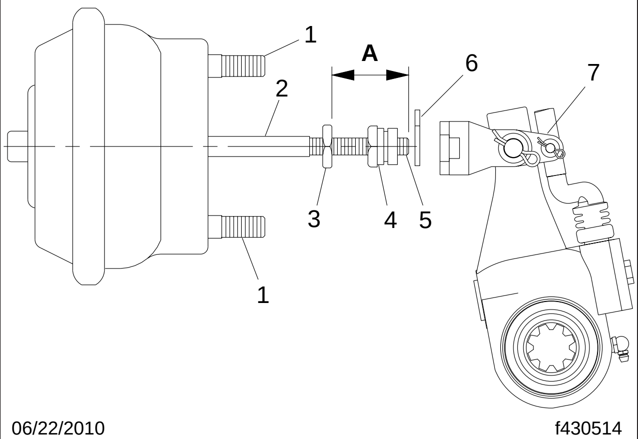
3. Rotate the manual hex adjustment counterclockwise until the ASA-5 slack adjuster is clear of the brake actuator pushrod.
4. Remove the ASA-5 slack adjuster from the camshaft of the foundation brake by removing the retaining clip and any spacers or washers that may be present.

ASA-5 Slack Adjuster with Quick-Connect Yoke

NOTE: Considerably more torque is required to rotate the manual hex adjustment counterclockwise than is necessary to rotate it clockwise. The torque may be as high as 70 lbf·ft (95 N·m).

1. Rotate the ASA-5 manual hex adjustment counterclockwise until the brake actuator pushrod just begins to move out of the actuator. See **Fig. 3**
2. Pinch the ’legs’ of the retaining ring together and pull the ASA-5 slack adjuster away from the brake actuator pushrod until the adaptor bushing is free of the yoke. Remove the retaining ring from the adaptor bushing.

Slack Adjuster Removal and Installation



A. 1"

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor Bushing
5. Flush
6. Retaining Ring
7. Yoke

Fig. 3, Quick-Connect Yoke Assembly

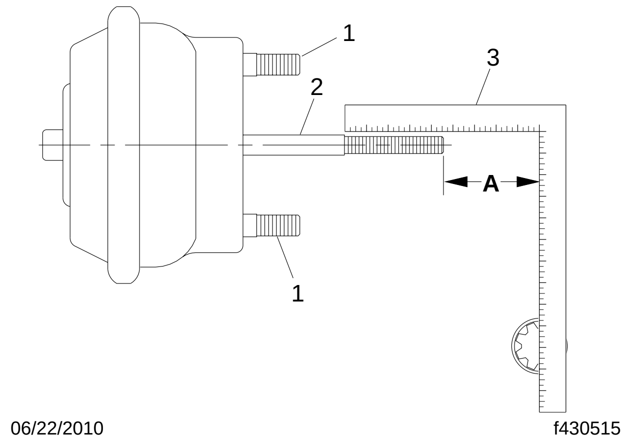
3. Rotate the manual hex adjustment counterclockwise until the ASA-5 slack adjuster is clear of the brake actuator pushrod.
4. Remove the ASA-5 slack adjuster from the camshaft of the foundation brake by removing the retaining clip and any spacers or washers that may be present.

Installation

1. Before mounting the ASA-5 slack adjuster on the camshaft, check the brake chamber pushrod length to determine if shortening or replacement are required.

   1.1 With the brake chamber in the released position, place a square (or equivalent object) so that one edge is parallel to the actuator pushrod while the other edge bisects the brake camshaft. Measure the distance from the pushrod end to the vertical edge of the square as shown in **Fig. 4** and compare it to the values in **Table 1**.

   1.2 If measurement A is less than the minimum values shown in **Table 1**, the brake actuator pushrod must be shortened. If measurement A is greater than the maximum values, the brake actuator pushrod may require replacement.



A. Distance

1. Mounting Stud
2. Brake Actuator Pushrod
3. Square

Fig. 4, Measuring the Brake Actuator Pushrod

NOTE: The extended adaptor is available as a separate part (5/8–18 and 1/2–20), and may avoid the need to replace the brake actuator pushrod. The extended adaptor is only available for the easy-on yoke assembly.

IMPORTANT: Installing any other type of pushrod extender is not recommended, because they may loosen over time and result in an improperly adjusted brake.

2. Inspect the foundation brake, brake chamber and related components. Make certain the camshaft bushings and seals are not excessively worn. Lubricate the camshaft bushings. Check the brake chamber bracket for cracks and corrosion. The brake actuator pushrod should not be loose or bent, and the return spring should be firm. Replace parts as needed.

Brake Actuator Pushrod Measurement		
Slack Adjuster Arm Length (inches)	**Standard Easy-On or Quick-Connect Adaptor (inches)**	**Extended Easy-On Adaptor (inches)**
5	1-15/16 to 3-1/32	2-7/16–3-17/32
5-1/2	1-15/16 to 3-3/16	2-7/16–3-11/16
6	1-3/16 to 3-3/16	1-11/16–3-11/16

Table 1, Brake Actuator Pushrod Measurement

3. Install the ASA-5 slack adjuster on the brake camshaft.

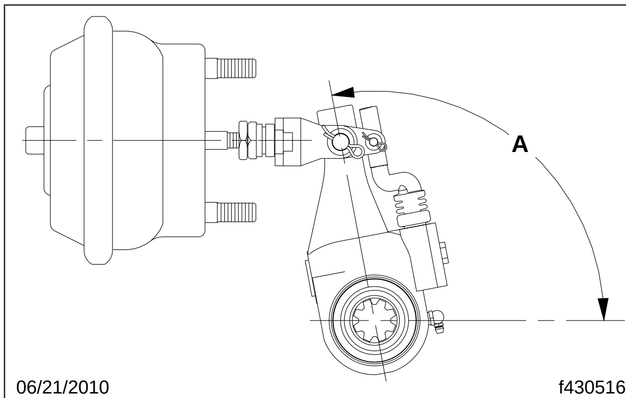
   3.1 If the adjuster has the easy-on yoke shown in **Fig. 2**, position the brake actuator pushrod jam nut approximately 1-5/16 inches from the end of the brake actuator pushrod. Thread the easy-on yoke adaptor on the brake actuator pushrod until it is approximately 3/8 inch from the end of the brake actuator pushrod end.

   Turn the slack adjuster manual hex adjustment clockwise until the adaptor extends into the threaded bore of the yoke approximately 1/8 inch. Thread the adaptor into the yoke and tighten 120 lbf·in (1356 N·cm).

   3.2 If the adjuster has the quick-connect yoke shown in **Fig. 3**, position the brake actuator pushrod jam nut approximately 1 inch from the end of the brake actuator pushrod. Thread the quick-connect adaptor bushing on the brake actuator pushrod until it is flush with the end of the brake actuator pushrod. Install the retaining ring on the adaptor bushing, making certain it is in the adaptor bushing groove.

   Turn the slack adjuster manual hex adjustment clockwise until the adaptor bushing begins to enter the yoke. Fully compress the retaining ring 'legs' and continue turning the manual hex adjustment until the adaptor bushing is completely in the yoke. Allow the retaining ring to expand into the corresponding groove in the yoke. Make certain the retaining ring is seated in both the yoke and the adaptor bushing groove by manually pulling the slack adjuster arm, attempting to separate the adaptor bushing and yoke.

   Figure 5 shows the angle of a properly installed ASA-5 slack adjuster. See **Table 2** for a list of slack adjuster arm lengths and allowable range of angles.



A. Angle

Fig. 5, Installation Angle

Slack Adjuster Angle	
Arm Length (inches)	**Angle (degrees)**
5	99–113
5.5	98–111
6	90–109

Table 2, Slack Adjuster Angle

4. Run the brake actuator pushrod jam nut down against the adaptor or adaptor bushing. Hold the adaptor or adaptor bushing hex with a wrench and tighten the jam nut 25 to 33 lbf·ft (34 to 45 N·m) for the 1/2–20 thread and 33 to 50 lbf·ft (45 to 68 N·m) for the 5/8–18 thread.

IMPORTANT: The vehicle brakes should be adjusted using the vehicle or brake manufacturer's

Slack Adjuster Removal and Installation

recommendation. If they are not available, the following procedure can be used.

5. Manually adjust the brakes.

   Rotate the manual hex adjustment clockwise until the linings are snug against the drum. Turn the hex adjustment counterclockwise 1/2 turn. Pull the actuator pushrod to confirm that approximately 1/2 inch of pushrod free stroke exists. Apply 85 psi (586 kPa) to the brake pedal, and check that the pushrod stroke is below the readjustment limit. If the stroke exceeds the limit, check the condition of the foundation brakes. See the *Brake Inspection* instructions below.
6. Manually uncage the spring brakes before returning the vehicle to service.
7. Once the slack adjuster is installed, check to ensure clearance requirements with the brake fully released and at the actuator's maximum stroke. Also consider clearances with the vehicle suspension springs depressed to the jounce bumpers, as well as in rebound.

Brake Inspection

The following test can be used to inspect the condition of the foundation brake and to determine how much of the chamber stroke is caused by the condition of the foundation brake.

1. If not already done, chock the tires.
2. Raise the axle so that the wheel can be rotated.
3. Adjust the slack adjuster to produce light brake drag with wheel rotation.
4. Apply 80 to 90 psi (552 to 621 kPa) to the brake pedal and measure the stroke.
5. If the stroke significantly exceeds the values shown in **Table 3**, the brake may be out of the norm and brake maintenance may be required. For maintenance procedures, see maintenance operation **42-05** in the *Recreational Vehicle Chassis Maintenance Manual*.

Brake Stroke*			
Area Length (AL) Factor†	**15 x 4 Front Brake**	**16.5 x 7 Tractor, Truck, or Bus Brake**	**16.5 x 7 Trailer Brake**
12 x 5.0	1/2	N/A	N/A
12 x 5.5	1/2	N/A	N/A
16 x 5.0	5/8	1/2	N/A
16 x 5.5	3/4	1/2	N/A
16 x 6.0	7/8	5/8	N/A
20 x 5.0	5/8	1/2	3/8
20 x 5.5	3/4	5/8	1/2
20 x 6.0	7/8	3/4	5/8
24 x 5.0	N/A	5/8	1/2
24 x 5.5	N/A	5/8	5/8
24 x 6.0	N/A	3/4	5/8
30 x 5.0	N/A	3/4	5/8
30 x 5.5	N/A	7/8	3/4
30 x 6.0	N/A	1	7/8

* All values listed are in inches.

† 'A' is the area of chamber diaphragm multiplied by 'L', the length of the slack adjuster. More braking force is available with a larger AL factor.

Table 3, Brake Stroke

Troubleshooting Tables

Problem—Brake Actuator Stroke is Too Long

Problem—Brake Actuator Stroke is Too Long	
Possible Cause	**Remedy**
Loose actuator pushrod jam nut.	Reposition components and tighten to specification.
Excessive clearance between the adaptor/ adaptor bushing and yoke due to wear.	Replace damaged or worn parts.
Excessive clearance between components— • yoke pin–yoke; • link pin–link; • yoke pin–body.	Replace worn parts.
Damaged (worn) splines on slack or camshaft.	Replace damaged parts.
Weak or broken brake actuator return springs. Weak or broken brake shoe return spring.	Replace weak or broken springs.
Worn or broken foundation brake components, including camshaft bushings, brake chamber bracket, etc.	Repair or replace damaged or worn parts.
ASA-5® adjuster mechanism not functioning.	Lubricate and then test the adjuster mechanism. Repair or replace components as necessary.
Brake drum worn, excessively machined, bell-mouthed, excessive thermal expansion.	Replace or repair as necessary.
ASA-5 slack adjuster is damaged.	Replace component(s) or slack adjuster.
ASA-5 slack adjuster is improperly installed.	Correct the installation position.

Problem—Brakes Dragging–Over-Adjustment of Brakes

Problem—Brakes Dragging–Over-Adjustment of Brakes	
Possible Cause	**Remedy**
ASA-5 slack adjuster is improperly installed. Slack adjuster is too close to the actuator–brakes can not fully release.	Correct the ASA-5 slack adjuster installation.
Loose actuator pushrod jam nut.	Reposition the components and tighten to specification.
Spring brakes are not fully retracting.	Check the spring brake release air pressure. Repair or replace air valves as necessary. Repair or replace the spring brake.
Broken foundation brake components, including camshaft bushings.	Repair or replace damaged or worn parts.

Troubleshooting

Problem—Brakes Dragging–Over-Adjustment of Brakes	
Possible Cause	**Remedy**
Vehicle brake torque imbalance (more work is being done by some brakes than others; thermal expansion of drums).	Check all brakes to make sure they are working. Check the air pressure balance and threshold pressure (refer to Bendix publication BW-1555). Check driver braking habits such as use of the park brake valve. Use same friction material on all axles.
Brake drum out-of-round, excessive thermal expansion.	Repair or replace damaged or worn parts.
Air system malfunction, not exhausting completely.	Inspect and correct as necessary.
New lining swells during break-in.	Back-off adjustment until brakes are free.

Specifications

Bendix Extended Adaptors	
Extended Adaptor	**Bendix Part Number**
5/8–18	297700
1/2–20	297701

Table 1, Bendix Extended Adaptors

Brake Actuator Pushrod Measurement		
Slack Adjuster Arm Length (inches)	**Standard Easy-On or Quick-Connect Adaptor (inches)**	**Extended Easy-On Adaptor (inches)**
5	1-15/16 to 3-1/32	2-7/16 to 3-17/32
5-1/2	1-15/16 to 3-3/16	2-7/16 to 3-11/16
6	1-3/16 to 3-3/16	1-11/16 to 3-11/16

Table 2, Brake Actuator Pushrod Measurement

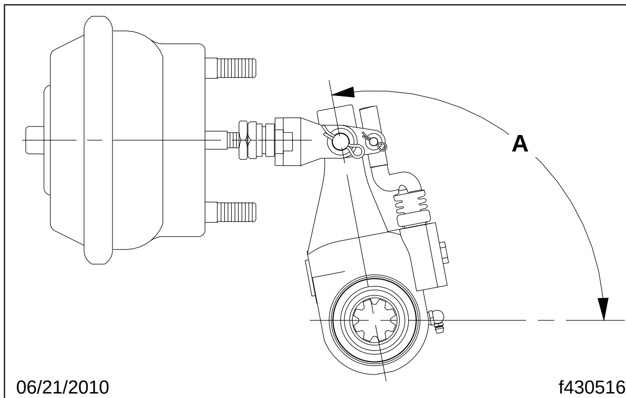
Actuator Stroke–Standard Stroke	
Brake Actuator Size	**Recommended Maximum Operating Stroke (Inches)**
30	2
24	1-3/4
20	1-3/4
16	1-3/4
12	1-3/8

Table 3, Actuator Stroke–Standard Stroke

Actuator Stroke–Long Stroke	
Brake Actuator Size	**Recommended Maximum Operating Stroke (Inches)**
30 Long Stroke	2-1/2
24 Long	2
24 Long Stroke	2-1/2
20 Long	2
16 Long	2

Table 4, Actuator Stroke–Long Stroke

Figure 1 shows the angle of a properly installed ASA-5 slack adjuster. See Table 5 for a list of slack adjuster arm lengths and allowable range of angles.



A. Angle

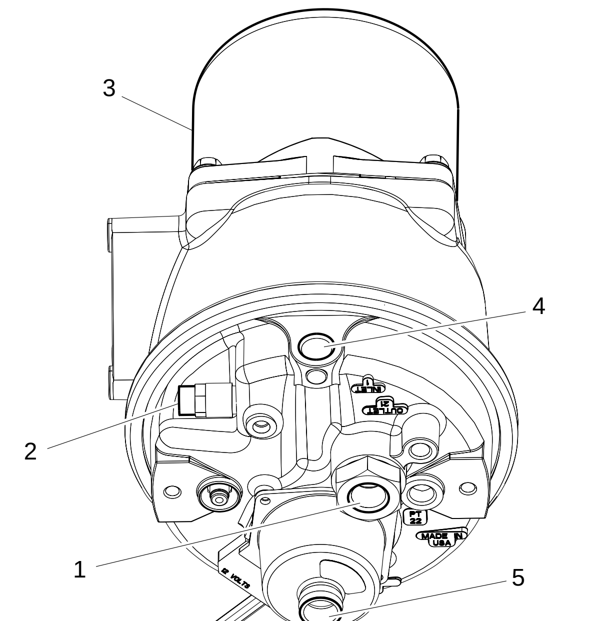
Fig. 1, Installation Angle

Slack Adjuster Angle	
Arm Length (inches)	**Angle (degrees)**
5	99–113
5.5	98–111
6	90–109

Table 5, Slack Adjuster Angle

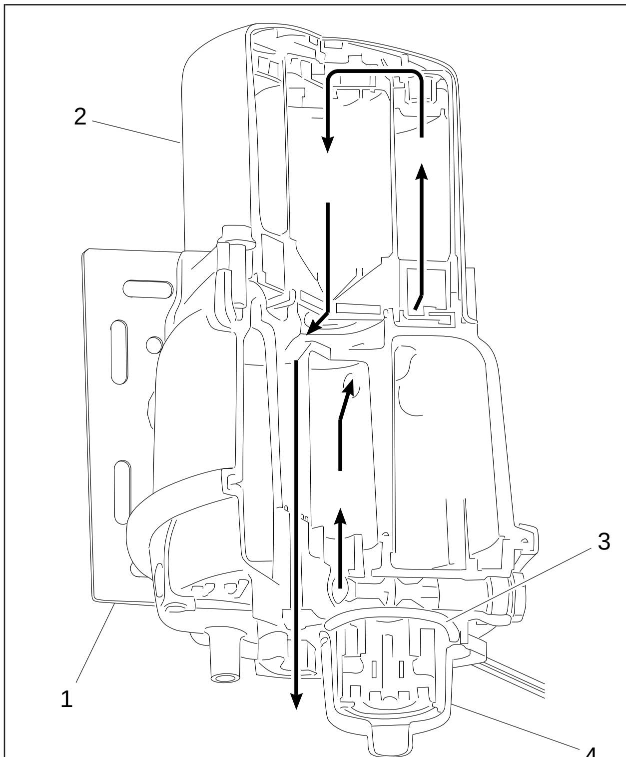
General Information[1]

The Haldex PURest® air dryer is designed to promote efficiency and extend the life of the air brake system. Using the combination of the integrated multi-treatment cartridge and a large purge volume, the PURest air dryer removes up to 99% of the contaminates in the air system and eliminates the need for a separate purge tank. The PURest air dryer also extends the life of the desiccant, and allows for better recovery from high-duty cycles. See **Figure 1** and **Fig. 2** for examples of the PURest air dryer.



1. Outlet Port
2. Safety Valve
3. Multi-treatment Cartridge
4. Inlet Port
5. Purge Exhaust Cover (1-inch hose fitting)

Fig. 1, PURest Air Dryer



1. Universal Mounting Bracket
2. Multi-treatment Cartridge
3. Built-In Heater
4. Purge Exhaust Cover

Fig. 2, PURest Charge Cycle

[1] The illustrations in this section are provided by Haldex and are used with permission.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don’t disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

Removal and Installation

Removal

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface and apply the park brake. Shut down the engine and chock the tires.
2. Drain all reservoirs to zero pressure.

CAUTION

The compressor discharge line may still contain residual pressure. When removing the line, make certain to hold it firmly and direct it away from your eyes to avoid any flying debris.

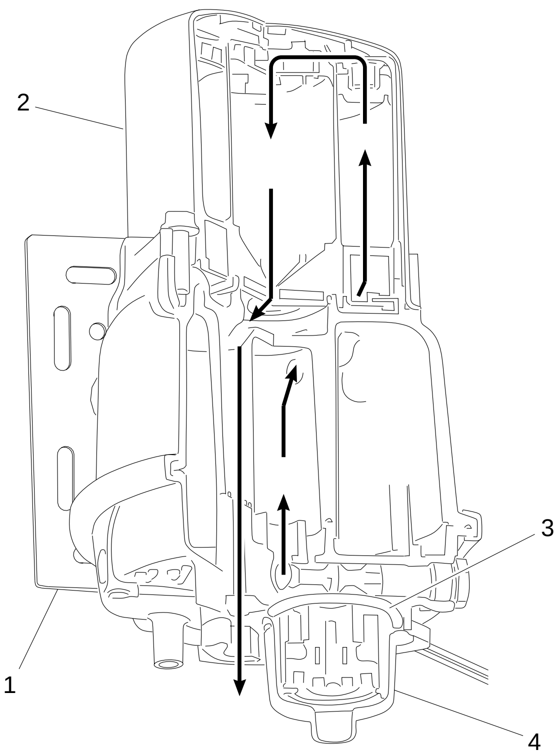
3. Mark the air lines and disconnect them from the end cover. Note the position of the end cover ports relative to the vehicle.
4. Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve housing assembly.
5. Remove the bolts, locknuts, and washers that hold the air dryer to the mounting bracket.
6. Remove the air dryer from the mounting bracket.

Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Position the air dryer on the mounting bracket. See Fig. 1.
2. Using the bolts, washers, and locknuts, secure the air dryer to the mounting bracket. Tighten the bolts 45 to 55 lbf·ft (61 to 75 N·m).
3. Connect the air lines previously marked to the ports on the end cover.
4. 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.
5. Test the air dryer following the instructions in Subject 120.



1. Universal Mounting Bracket
2. Multi-treatment Cartridge
3. Built-In Heater
4. Purge Exhaust Cover

Fig. 1, PURest Air Dryer (charge cycle shown)

Operating and Leakage Tests

Once the PURest air dryer has been installed, perform the following tests before putting the vehicle back in service.

1. Chock the tires.
2. Close all of the reservoir drain cocks.
3. Build up system air pressure to governor cutout and note that the air dryer purges with an audible exhaust of air.
4. Actuate the service brakes to reduce system air pressure to governor cut-in. Note that the system once again builds to full pressure and is followed by a purge.
5. To make certain that the air dryer will not cycle excessively, perform a leakage test.
    5.1 Apply the parking brakes. Build system pressure to governor cutout and allow pressure to stabilize for at least 1 minute.
    5.2 Observe the pressure gauge for 2 minutes and note any drop in pressure. The pressure should not drop more than 4 psi (28 kPa) with the brake released or 6 psi (41 kPa) with the brakes applied. Repair any noticeable leakage to avoid excessive air dryer cycling.
6. During normal operation, the compressor should recover from governor cut-in to governor cutout in 90 seconds or less.
7. During normal vehicle operation, the air compressor must remain unloaded for a minimum of 30 seconds between charge cycles. The minimum purge time is required to insure complete regeneration of the desiccant.

Troubleshooting

Problem—Water in the Air Dryer System

Problem—Water in the Air Dryer System	
Possible Cause	**Remedy**
There are contaminants in the desiccant.	Change the desiccant cartridge. Check the compressor for excessive oil passage.
The are leaks in the air system.	Tighten the air connections. Using a solution of soapy water, leak test the connections.

Problem—There is a Constant Exhaust of Air from the Air Dryer

Problem—There is a Constant Exhaust of Air from the Air Dryer	
Possible Cause	**Remedy**
The air dryer outlet check valve is defective.	Clean the valve seat and replace the check valve.

Problem—The Air Dryer is Constantly Cycling

Problem—The Air Dryer is Constantly Cycling	
Possible Cause	**Remedy**
There are leaks in the air system.	Tighten the air connections. Using a solution of soapy water, leak test the connections.
The air dryer outlet check valve is defective.	Clean the valve seat and replace the check valve.
An incorrect compressor size is installed. The duty cycle of the compressor should not exceed 25%.	Reduce the air demand or use a larger compressor.

Problem—The Safety Valve is Open

Problem—The Safety Valve is Open	
Possible Cause	**Remedy**
The desiccant cartridge is plugged.	There is excessive oil leaking from the compressor.
There is an ice block in the air dryer.	Check the heater function.
There is excessive system pressure.	Repair or replace the governor.

Problem—Unsatisfactory Air Dryer or Desiccant Cartridge Life

Problem—Unsatisfactory Air Dryer or Desiccant Cartridge Life	
Possible Cause	**Remedy**
Air at the dryer inlet exceeds 175°F (79°C).	Extend the length of the compressor discharge line by 12 to 15 feet (4 to 5 m).
The duty cycle of the compressor does not allow time for desiccant regeneration.	During normal operation, the compressor must remain unloaded for a minimum of 30 seconds to allow for sufficient purge. Extended loading times must be avoided. The air dryer must be by-passed in applications with high air use, such as bulk unloading.

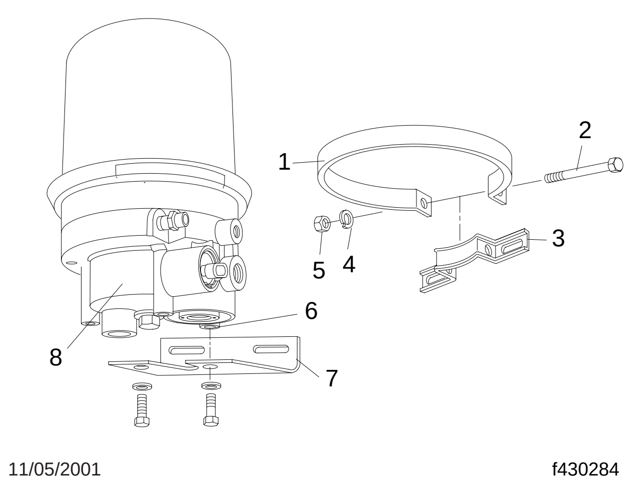
Troubleshooting

Problem—Poor Drying Efficiency

Problem—Poor Drying Efficiency	
Possible Cause	**Remedy**
Air at the dryer inlet exceeds 175°F (79°C).	Extend the length of the compressor discharge line by 12 to 15 feet (4 to 5 m).

General Information

The function of the AD-IP Integral Purge Air Dryer, shown in **Fig. 1**, is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which increases the life of the system and reduces maintenance costs. Daily manual draining of the reservoirs is eliminated.



1. Mounting Strap
2. 5/16-Inch Bolt
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer

Fig. 1, Bendix AD-IP Air Dryer

The AD-IP air dryer consists of a desiccant cartridge secured to a die-cast aluminum end cover with a single, central bolt. The end cover contains a check valve assembly, safety valve, heater and thermostat assembly, three pipe thread air connections, and the purge valve assembly. The removable purge valve assembly incorporates the purge valve mechanism and a turbocharger cutoff feature that is designed to prevent loss of engine turbocharger boost pressure during the purge cycle of the AD-IP air dryer. For ease of serviceability, all replaceable assemblies can be replaced without removal of the air dryer from its mounting on the vehicle.

To ease servicing, the desiccant cartridge and discharge check valve assembly are screw-in types. The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced **without** removing the air dryer from the vehicle. The screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The AD-IP has three female pipe thread air connections identified in **Table 1**.

Air Dryer Port Identification	
Port I.D.	**Function/Connection**
CON 4	Control Port (purge valve control and turbo cutoff)
SUP 11	Supply Port (air in)
DEL 2	Delivery Port (air out)

Table 1, Air Dryer Port Identification

Principles of Operation

The AD-IP air dryer alternates between two operational modes or cycles during operation: the charge cycle, shown in **Fig. 2**, and the purge cycle, shown in **Fig. 3**.

Charge Cycle

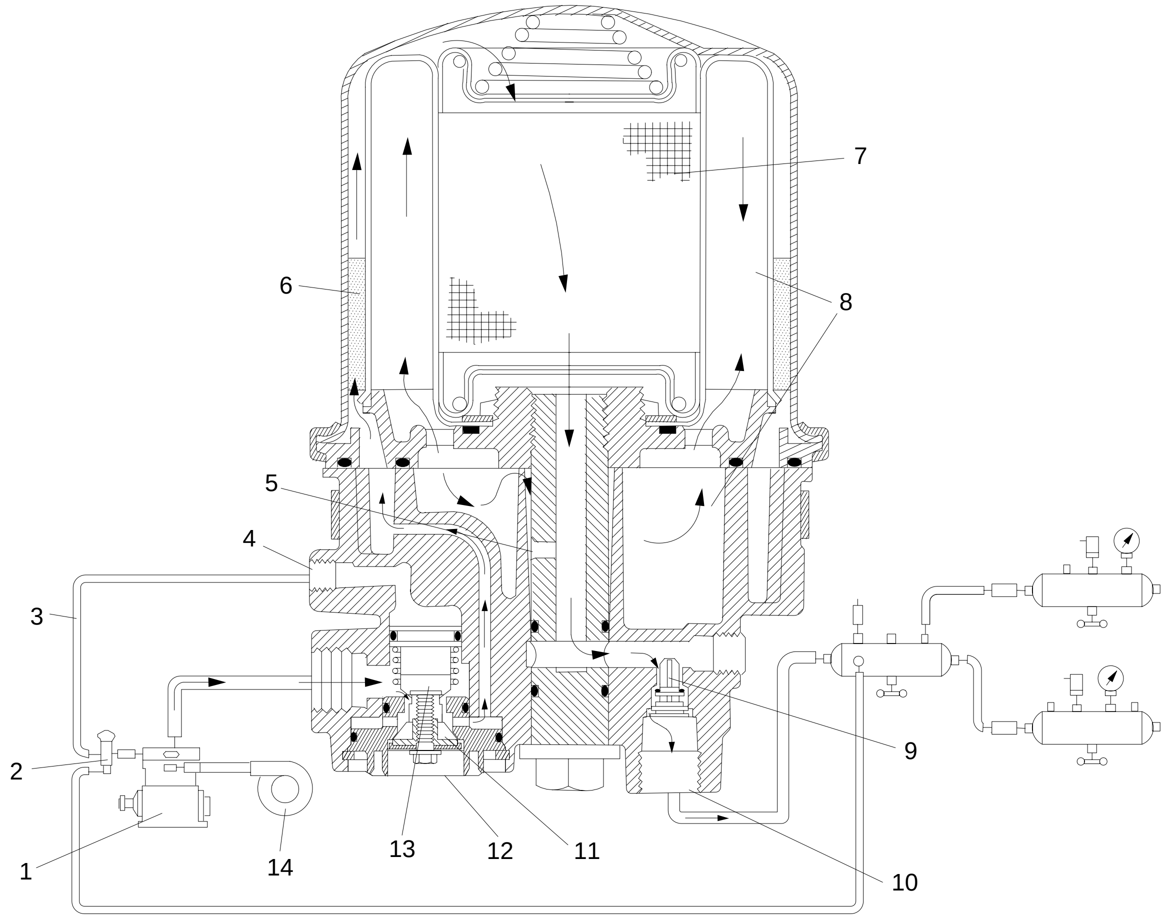
When the compressor is loaded (compressing air), compressed air, along with oil, oil vapor, water, and water vapor flows through the compressor discharge line to the supply port of the air dryer body.

As air travels through the end cover assembly, its direction of flow changes several times, reducing the temperature, causing contaminants to condense, and to drop to the bottom or sump of the air dryer end cover.

After exiting the end cover, the air flows into the desiccant cartridge. Once in the desiccant cartridge, air first flows through an oil separator located between the outer and inner shells of the cartridge. The separator removes water in liquid form as well as oil and solid contaminants.

Air, along with the remaining water vapor, is further cooled as it exits the oil separator and continues to flow upward between the outer and inner shells. Upon reaching the top of the cartridge the air reverses its direction of flow and enters the desiccant

General Information



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbocharger

Fig. 2, AD-IP Charge Cycle

drying bed. Air flowing down through the column of desiccant becomes progressively dryer as water vapor adheres to the desiccant material in a process known as adsorption. The desiccant cartridge, using the adsorption process, typically removes most of the water vapor from the pressurized air.

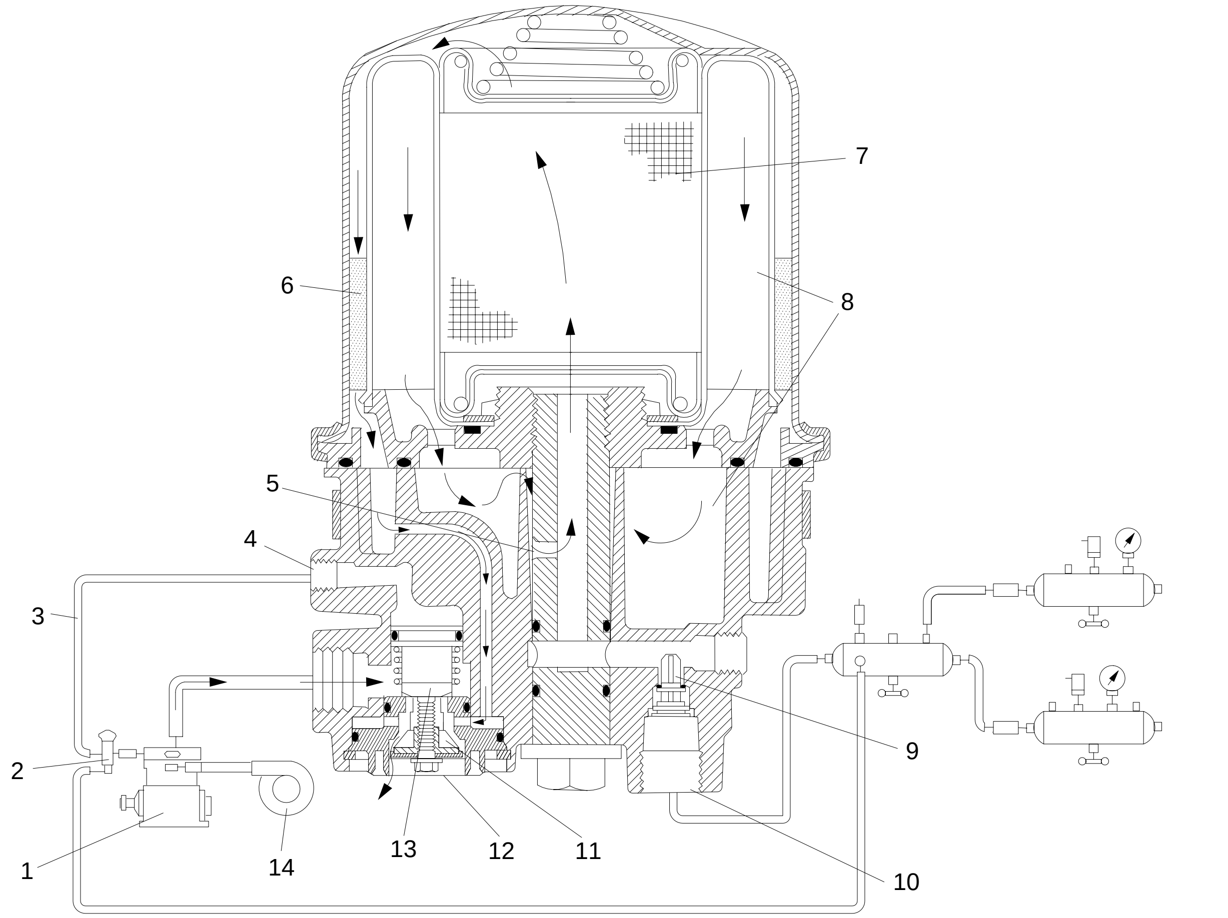
Dry air exits the bottom of the desiccant cartridge and flows through the center of the bolt used to secure the cartridge to the end cover. Air flows down the center of the desiccant cartridge bolt, through a cross-drilled passage and exits the air dryer delivery port through the delivery check valve.

Dry air flowing through the center of the desiccant cartridge bolt also flows out the cross-drilled purge orifice and into the purge volume.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting.

Purge Cycle

As air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor (air compressor stops compressing air) and



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbo

Fig. 3, AD-IP Purge Cycle

the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the line connecting the governor unloader port to the AD-IP end cover control port. The purge piston moves in response to air pressure, causing the purge valve to open to the atmosphere and the turbo cutoff valve to close off the supply of air from the compressor (this will be further discussed under the *Turbocharger Cutoff Feature* heading). Water and contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air which was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the purge volume through the desiccant drying bed to the open purge valve.

The initial purge and desiccant cartridge decompression lasts only a few seconds and is evidenced by an audible burst of air at the AD-IP exhaust.

The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume

General Information

through the purge orifice in the desiccant cartridge bolt, then through the center of the bolt and into the desiccant bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Generally 30 seconds are required for the entire purge volume of a standard AD-IP to flow through the desiccant drying bed.

The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the 30-second purge cycle is complete, the desiccant has been reactivated or dried. The air dryer is ready for the next charge cycle to begin. However, the purge valve will remain open and will not close until air brake system pressure is reduced and the governor signals the compressor to charge the system.

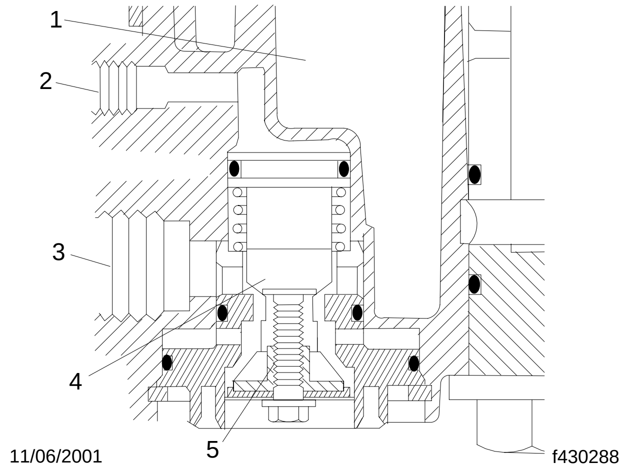
NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to **Group 42** of the *Recreational Vehicle Chassis Maintenance Manual* for intervals and procedures.

Turbocharger Cutoff Feature

NOTE: The air compressor is naturally aspirated; the air passes from the vehicle air filter directly to the air compressor intake.

The primary function of the turbo cutoff valve is to prevent loss of engine turbocharger air pressure through the AD-IP in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also removes the "puffing" of air out of the open purge exhaust, when a naturally aspirated, single-cylinder compressor, equipped with an inlet check valve, is in use. See **Fig. 4**.

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and AD-IP inlet port cannot enter the air dryer. In this manner, the turbo cutoff effectively maintains turbocharger boost pressure to the engine.



1. Purge Volume
2. Control Port
3. Supply Port
4. Turbo Cutoff Valve
5. Purge Valve

Fig. 4, AD-IP Turbo Cutoff

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

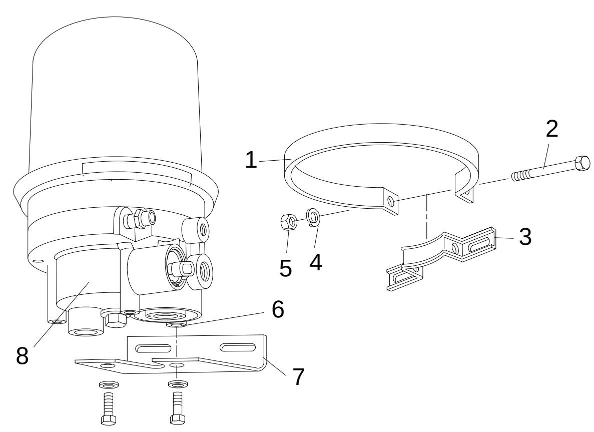
  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and chock the tires.
2. Completely drain all of the reservoirs.
3. Mark and disconnect the three air lines from the end cover, and note the position of end cover ports relative to the vehicle.
4. Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve assembly.
5. Remove the four bolts that secure both the upper and lower mounting brackets to the vehicle, and remove the air dryer from the vehicle. See **Fig. 1**.



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1. Mounting Strap
2. 5/16-Inch Bolt
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer

Fig. 1, Bendix AD-IP Air Dryer

6. Mark the relationship of the saddle bracket to the end cover assembly. Remove the 5/16-inch bolt, washer, and nut that secures the upper mounting strap to the saddle bracket. Remove the upper mounting strap from the end cover assembly.
7. Mark the relationship of the lower bracket to the end cover assembly. Remove the two 3/8-inch end cover capscrews and two washers that retain the lower mounting bracket to the end cover.
8. Remove the air dryer from its mounting brackets.

Installation

1. Install the lower mounting bracket on the end cover and secure it using the two 3/8-inch capscrews and washers. Tighten the capscrews 25 to 30 lbf·ft (34 to 41 N·m). See **Fig. 1**.
2. Install the saddle bracket and mounting strap on the end cover, and using the 5/16-inch bolt, washer, and nut secure the strap to the saddle bracket. Tighten the 5/16-inch nut on the upper mounting bracket 60 to 100 lbf·in (678 to 1130 N·cm).
3. Install the AD-IP on the vehicle using the four bolts that secure both the upper and lower mounting brackets.
4. As marked earlier in "Removal," connect the three air lines to the ports on the end cover.
5. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
6. Test the air dryer, following instructions in **Group 42** of the *Recreational Vehicle Chassis Maintenance Manual*.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

NOTE: Refer to **Fig. 1** during disassembly.

NOTICE

While servicing the air dryer, do not use a clamping device (vise, C-clamp, etc.) to hold any die cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Loosen the desiccant cartridge bolt, then separate the desiccant cartridge from the end cover. Pull the desiccant cartridge bolt out of the end cover. See **Fig. 1**.

CAUTION

Disassembly of the desiccant cartridge assembly should not be attempted! Detail parts for the cartridge are not available and the cartridge contains a 150 lb spring which can not be mechanically caged. Releasing the spring could cause serious personal injury.

3. Remove both O-rings from the desiccant cartridge bolt.
4. Remove the retaining ring that secures the purge valve assembly in the end cover.
5. Remove the 1/4-inch shoulder bolt from the bottom of the purge valve housing assembly, using a 3/8-inch socket wrench and a large blade screwdriver, inserted in the slot on top of the purge piston. Remove the exhaust diaphragm, and the purge valve from the purge valve housing.
6. Remove the O-rings from the purge valve housing.
7. Remove the purge piston and the return spring. Remove the O-ring from the purge piston.
8. Remove the retaining ring that secures the delivery check valve assembly in the end cover. Remove and separate the perforated plate, spring, check valve body, and O-ring.
9. Remove the retaining ring that secures the heater and thermostat assembly in the end cover. Gently pull the heater and thermostat out of the end cover and remove the O-ring.
10. Using a 9/16-inch wrench, remove the safety valve assembly from the end cover.

Cleaning and Inspection

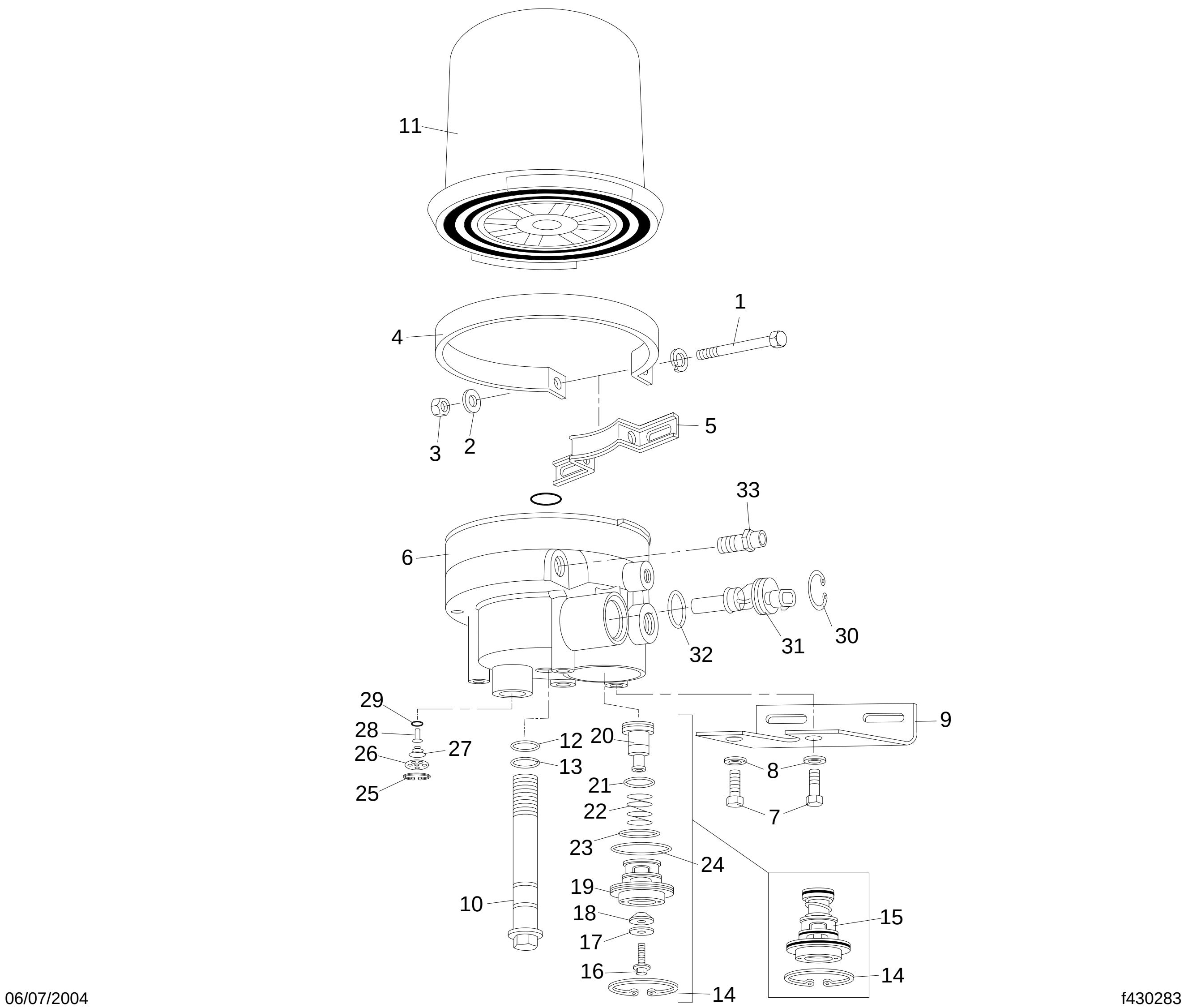
1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.

NOTE: Don’t clean the desiccant cartridge.

2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.
8. Make certain that the purge orifice in the cartridge bolt is open and free of obstructions.
9. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
10. Replace all removed O-rings with new ones that are provided in the kits.

    Replace parts that show any of the conditions described in the previous steps.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



1. 5/16-Inch Bolt
2. 5/16-Inch Lockwasher
3. 5/16-Inch Locknut
4. Upper Bracket Strap
5. Saddle Bracket
6. End Cover
7. 3/8-Inch Capscrew
8. 3/8-Inch Lockwasher
9. Lower Mounting Bracket
10. Cartridge Bolt
11. Desiccant Cartridge
12. O-Ring
13. O-Ring
14. Retaining Ring
15. Purge Valve Cartridge Assembly
16. Shoulder Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. Purge Valve Housing
20. Purge Valve Piston
21. O-Ring
22. Piston Return Spring
23. O-Ring
24. O-Ring
25. Retaining Ring
26. Perforated Plate
27. Check Ring Spring
28. Check Valve
29. O-Ring
30. Retaining Ring
31. Heater/Thermostat Assembly
32. O-Ring
33. Safety Valve Assembly

Fig. 1, AD-IP (exploded view)

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

Assembly

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.
2. Install and center the exhaust diaphragm over the shoulder bolt, making certain that the diaphragm ID is over the bolt shoulder. Then install the purge valve on the shoulder bolt, making certain its metal support side is against the diaphragm.
3. Push the purge piston into the housing until it bottoms, and insert a large blade screwdriver in the piston's slotted head. While depressing the purge piston with the screwdriver, install the shoulder bolt with exhaust diaphragm and purge valve in the piston. Tighten the shoulder bolt 60 to 80 lbf·in (678 to 904 N·cm).
4. Install the two O-rings on the purge valve housing, placing each in its appropriate location. Install the assembled purge valve housing in the end cover while making certain the purge valve housing is fully seated against the end cover. Secure the purge valve housing in the end cover, using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
5. Using a 9/16-inch wrench, install the safety valve assembly into the end cover.
6. Install the O-ring on the check valve body, and push the O-ring down, over the three guide lands until it is in the O-ring groove of the check valve body. Install the check valve spring on the check valve body so that the small coils of the spring slip over the check valve body. Install the assembled check valve body, O-ring, and spring in the end cover so that the O-ring rests on its seat in the end cover, and the spring is visible.
7. Install the O-ring on the heater and thermostat assembly. After making certain the sponge-rubber cushion is positioned between the connector body and thermostat, gently push the heater and thermostat assembly into the end cover, making certain the heating element enters the small diameter bore in the larger heater and thermostat bore in the end cover. Secure the heater and thermostat assembly in the body, using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
8. Install both O-rings on the desiccant cartridge bolt, and using a twisting motion, insert the assembled desiccant cartridge bolt in the end cover.
9. Install the desiccant cartridge on the end cover, making certain the cartridge is properly seated and flush on the end cover.

NOTE: It may be necessary to rotate the cartridge slightly until the anti-rotation lugs are properly aligned and they allow the cartridge to rest flush against the end cover.

10. Tighten the desiccant cartridge bolt 50 lbf·ft (68 N·m), to secure the desiccant cartridge to the end cover.
11. Install the air dryer. For instructions, see **Subject 110**.

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Troubleshooting

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (830 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed.
The check valve in the air dryer end cover is inoperative.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir.
Purge valve stays open; supply air leaks to control side.	Replace the purge valve assembly O-rings.

Troubleshooting

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
Air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat. See **Group 83** in this manual.
Desiccant cartridge not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Troubleshooting

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet is pressurized by the engine turbocharger.	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD-9 air dryer is normal, and may be heard. This slight loss of air will not affect the engine or turbocharger performance.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

General Information

The function of the Bendix AD-9 air dryer is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. See **Fig. 1**.

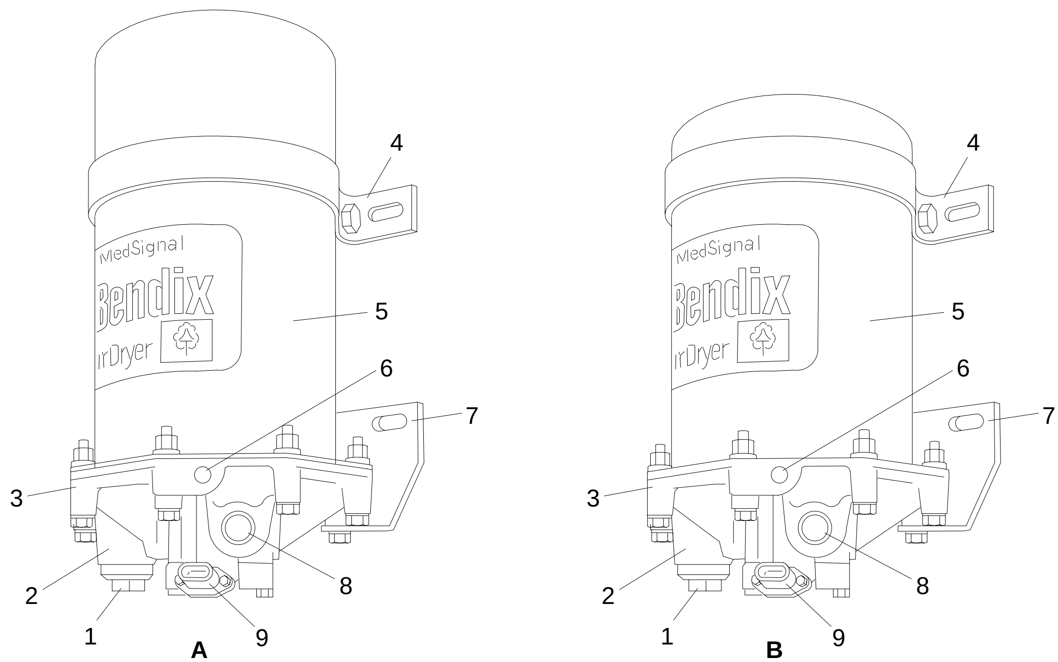
The AD-9 air dryer consists of the desiccant cartridge and a die-cast aluminum end cover secured to a cylindrical steel outer shell with eight bolts and nuts. The end cover contains a check valve assembly, a safety valve, three threaded air connections, and the purge valve housing assembly. The removable purge valve housing assembly features a purge valve mechanism and a turbocharger cutoff that are designed to prevent loss of engine turbo boost pressure during the purge cycle of the air dryer.

To ease servicing, the desiccant cartridge and discharge check valve assembly are screw-in types. The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced without removing the air dryer from the vehicle. The screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The AD-9 has three female pipe thread air connections; each is identified as follows in **Table 1**.

Port I.D.	Function/Connection
4-CON	Control Port (purge valve control and turbo cutoff)
11-SUP	Supply Port (air in)
2-DEL	Delivery Port (air out)

Table 1, Air Dryer Port Identification



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A. Extended Purge Air Dryer
B. Standard Air Dryer

1. Delivery Port
2. Check Valve Assembly
3. End Cover
4. Upper Bracket
5. Outer Shell
6. Control Port
7. Lower Bracket
8. Supply Port
9. Wiring Harness

Fig. 1, Bendix AD-9 Air Dryer

General Information

The standard air dryer uses a metal seat turbo cutoff valve. See **Fig. 2**. The function of the metal seat is to prevent turbocharger boost pressure loss through the air dryer during the purge (compressor unloaded) mode. Some low level turbo air leakage can occur in the unloaded mode.

Principles of Operation

The AD-9 air dryer alternates between two operational modes or cycles during operation: the charge cycle and the purge cycle.

Charge Cycle

When the compressor is loaded (compressing air), pressurized air, along with oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer end cover. As air travels through the end-cover assembly, its direction of flow changes several times, reducing the temperature, causes contaminants to condense and drop to the bottom or sump of the air dryer end cover. See **Fig. 3**.

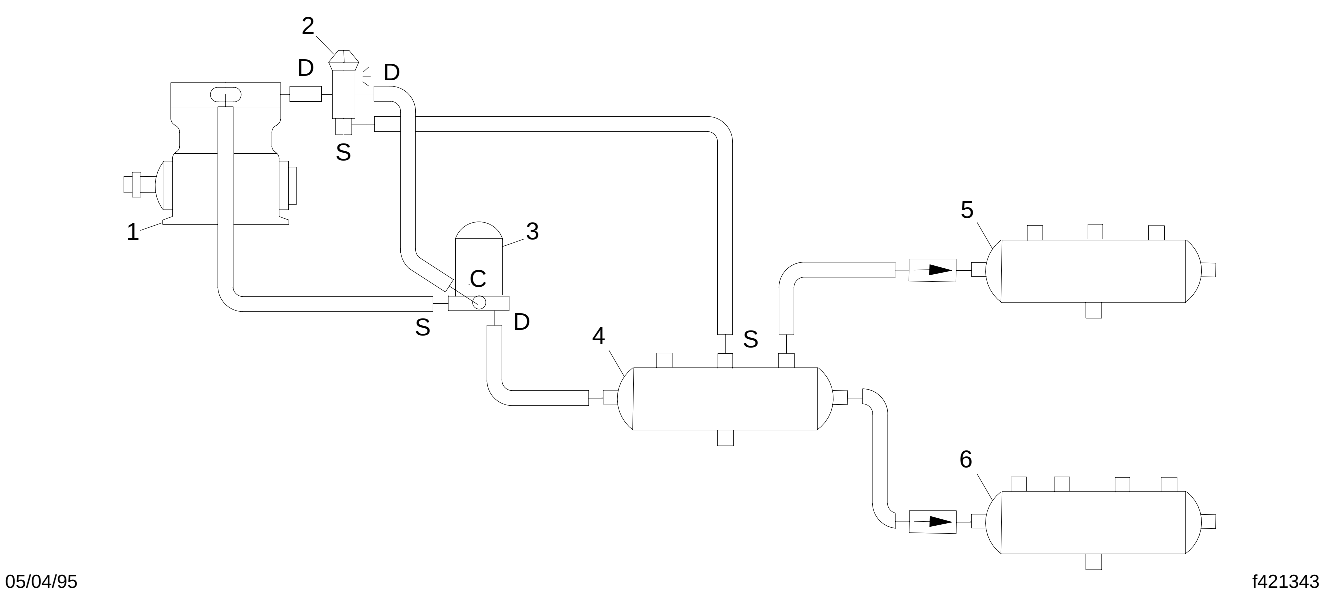
After exiting the end cover, air flows into the desiccant cartridge. Once in the cartridge, air first flows through an oil separator, which removes water, oil, oil vapor, and solid contaminants.

Air exits the oil separator and enters the desiccant drying bed. Air flowing through the column of desiccant becomes progressively drier as water vapor sticks to the desiccant material in a process known as adsorption. The desiccant cartridge, using the adsorption process typically removes 95 percent of the water vapor from the pressurized air.

Most of the dry air exits the desiccant cartridge through its integral single check valve to fill the purge volume between the desiccant cartridge and outer shell. Some air also exits the desiccant cartridge through the purge orifice adjacent to the check valve.

Dry air flows out of the purge volume through the single check valve assembly and out the delivery port to the first (supply) reservoir of the air system.

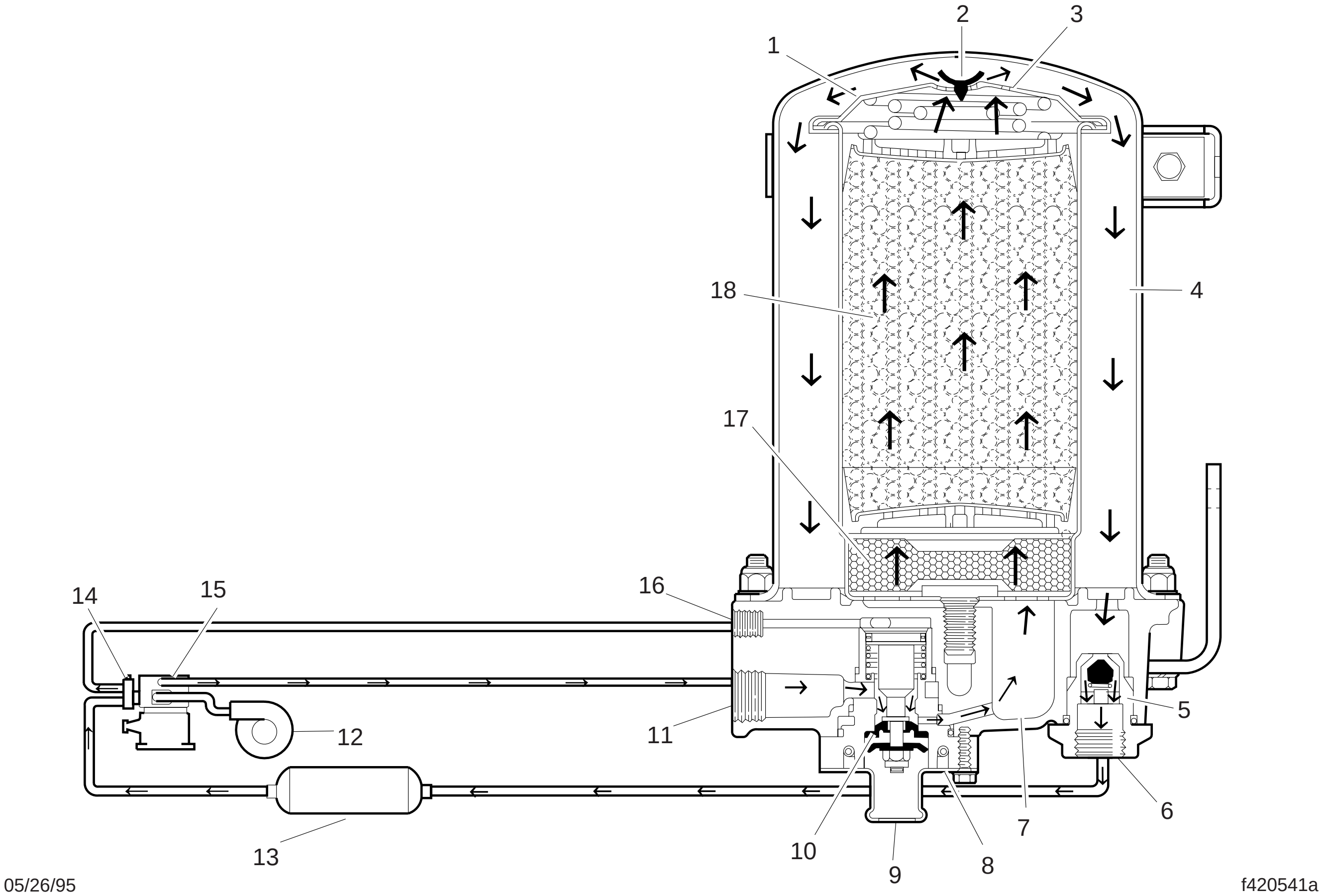
The air dryer remains in the charge cycle until air brake system pressure builds to the governor cutout setting.



C. Control
D. Delivery
S. Supply

1. Air Compressor
2. D-2 Governor
3. Air Dryer
4. Supply Reservoir
5. Primary Reservoir
6. Secondary Reservoir

Fig. 2, Standard Air Dryer Plumbing Diagram



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Supply Port
12. Engine Turbocharger
13. Reservoir
14. Governor
15. Compressor
16. Control Port
17. Oil Separator
18. Desiccant Bed

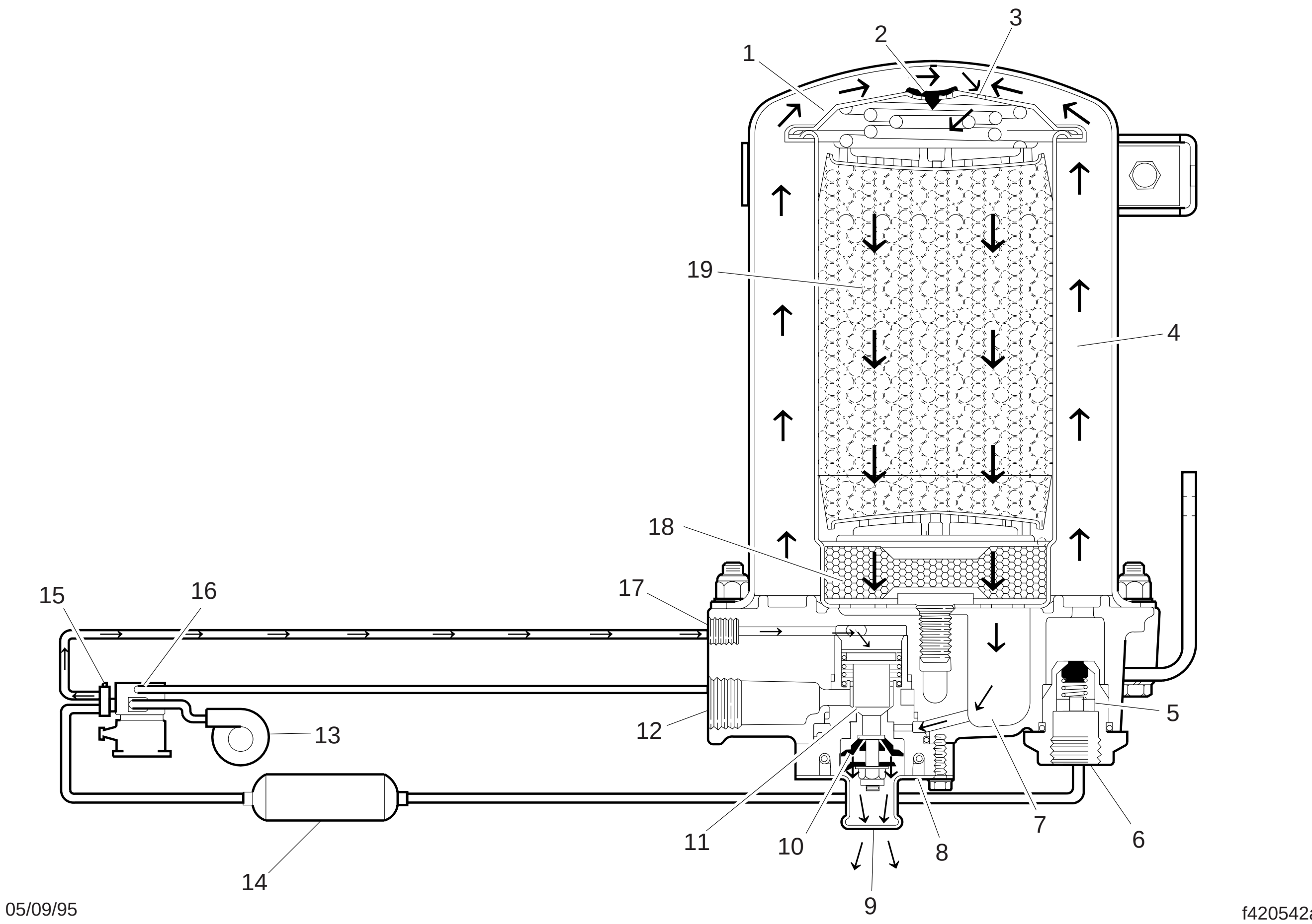
Fig. 3, AD-9 Charge Cycle

Purge Cycle

When the brake system pressure reaches the governor cutout setting, the compressor unloads (air compression stopped), and the purge cycle of the air dryer begins. See **Fig. 4**. When the governor unloads the compressor, it pressurizes the unloader mechanism and line connecting the governor unloader port to the AD-9 end cover control port. The purge piston moves in response to air pressure, and causing the purge valve to open to atmosphere and partially close off the supply of air from the compressor. This is discussed further under "Turbocharger Cutoff Feature."

Contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air that was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the desiccant drying bed to the open purge valve.

General Information



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Turbocharger Cutoff Piston
12. Supply Port
13. Engine Turbocharger
14. Reservoir
15. Governor
16. Compressor
17. Control Port
18. Oil Separator
19. Desiccant Bed

Fig. 4, AD-9 Purge Cycle

The initial purge and desiccant cartridge decompression last only a few seconds and are signaled by an audible burst of air at the AD-9 exhaust. The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume through the desiccant cartridge purge orifice and into the desiccant drying bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. Dry air flowing through the drying bed reactivates the desiccant material by removing the water vapor sticking to it. Generally, it takes 15 to 30 seconds for the entire purge volume of a standard AD-9 to flow through the desiccant drying bed.

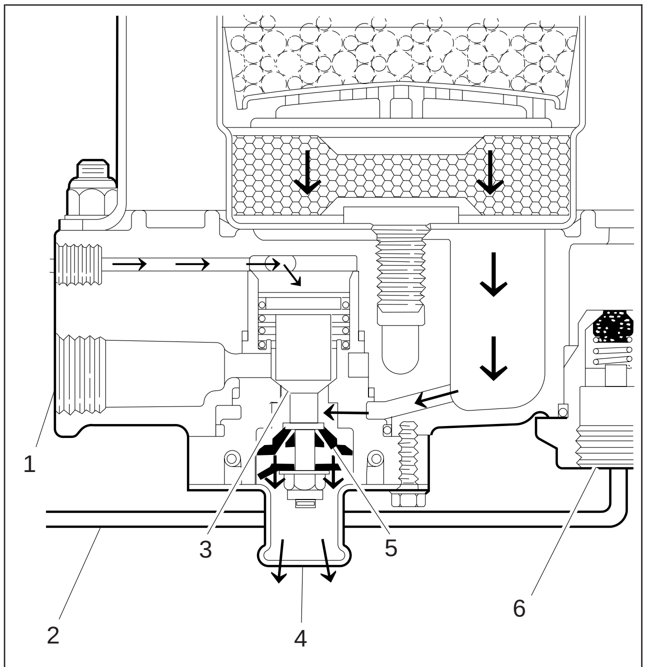
The end cover single check valve assembly prevents compressed air in the brake system from returning to the air dryer during the purge cycle. After the 30 second purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

The purge valve will remain open after the purge cycle is complete, and will not close until air brake system pressure is reduced and the governor signals the compressor to charge.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to **Group 42** of the *Recreational Vehicle Chassis Maintenance Manual* for intervals and procedures.

Turbocharger Cutoff Feature

Primarily, the turbo cutoff valve prevents loss of engine turbocharger air pressure through the AD-9 in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also reduces the puffing of air out the open exhaust when a naturally aspirated, single-cylinder compressor equipped with an inlet check valve is in use. See **Fig. 5**.



1. Supply Port
2. Delivery Line
3. Turbocharger Cutoff Piston
4. Exhaust
5. Purge Valve
6. Check Valve Assembly

Fig. 5, AD-9 Turbo Cutoff

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of the purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the discharge line and AD-9 supply port is restricted from entering the air dryer. While the turbo cutoff *effectively* prevents loss of turbocharger boost pressure to the engine, some seepage of air may be detected under certain conditions of compressor, engine, and turbocharger operation. Even so, there will be low pressure trapped in the discharge line.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push-rods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don’t disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

Air Dryer Removal and Installation

Removal

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain all reservoirs to zero pressure.

CAUTION

The compressor discharge line may still contain residual pressure. When removing the line, make certain to hold it firmly and direct it away from your eyes to avoid any flying debris.

3. Identify and disconnect the three air lines from the end cover. Note the position of end cover ports relative to the vehicle.
4. Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve housing assembly.
5. Loosen the hexbolt that secures the upper mounting strap.
6. Remove, save, and mark the two end cover bolts, locknuts, and four special washers that retain the lower mounting bracket to the end cover. Also mark the tow holes of the end cover. These bolts are longer than the other six bolts.
7. Remove the air dryer from its mounting brackets.

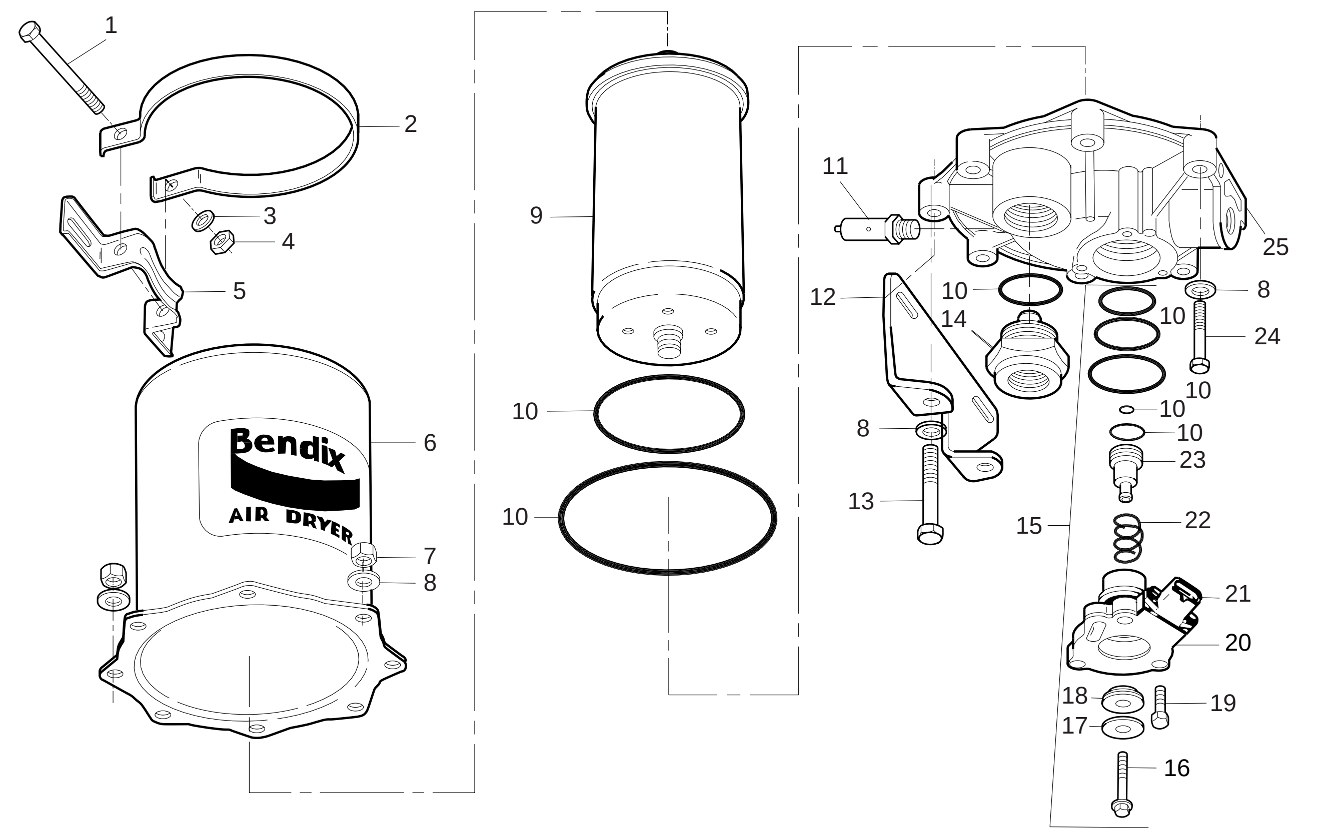
Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Position the air dryer into the upper mounting bracket and strap. Align the two unused holes in the end cover with the bottom mounting bracket so that the bottom bracket supports the air dryer. The end cover should rest on the bracket. See **Fig. 1**.
2. Using the remaining two bolts, four special washers, and two locknuts, secure the air dryer to the lower bracket. Tighten the two remaining bolts 23 to 32 lbf·ft (31 to 43 N·m).
3. Tighten the bolt and nut on the upper mounting bracket strap 80 to 120 lbf·in (904 to 1356 N·cm).
4. Connect the three air lines to the correct ports on the end cover as identified in "Removal".
5. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
6. Test the air dryer following instructions in **Group 42** of the *Recreational Vehicle Chassis Maintenance Manual.*

Air Dryer Removal and Installation



1. 5/16-Inch x 4-1/2-Inch Upper Bracket Bolt
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Bolt (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Bolt
25. End Cover

Fig. 1, Bendix AD-9 Air Dryer

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTICE

While servicing the air dryer, do not use a clamping device (vise, C-clamp, etc.) to hold any die-cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Remove the check valve assembly and O-ring. Remove the O-ring from the check valve assembly, as follows. See **Fig. 1**.
3. Remove the purge valve housing assembly, as follows. See **Fig. 1**.

   3.1 Remove the three self-tapping screws that secure the purge valve housing assembly to the end cover assembly.

   3.2 Pull the purge valve housing assembly out of the end cover assembly.

   3.3 Remove and discard the three O-rings from the exterior of the purge valve housing assembly.

   NOTE: These O-rings may lodge in and have to be removed from the end cover bores.
4. Remove the heater and thermostat assembly, as follows. See **Fig. 1**.

   4.1 Remove and discard the two screws that attach the heater and thermostat assembly to the purge valve housing.

   4.2 Gently rotate the electrical connector to the left until the thermostat clears the purge valve housing. Then, slide the heater element out, to the right and up. Discard the assembly.
5. Disassemble the purge valve housing assembly, as follows. See **Fig. 1**.

   5.1 If a flat non-extended exhaust cover is used, leave it intact while servicing the purge valve housing assembly.

   If an extended-type exhaust cover is used for the attachment of an exhaust hose, *carefully* separate the exhaust cover from the purge valve housing. *Use a thin flat blade to pry the exhaust cover off, taking care not to damage the potting material (RTV sealant) under the cover.*

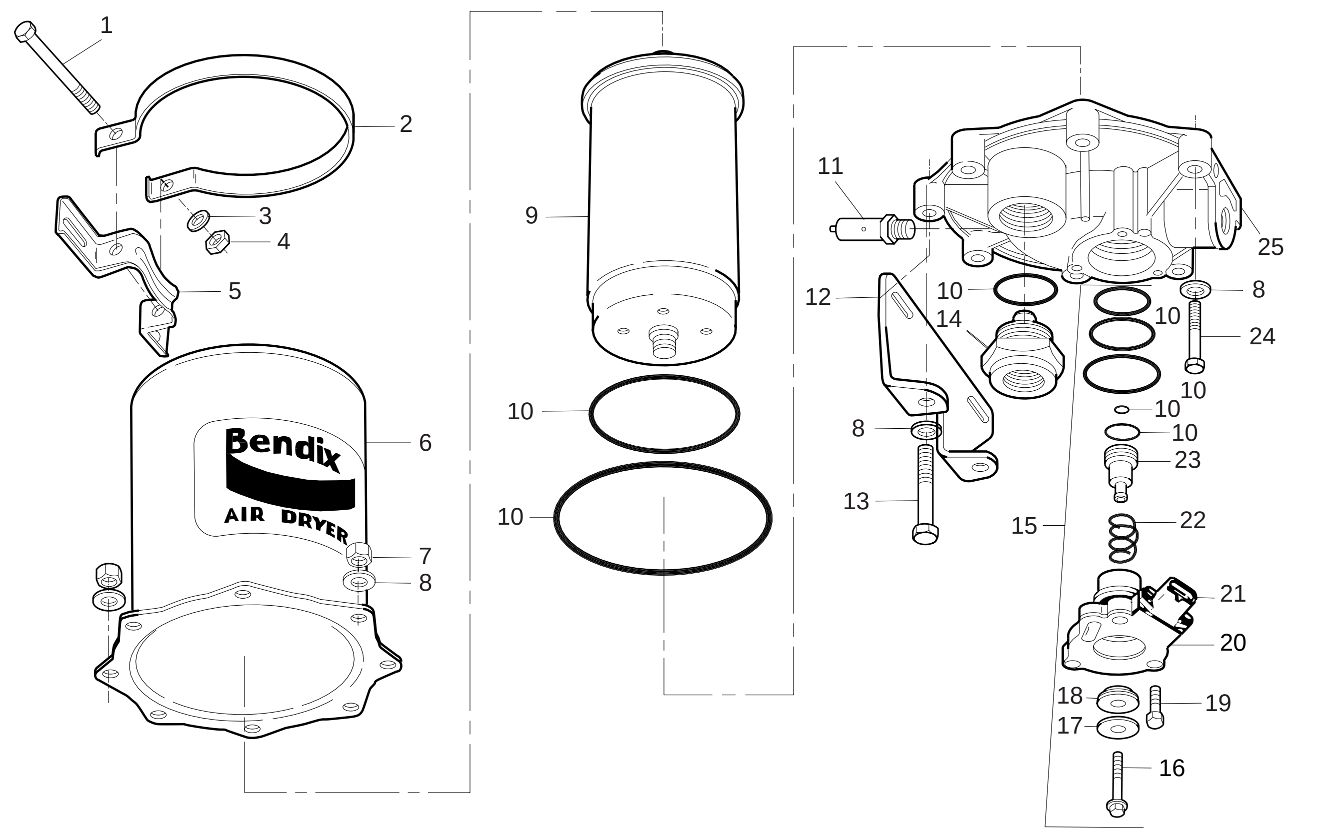
   5.2 Remove the bolt from the bottom of the purge valve housing assembly. Remove the diaphragm and the purge valve from the purge valve housing.

   5.3 Remove the purge piston, the return spring and two O-rings (one on the outside and the other in the inside of the purge piston).
6. Remove the remaining six bolts, locknuts, and twelve special washers that secure the end cover to the housing. Separate the end cover and desiccant cartridge from the housing. See **Fig. 1**.
7. Remove the end-cover-to-outer-housing O-ring. See **Fig. 1**.
8. Don't remove the safety valve from the end cover unless it is known to be inoperative. If replacement is needed, apply thread sealant or Teflon® tape on the threads of the replacement valve and tighten 120 to 400 lbf·in (1356 to 4519 N·cm). Make sure the drain hole (slot) is facing down.
9. Place a strap or chain wrench around the desiccant cartridge so that it is about 2 to 3 inches (5 to 8 cm) away from the end cover. Rotate the cartridge counterclockwise until it completely separates from the end cover.

NOTE: Torque of up to 50 lbf·ft (68 N·m) may be needed to do this disassembly.

10. Remove the desiccant cartridge O-ring from the end cover. See **Fig. 1**.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



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1. 5/16-Inch x 4-1/2 Inch Upper Bracket Bolt
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Bolt (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Capscrew
25. End Cover

Fig. 1, AD-9 (exploded view)

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

Cleaning and Inspection

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.
2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.
8. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
9. Replace all removed O-rings with new ones that are provided in the kits.

   Replace parts that show any of the conditions described in the previous steps.

Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.

IMPORTANT: When installing the heater and thermostat assembly, make sure that the seal ring under the electrical connector is not twisted.

2. Install the heater and thermostat assembly, as follows.

   2.1 Insert the heater element into the slot in the purge valve housing until the connector contacts the housing.

   2.2 Gently push the connector and the thermostat to the left until the thermostat clears the cavity in the housing. Then, turn the connector to the right while pushing the thermostat all the way down into the cavity.

   Make sure that the connector is seated evenly against the housing.

   2.3 Install the two mounting screws. Tighten the screws 10 to 20 lbf·in (113 to 226 N·cm).

3. Assemble the purge-valve housing, as follows.

   3.1 Install the O-ring on the purge piston. Place the return spring in the purge-valve housing. Place the O-ring in the bore of the purge piston. Insert the purge piston into the spring. Push the piston into the purge-valve housing until it bottoms.

   3.2 While holding the purge piston in, install the following parts: the purge valve with its rubber side first, followed by the diaphragm and the bolt. Torque the purge valve bolt 60 to 80 lbf·in (678 to 904 N·cm).

   3.3 Install the three O-rings in their correct locations on the purge-valve housing.

   3.4 If an extended type exhaust cover was removed, install it on the purge-valve housing assembly, making sure the "bubble" portion is positioned over the thermostat.

   3.5 Install the assembled purge-valve housing in the end cover; make sure you orient both parts so that the connector is about 10 degrees clockwise from the supply port. Also, make sure the purge-valve housing is fully seated against the end cover.

   3.6 Secure the purge-valve housing to the end cover using the three self-tapping screws.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

Start all three screws by hand, then torque them 85 to 125 lbf·in (960 to 1412 N·cm).

4. Install an O-ring on the check-valve assembly, then install the assembly in the end cover using a socket. Tighten it 200 to 250 lbf·in (2260 to 2825 N·cm).
5. Install the desiccant cartridge in the end cover, as follows.

   5.1 Install the smaller desiccant cartridge O-ring in its groove in the end cover. Using a light coat of barium grease, lubricate the bottom of the desiccant cartridge in the area that will contact the O-ring and end cover.

   5.2 Screw the desiccant cartridge into the end cover until the cartridge contacts the O-ring. Using a strap or chain wrench positioned 2 to 3 inches (5 to 8 cm) from the bottom of the cartridge, turn the desiccant cartridge clockwise 180 to 225 degrees beyond the position where initial contact was made with the O-ring. Torque should not exceed 50 lbf·ft (68 N·m).
6. Install the housing over the desiccant cartridge, as follows.

   6.1 Install the large O-ring on the shoulder in the end cover. Place the housing over the desiccant cartridge and align the holes.

   6.2 Install the six bolts, locknuts, and the twelve special washers, making sure they are positioned as referenced earlier. The two longer bolts will be used to secure the air dryer to its mounting bracket.

   6.3 Tighten the six bolts and nuts in a star pattern (depending on lower bracket location) 23 to 32 lbf·ft (31 to 43 N·m). See **Fig. 2**.

NOTE: The two remaining bolt holes in the end cover and two 3/8-inch bolts must be the ones marked during removal to ensure correct orientation of the ports and adequate length of the bolts.

7. Connect the electrical connector to the heater and thermostat assembly.
8. Test the air dryer for proper operation. For instructions, see **Subject 130**.

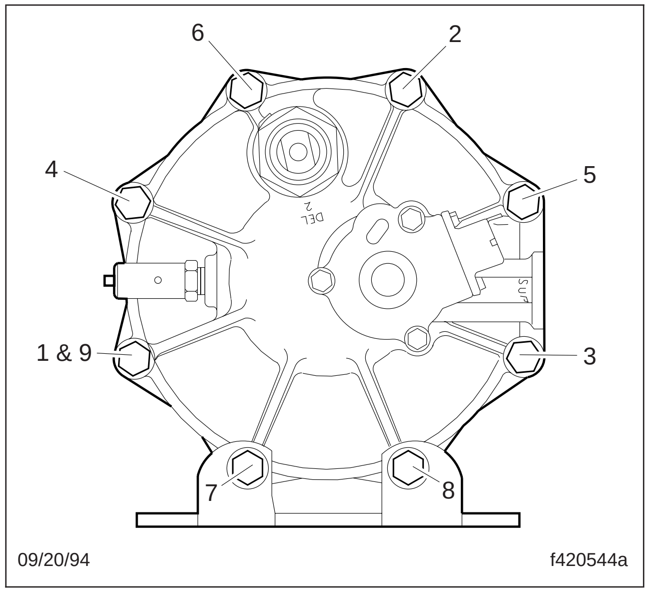


Fig. 2, End Cover to Housing Torque Pattern

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Troubleshooting Tables

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (827 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed.
The check valve in the air dryer end cover is inoperative.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Purge valve stays open; supply air leaks to control side.	Replace the purge valve assembly O-rings.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
Air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat. See **Group 83** in this manual.
Desiccant cartridge not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Troubleshooting

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

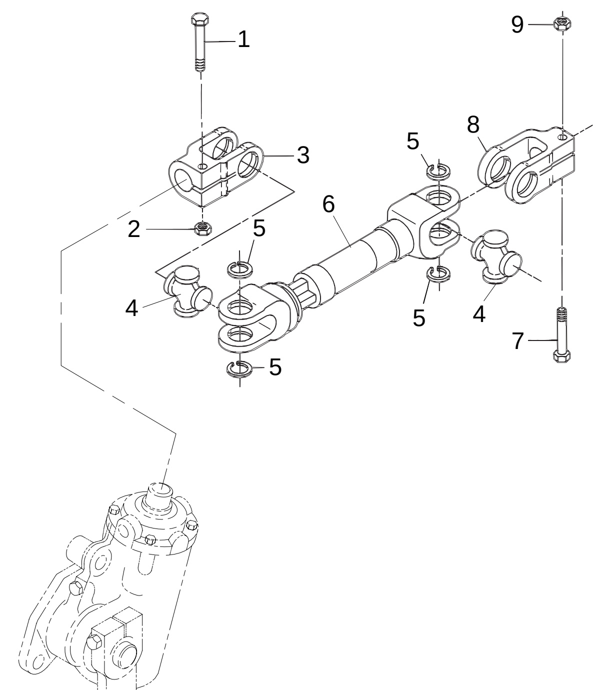
Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet is pressurized by the engine turbocharger.	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD-9 air dryer is normal, and may be heard. This slight loss of air will not affect the engine or turbocharger performance.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

General Description

The steering driveline connects the steering column and jacket assembly to the steering gear by means of a telescoping shaft with integral yokes, an upper and a lower end yoke, and a pair of universal joints. See **Fig. 1.**



1. Lower Pinch Bolt, 7/16–20 x 2.25, Grade 8
2. Lower Pinch Bolt Nut, 7/16–20, Grade 8
3. Steering Gear Input Yoke
4. Journal and Bearings
5. Snap Ring
6. Steering Driveline
7. Upper Pinch Bolt, 3/8–24, Grade 8
8. Steering Column Output Yoke
9. Upper Pinch Bolt Nut, 3/8–24, Grade 8

Fig. 1, Steering Driveline Installation

The driveline shaft consists of a tubular upper section, splined on the inside, which mates with an externally 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 steering column and steering gear, which occur when the relative positions of the frame rails and body change during vehicle operation.

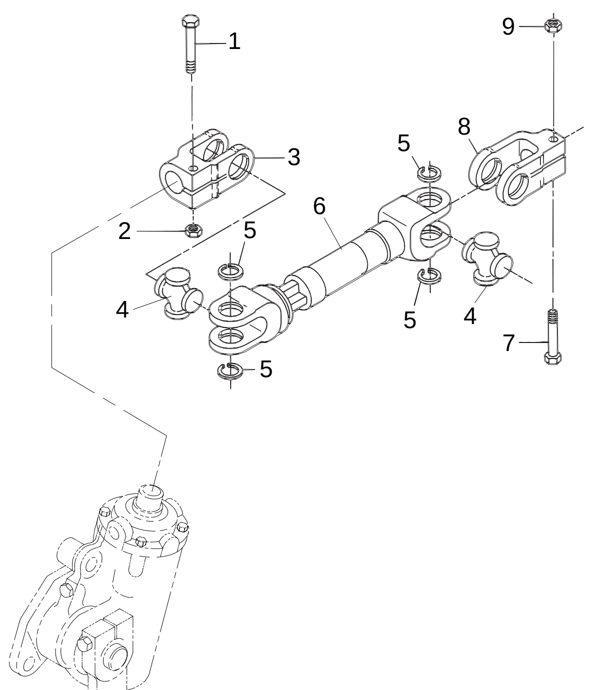
The upper end yoke is internally serrated to match the external serrations at the end of the steering column shaft; the lower end yoke is internally serrated to match the external serrations on the steering gear input shaft. Each end yoke is secured to its respective shaft by a pinch bolt that engages 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

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.
3. Disconnect the lower end yoke. See **Fig. 1**.



1. Lower Pinch Bolt, 7/16–20 x 2.25, Grade 8
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3. Steering Gear Input Yoke
4. Journal and Bearings
5. Snap Ring
6. Steering Driveline
7. Upper Pinch Bolt, 3/8–24, Grade 8
8. Steering Column Output Yoke
9. Upper Pinch-Bolt Nut, 3/8–24, Grade 8

Fig. 1, Steering Driveline Installation

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 into the driveline tube, as you remove the lower end yoke.

4. Disconnect the upper end yoke.

4.1 Remove the four screws holding the steering driveline boot to the floor.

4.2 Slide the boot down the steering driveline.

4.3 Remove the pinch-bolt nut and pinch bolt from the upper end yoke. Discard the nut.

4.4 Remove the upper end yoke from the steering column shaft.

Installation

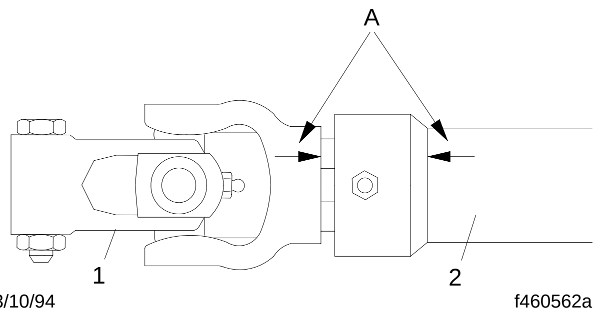
1. Clean the steering gear input shaft, steering column, and end yokes. See **Fig. 1**.

1.1 Thoroughly clean the end yokes, the steering column shaft, 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 upper end yoke onto the steering column shaft, then install the 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 a new pinch-bolt nut, and tighten it 30 to 40 lbf·ft (40 to 54 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, and the steering gear is centered with the timing mark on the end of the sector shaft in line with the mark on the housing trunnion. Also, be sure the arrows on the driveline shaft and the driveline tube are aligned. See **Fig. 2**.

Steering Driveline Removal and Installation



A. Align arrows.

1. Lower End Yoke
2. Driveline Tube and Yoke Assembly

Fig. 2, Alignment Arrow Locations

CAUTION

If the arrow on the driveline shaft is not aligned with the arrow on the driveline 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. Install the boot.
7. Apply white Torque Seal F–900 to the exposed pinch bolt thread and to the locknut.
8. Lubricate the driveline tube and both U-joints with lithium-based grease, NLGI grade 2. Apply until grease appears at the lower end of the tube splines and all four U-joint cross seals.
9. Align the steering wheel spokes.
   - 9.1 With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 3 o'clock and 9 o'clock positions.
   - 9.2 If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.
10. Leave the parking brakes applied and the chocks at the rear tires.
11. Raise the front of the vehicle, so that the front tires are off the ground, then place safety stands under the frame.

WARNING

Driving a vehicle with hard steering or binding in the steering system is hazardous and could result in partial or complete loss of steering control during vehicle operation, causing personal injury or property damage.

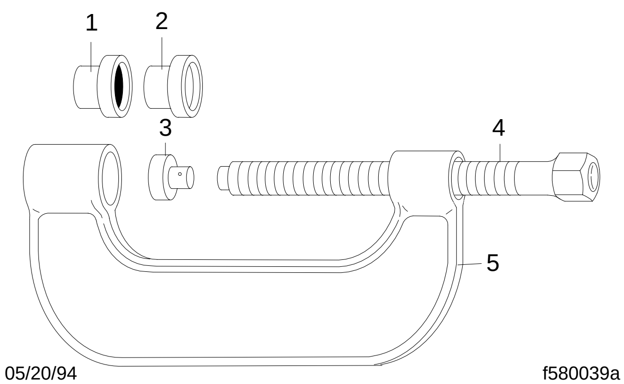
12. Turn the steering wheel through full travel, checking for hard steering or binding. If there is difficulty, check the assembly and installation of the driveline parts. If the cause is not the driveline, refer to the applicable steering gear section in this group.
13. Remove the safety stands, lower the vehicle to the ground, and remove the chocks.

Steering Driveline Disassembly and Assembly

Disassembly

1. Remove the steering driveline from the vehicle. Refer to **Subject 100** for instructions.
2. Slide the driveline shaft and yoke assembly out of the driveline tube and yoke assembly.
3. Remove the steering driveline U-joint.

   3.1 Clamp the frame of a U-joint tool in a vise. See **Fig. 1**.



1. Bushing Adaptor
2. Bearing Driver
3. Expansion Plug
4. Pressure Screw
5. Frame

Fig. 1, Universal Joint Tool

   3.2 Wearing safety goggles, remove the needle bearing cup snap rings from the needle bearing cups by pushing an open end of each snap ring with a screwdriver.

WARNING

Snap rings can become potentially harmful projectiles when they are being removed. Wear safety goggles to prevent eye injury.

   3.3 Select a U-joint tool expansion plug of slightly smaller diameter than the needle bearing cup, and place it on the pressure screw. Select a bushing adaptor of slightly larger inside diameter than the needle bearing cup, and place it on the opposite end of the tool.

   3.4 Place the integral yoke of the driveline tube in the U-joint tool. Position the bushing adaptor to receive a needle bearing cup, and place the expansion plug against the opposite needle bearing cup.

   3.5 Tighten the pressure screw to press one needle bearing cup out of the driveline yoke, then remove the cup. In some cases, it might be necessary to give the pressure screw a sharp blow with a brass hammer while the screw is under pressure.

   3.6 Reverse the driveline tube and yoke assembly, and press against the U-joint cross to force out the other needle bearing cup.

   3.7 Remove the driveline tube and yoke assembly from the U-joint tool, then remove the upper end yoke and the U-joint cross from the driveline yoke.

   3.8 Place the upper end yoke in the U-joint tool. Position the bushing adaptor to receive a needle bearing cup, and place the expansion plug against the opposite needle bearing cup.

   3.9 Tighten the pressure screw to press one needle bearing cup out of the upper end yoke, then remove the cup. In some cases, it might be necessary to give the pressure screw a sharp blow with a brass hammer while the screw is under pressure.

   3.10 Reverse the upper end yoke in the U-joint tool, and press against the U-joint cross to force out the other needle bearing cup.

   3.11 Remove the upper end yoke from the U-joint tool, then remove the U-joint cross from the upper end yoke.

4. Repeat the applicable steps above for the driveline shaft and yoke assembly and the lower end yoke.

Assembly

1. Install the steering driveline U-joint.

   1.1 Clamp the frame of a U-joint tool in a vise. See **Fig. 1**.

   1.2 Select a U-joint tool expansion plug of a slightly smaller diameter than the needle

Steering Driveline Disassembly and Assembly

bearing cup, and place it on the pressure screw. Place a bearing driver on the opposite end of the tool.

1.3 Position the U-joint cross in the upper end yoke so that the U-joint cross lube fitting points toward one of the yoke ears.

1.4 Make certain the U-joint cross seals are in place on the needle bearing cups, then start both needle bearing cups into the yoke ears from the outside. Place the upper end yoke in the U-joint tool with the bearing driver against one of the needle bearing cups and the expansion plug against the opposite needle bearing cup.

1.5 Tighten the pressure screw, making sure that both needle bearing cups press straight and true into the yoke ears. Work the U-joint cross during this operation to ensure free movement. If the needle bearing cups don't seat correctly, or if the U-joint binds, give the yoke shoulder near each cup a sharp blow with a brass hammer.

1.6 Press the needle bearing cup on the screw end of the U-joint tool all the way in, until there is enough clearance to insert a new needle bearing cup snap ring. Insert the snap ring, and fully seat it in its groove.

WARNING

Use new snap rings when assembling the U-joints. Used snap rings are often distorted and overstressed from disassembly. Also, snap rings not fully seated in their grooves could work loose, resulting in a hazardous vehicle operating condition.

1.7 Reverse the upper end yoke in the U-joint tool, and push the other needle bearing cup until there is clearance to insert the other snap ring. Insert the snap ring, then remove the upper end yoke from the U-joint tool.

1.8 With the U-joint cross lube fitting facing away from the base of the upper end yoke, position the U-joint cross and the upper end yoke in the driveline tube and yoke assembly.

NOTE: The U-joint cross lube fitting should face away from the base of the upper end yoke to provide access for lubrication when the steering driveline is installed on the vehicle.

1.9 Make certain the U-joint cross seals are in place on the needle bearing cups, then start both needle bearing cups into the yoke ears. Place the driveline tube and yoke assembly in the U-joint tool with the bearing driver against one of the needle bearing cups and the expansion plug against the opposite needle bearing cup.

1.10 Tighten the pressure screw, making sure that both needle bearing cups press straight and true into the yoke ears. Work the U-joint cross during this operation to ensure free movement. If the needle bearing cups don't seat correctly, or if the U-joint binds, give the yoke shoulder near each cup a sharp blow with a brass hammer.

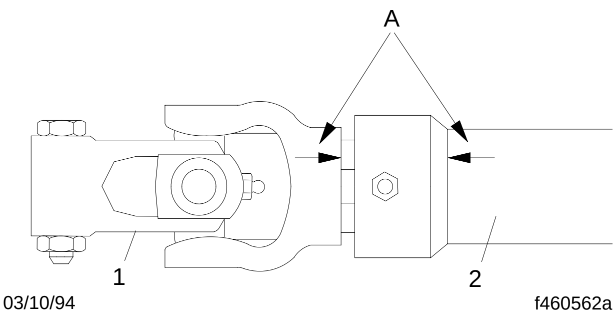
1.11 Press the needle bearing cup on the screw end of the U-joint tool all the way in, until there is enough clearance to insert a needle bearing cup snap ring. Insert the snap ring. Reverse the driveline tube and yoke assembly in the U-joint tool and push the other needle bearing cup until there is clearance to insert the other snap ring. Insert the snap ring.

2. Remove the driveline tube and yoke assembly from the U-joint tool.
3. Repeat the applicable steps above for the lower end yoke and the driveline shaft and yoke assembly.
4. Slide the lower driveline shaft into the driveline tube, so that the arrow on the driveline shaft yoke is aligned with the arrow on the driveline tube. See **Fig. 2**.

CAUTION

If the arrow on the driveline shaft yoke isn't aligned with the arrow on the driveline tube, the U-joints will be out of phase. Assembling the driveline with the U-joints out of phase could result in binding at the U-joints.

Steering Driveline Disassembly and Assembly



A. Align arrows.

1. Lower End Yoke
2. Driveline Tube and Yoke Assembly

Fig. 2, Driveline Alignment

5. Install the steering driveline in the vehicle. Refer to **Subject 100** for instructions.

Specifications

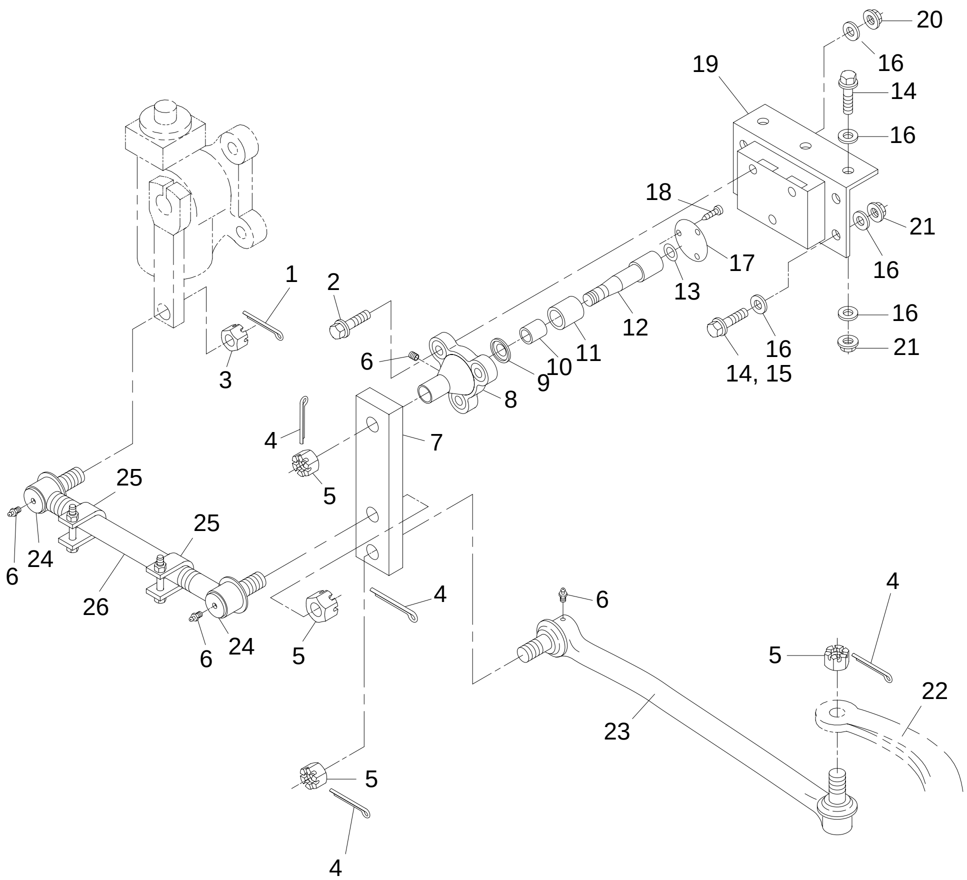
Torque Values			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Lower End Yoke Pinch-Bolt Nut	8	7/16–20 UNF	45 to 55 (61 to 75)
Upper End Yoke Pinch-Bolt Nut	8	3/8–24 UNF	30 to 40 (40 to 54)

Table 1, Torque Values

General Description

The Model XC uses two drag links to connect the steering gear pitman arm to the steering axle. The forward one is adjustable. The rear is not. The two are joined by an "idler" pitman arm that mounts onto the frame rail. See **Fig. 1**.

The socket ball studs, one located at each end of each drag link, rotate to allow for changing angles between the pitman arm and steering arm as the vehicle is steered and the suspension articulates.



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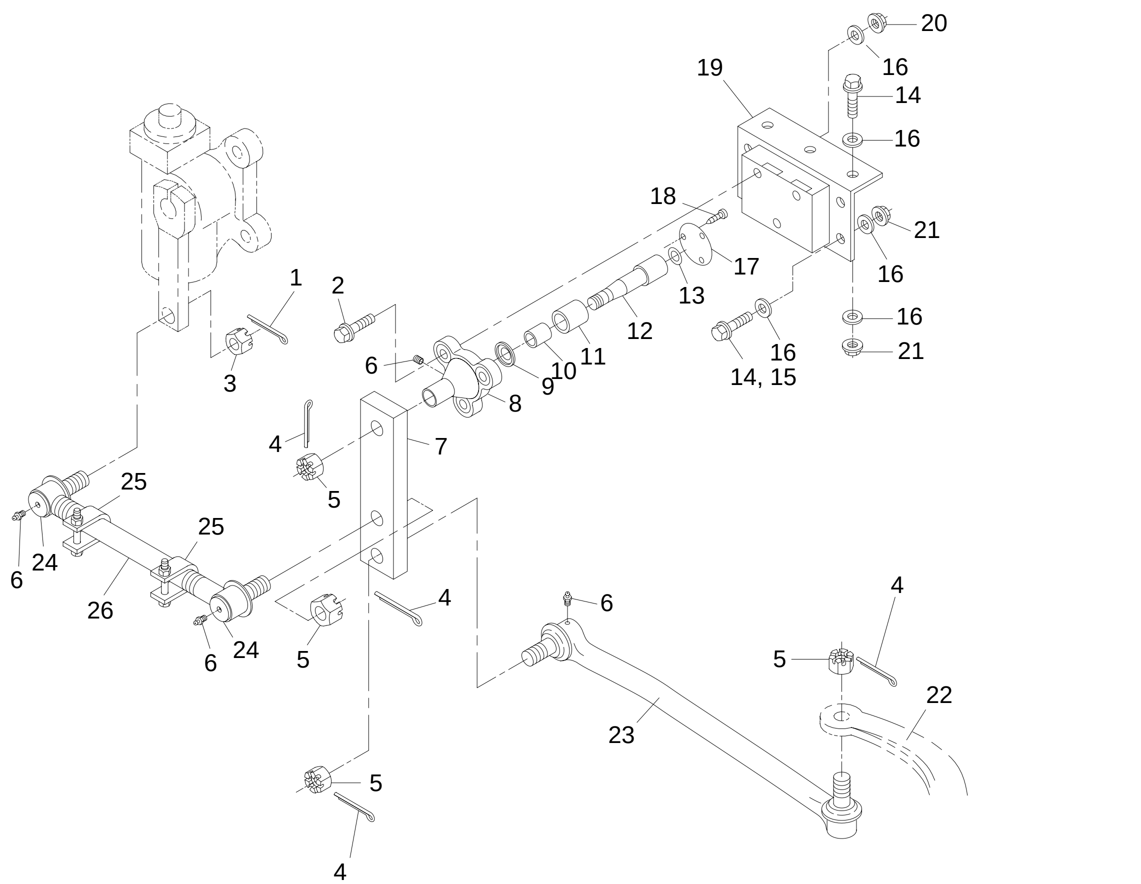
1. Cotter Pin, 2-Inch
2. Capscrew, 1/2–13, Grade 8
3. Castle Nut
4. Cotter Pin, 1-1/3 Inch
5. Idler Pitman Arm Castle Nut
6. Lube Fitting
7. Idler Pitman Arm
8. Steering Bellcrank Housing
9. Oil Seal
10. Bearing, 1.25-Inch Diameter
11. Bearing, 1.75-Inch Diameter
12. Idler Arm Shaft
13. Spring Washer
14. Capscrew, 1/2–13 x 1.25 Inch, Gr. 8
15. Capscrew, 1/2–13 x 1.5 Inch, Gr. 8, Dichromate (some installations)
16. Washer
17. Cover Plate
18. Screw, 1/4–20, Grade 8
19. Idler Arm Bracket Assembly
20. Hexnut, 1/2–13
21. Hexnut
22. Steering Axle Arm
23. Rear Drag Link
24. Forward Drag Link Socket End
25. Clamp Assembly
26. Forward Drag Link

Fig. 1, Model XC Drag Link Assembly

Drag Link Removal and Installation

Removal



1. Cotter Pin, 2-Inch
2. Capscrew, 1/2–13, Grade 8
3. Castle Nut
4. Cotter Pin, 1-1/3 Inch
5. Idler Arm Castle Nut
6. Lube Fitting
7. Idler Pitman Arm
8. Steering Bellcrank Housing
9. Oil Seal
10. Bearing, 1.25-Inch Diameter
11. Bearing, 1.75-Inch Diameter
12. Idler Arm Shaft
13. Spring Washer
14. Capscrew, 1/2–13 x 1.25 Inch, Gr. 8
15. Capscrew, 1/2–13 x 1.5 Inch, Gr. 8, Dichromate (some installations)
16. Washer
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19. Idler Arm Bracket Assembly
20. Hexnut, 1/2–13
21. Hexnut
22. Steering Axle Arm
23. Rear Drag Link
24. Forward Drag Link Socket End
25. Clamp Assembly
26. Forward Drag Link

Fig. 1, Model XC Drag Link Assembly

1. Position the tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service operations are to be performed. *Do not turn the steering wheel at any time while the drag link is still attached to both the pitman arm and the axle steering arm.* If the steering wheel is turned, the front tires will not be straight ahead.
2. Apply the parking brakes, and chock the rear tires.

Drag Link Removal and Installation

3. Remove the nut that holds the idler arm, and remove the arm from the shaft. See **Fig. 1**.
4. Remove the cotter pin and castle nut from the forward end of the rear drag link.
5. Remove the cotter pin and castle nut from the rear end of the rear drag link, and remove the drag link.
6. Remove the cotter pin and castle nut from the rear end of the forward drag link.
7. Remove the cotter pin and castle nut from the forward end of the forward drag link, and remove the drag link.

Installation

1. Install the drag links.
   - 1.1 Position the forward and rear drag links, joining them at the idler arm.
   - 1.2 Tighten the ball stud nuts 160 to 300 lbf·ft (217 to 407 N·m).
   - 1.3 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.*
   - 1.4 Install new cotter pins through the ball studs and nuts, and lock the cotter pins in place.

WARNING

Failure to install and lock new cotter pins in the ball studs and nuts could result in disengagement of the parts, causing loss of steering control which could result in personal injury or property damage.

2. Install the idler arm, and tighten the nut 650 lbf·ft (881 N·m).
3. Remove the chocks from the tires.

Ball Stud Testing, On Vehicle

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 160 to 300 lbf·ft (217 to 407 N·m).

Grasp each drag link near the forward 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 each drag link near the rear 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

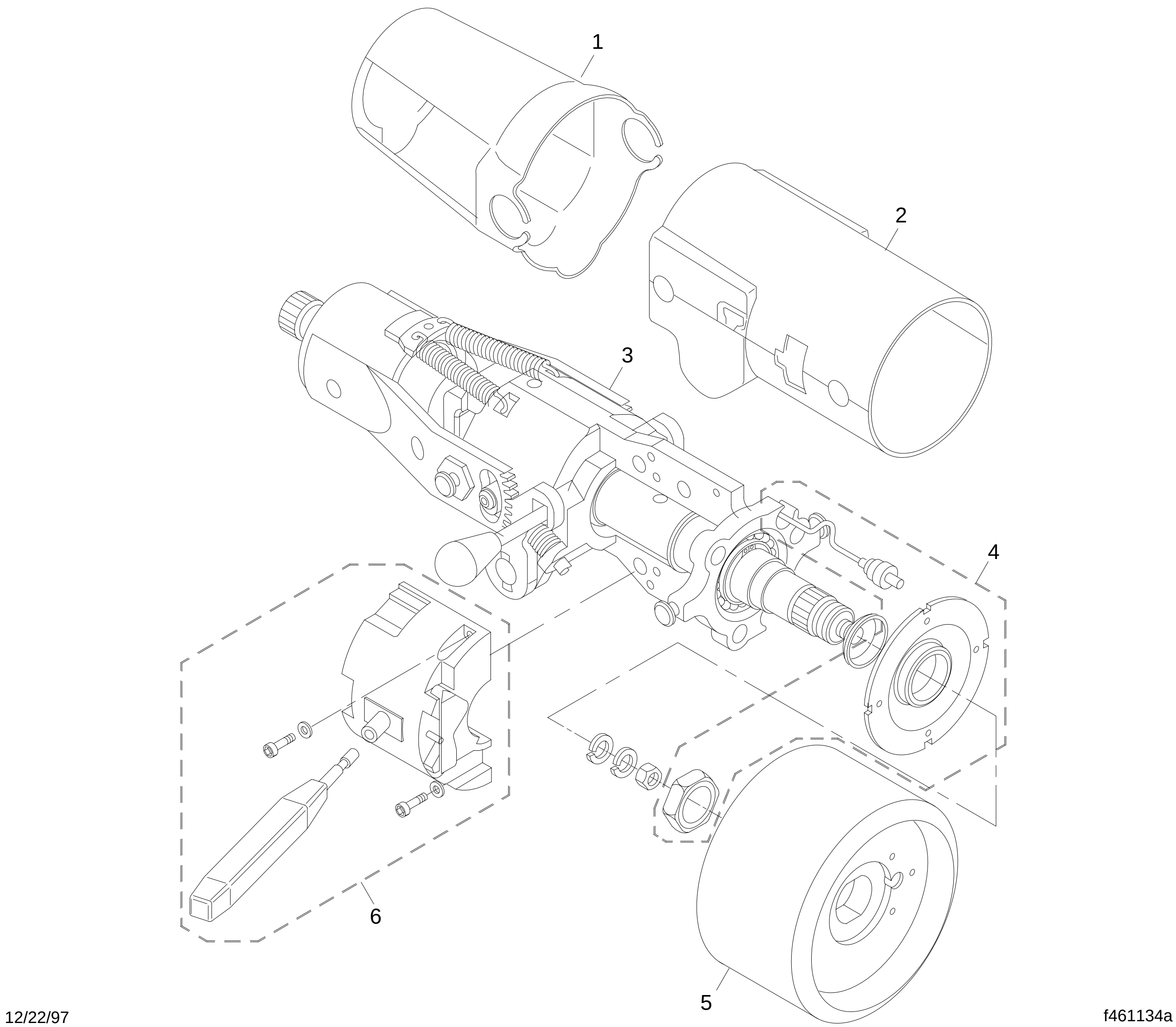
Torque Values	
Nut Size	**Torque lbf·ft (N·m)**
3/4–16	90–170 (122–230)
7/8–14	160–300 (217–407)

Table 1, Torque Values

General Description

To change the position of the steering wheel, pull the lever upward and move the steering wheel to the desired position. Release the lever to lock. The steering wheel can also be tilted up to provide easier exit and re-entry. See **Fig. 1** and **Fig. 2**.

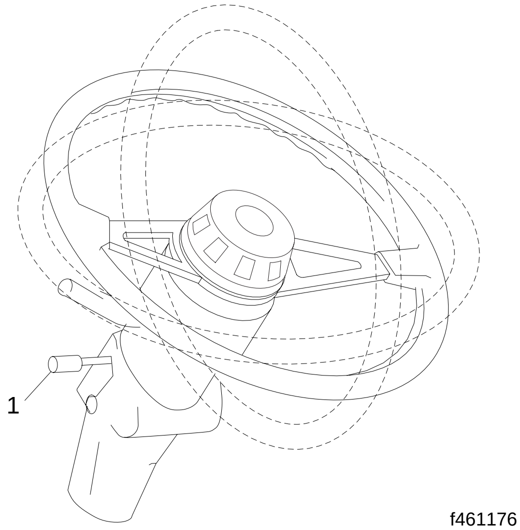
If the vehicle is equipped with a telescoping steering column, push the lever down and extend or retract the steering column as desired.



1. Trough Cover
2. Upper/Lower Cover
3. Steering Column Core
4. Horn Brush Kit
5. Gap Hider Collar
6. Turn Signal Kit

Fig. 1, Tilt Steering Column Assembly

General Information

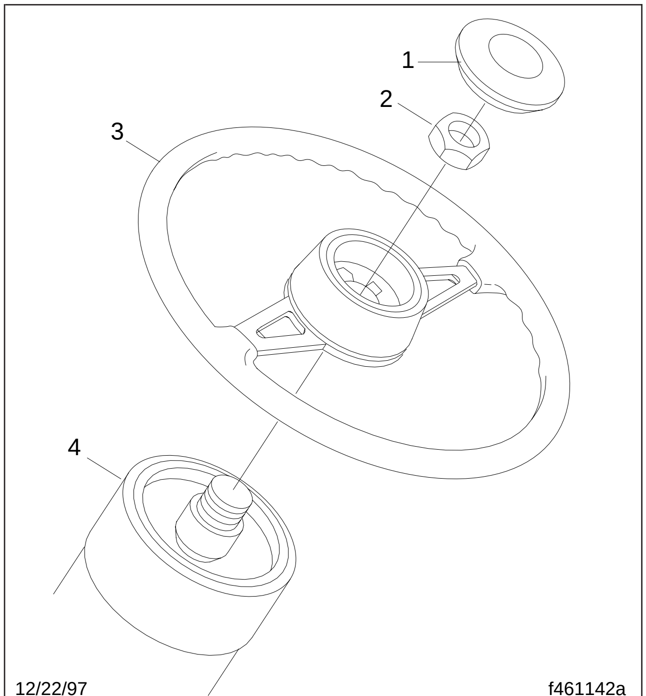


1. Tilt/Telescope Lever

Fig. 2, Tilt/Telescoping Steering Column

Steering Wheel Removal and Installation

Removal



1. Horn Button
2. Steering Wheel Nut
3. Steering Wheel
4. Steering Column

Fig. 1, Steering Wheel Assembly

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**.
5. Using a deep socket to avoid damaging the wires, remove the steering wheel nut.
6. Using a steering wheel puller, remove the steering wheel from the steering column.

Installation

1. Make sure the front tires are pointed straight ahead and the steering gear is centered.
2. Put the steering wheel on the steering column so that the spokes are within 10 degrees of the 3 o'clock and 9 o'clock positions.
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.

5. Install the horn button in the steering wheel hub so the logo on it is aligned with the steering wheel spokes. See **Fig. 2**.

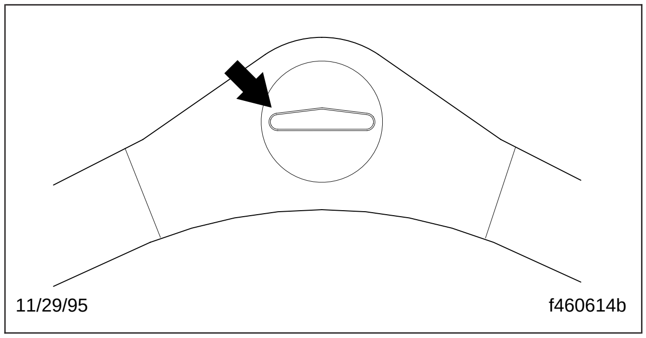


Fig. 2, Align the Logo

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 Removal and Installation

Removal

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. Apply the parking brakes, and chock the tires.
3. Press the column tilt switch and allow the column to move to the neutral (center) position.
4. Remove the steering wheel. For Instructions, see **Subject 100**.
5. Remove the trough cover and the upper/lower cover.
6. Remove and discard the pinch bolt and nut from the steering driveline yoke at the lower end of the steering column.
7. Disconnect the steering column from the steering driveline U-joint yoke.
8. Remove the four 9/16-inch capscrews that secure the column to its mounting bracket.
9. Remove the steering column from the vehicle.

Installation

1. Position the steering column in its mounting bracket. Install the four capscrews and tighten them 146 lbf·ft (198 N·m).
2. Slide the upper steering driveline yoke onto the column shaft, then 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 a new pinch-bolt nut, and tighten it 37 lbf·ft (50 N·m).
3. Install the trough cover and the upper/lower cover.
4. Install the steering wheel. For instructions, refer to **Subject 100**.
5. Remove the tire chocks. Test drive the vehicle and make sure that the steering column assembly operates smoothly; if not, repeat the service operations.

Specifications

Torque Values	
Description	**Torque lbf·ft (N·m)**
Steering Column Mounting Capscrews	146 (198)
Steering Wheel Nut	60 (81)
Steering Driveline Pinch Bolt	37 (50)

Table 1, Torque Values

General Description

The Ross TAS55, TAS65 and TAS85 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 TAS55 is for front axle capacities up to 12,000 lbs (5448 kg), and the TAS65 is for front axle capacities up to 14,300 lbs (6500 kg). The TAS85 is for front axle capacities up to 18,000 lbs (8200 kg).

Both 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 TAS55 needs 2.6 gpm (9.8 Lpm), the TAS65 needs 3.0 gpm (11.4 Lpm), and the TAS85 needs 3.6 gpm (13.6 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**, Ref. 16. The sector shaft swings the pitman arm. The pitman arm pulls or pushes the drag link, and the drag link moves the axle steering arm, steering the vehicle.

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 wormshaft. See **Fig. 2**, Ref. 8. The outside end of the torsion bar is fastened to the input shaft, and the inside end is fastened to the wormshaft; 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.

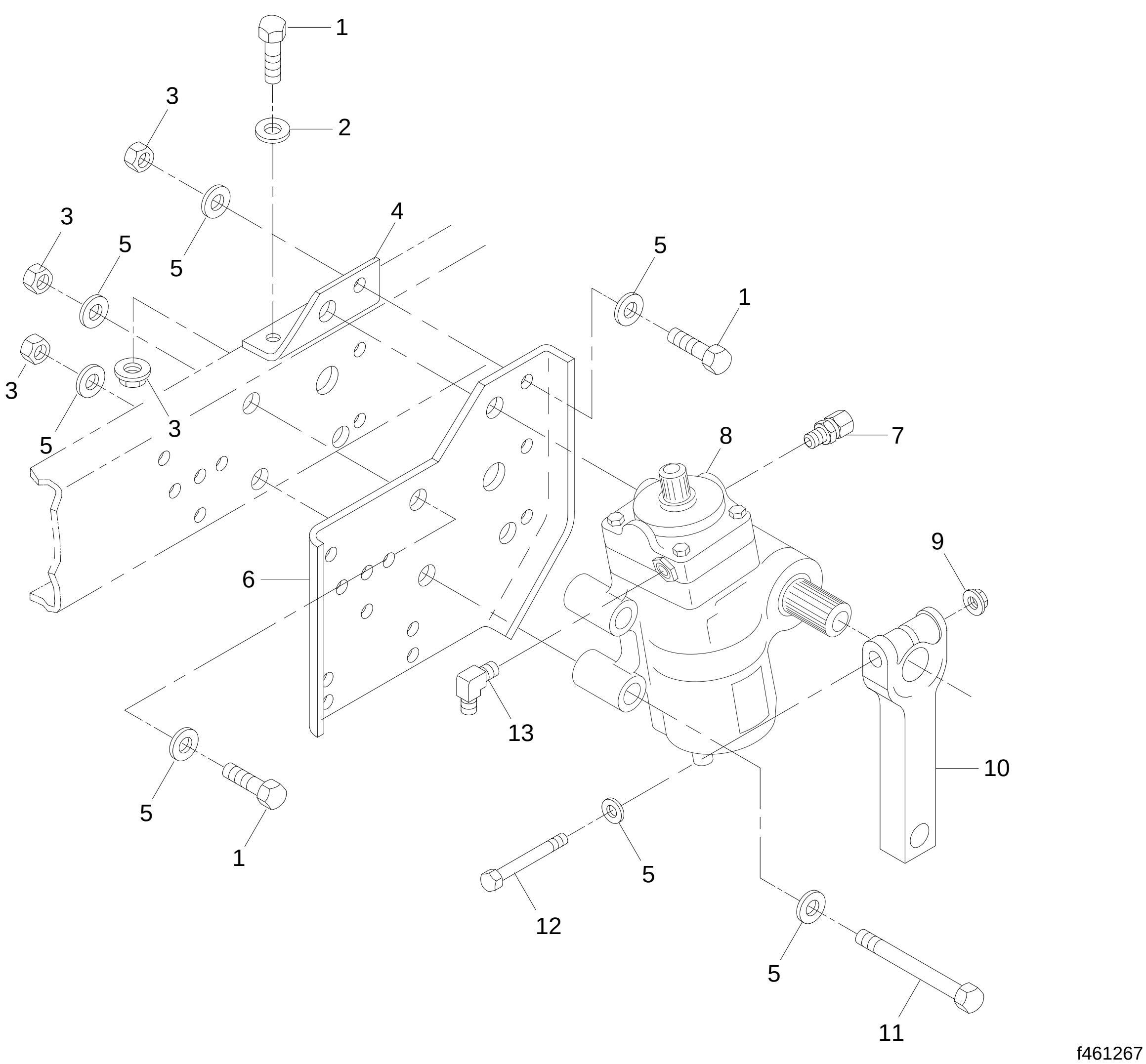
The torsion bar controls the hydraulic fluid. As the driver turns the steering wheel to turn the input shaft, and the front wheels resist turning and hold the rack piston and worm shaft in place, the torsion bar connecting the input shaft and worm shaft twists slightly. That twisting aligns holes in the hydraulic control valve with channels that carry hydraulic fluid. See **Fig. 2**, Ref. 9. 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**, Ref. 3.

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 transmit the shock to the rack piston, but the power steering fluid helps to hold the piston in place and

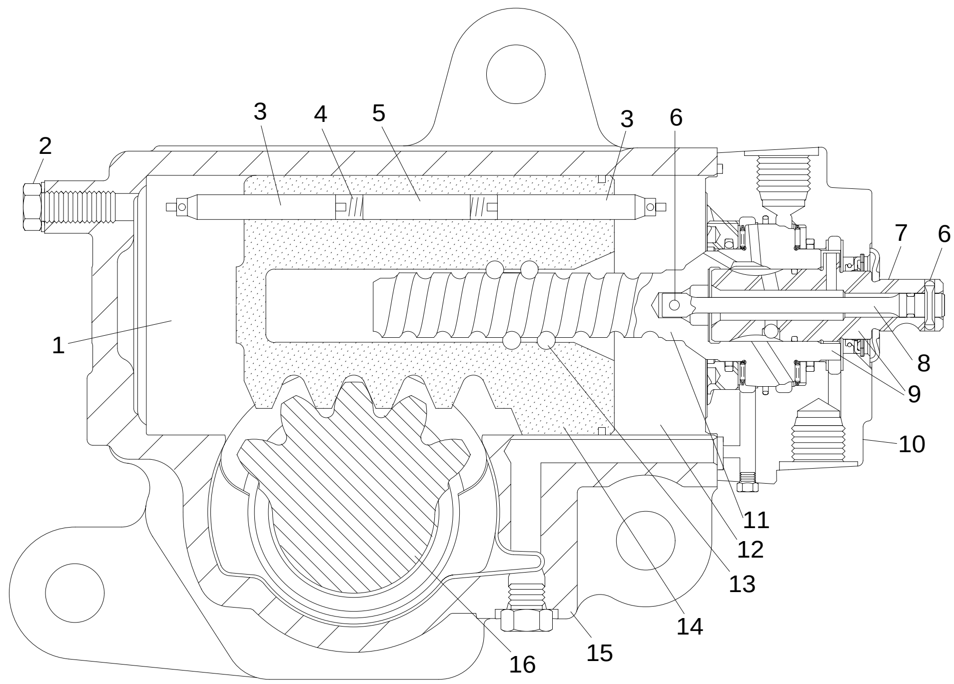
General Information



1. Capscrew, 1/2–13, Grade 8
2. Washer, 1/2 x 1.06
3. Hexnut, 1/2–13
4. Steering Gear Angle Bracket
5. Washer
6. Steering Gear Mounting Plate
7. Straight Fitting
8. Steering Gear
9. Locknut, 3/4–16
10. Pitman Arm
11. Capscrew, 7/8–14, Grade 8
12. Capscrew, 3/4–16, Grade 8
13. 90-Degree Elbow Fitting

Fig. 1, Power Steering Gear Installation

dampen the shock before it can move up the worm shaft to the steering driveline and the steering wheel.

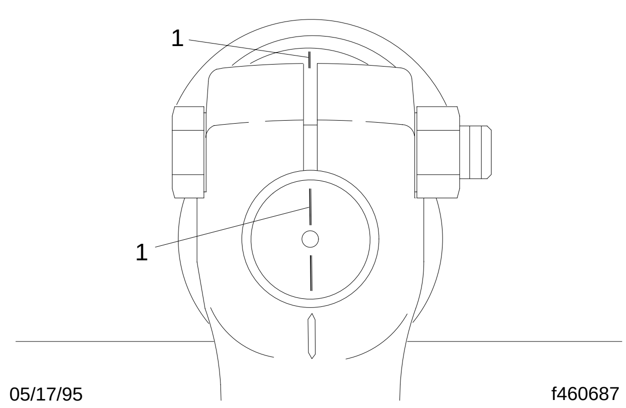


1. Lower Cylinder Cavity
2. Poppet Fixed Stopscrew
3. Poppet Assembly
4. Poppet Spring
5. Push Tube
6. Pin
7. Input Shaft
8. Torsion Bar
9. Control Valve
10. Valve Housing
11. Worm Shaft
12. Upper Cylinder Cavity
13. Ball (recirculating)
14. Rack Piston
15. Gear Housing
16. Sector Shaft

Fig. 2, Steering Gear Sectional 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, Position the Sector Shaft

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).

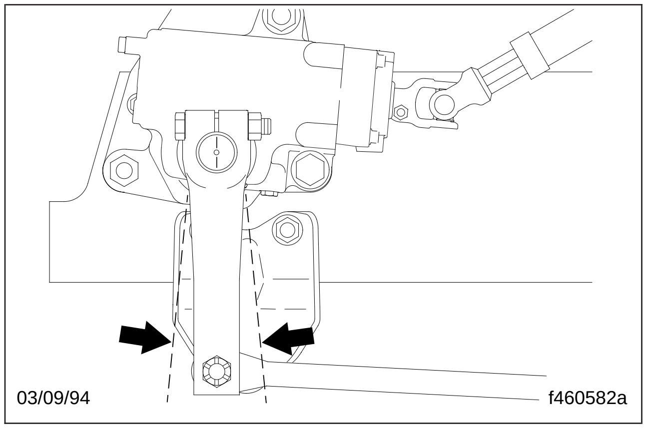


Fig. 2, Checking Sector Shaft Free-Play

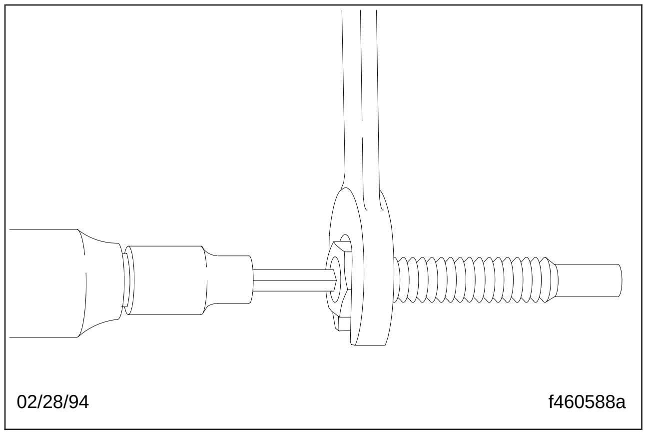


Fig. 3, Screw in the Poppet Adjusting Screw

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.

Poppet Valves Adjustment

TAS55, TAS65 and TAS85 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, the steering gear is centered. See **Fig. 1**.

   3.3 Using an allen wrench turn the adjusting screw and nut without rotat-ing the nut, into the steering gear housing until the nut is firmly against the housing. Tighten the nut 33 to 37 lbf·ft (45 to 50 N·m). See **Fig. 5**.

   NOTE: It may be necessary to move the sector shaft slightly from the "straight-ahead

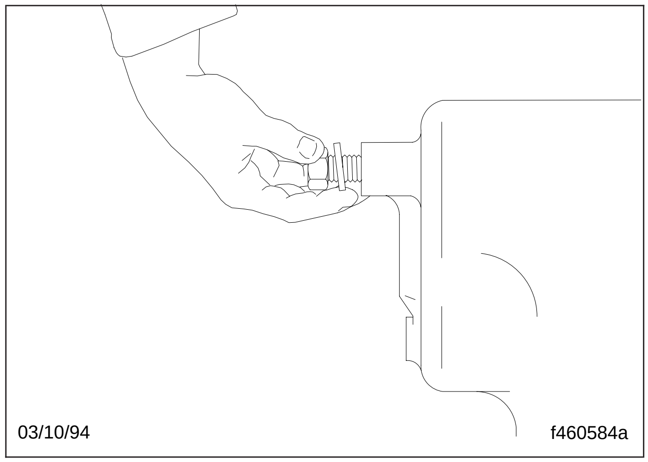


Fig. 4, Remove the Poppet Fixed Stopscrew and Washer

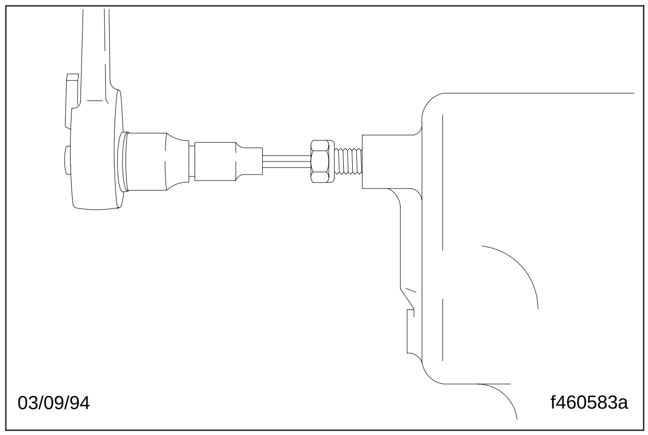


Fig. 5, Turn the Adjusting Screw

position" to assemble the service adjusting screw as instructed and then return it to "straight ahead."

4. Adjust the poppets manually.

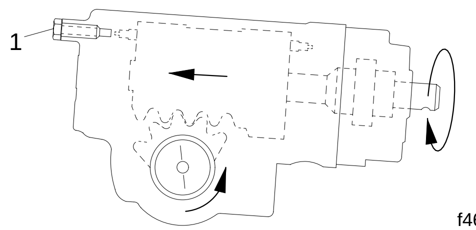
   4.1 Check the fluid level and fill the power steering reservoir with Dexron II type ATF if required.

   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**.



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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).

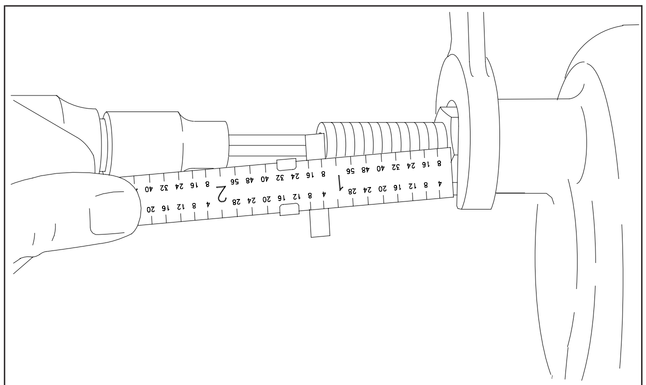

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Fig. 7, Back Out the Adjusting Screw and Measure

IMPORTANT: Make sure the adjusting screw does not protrude more than 1-1/16 inches (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 (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**.

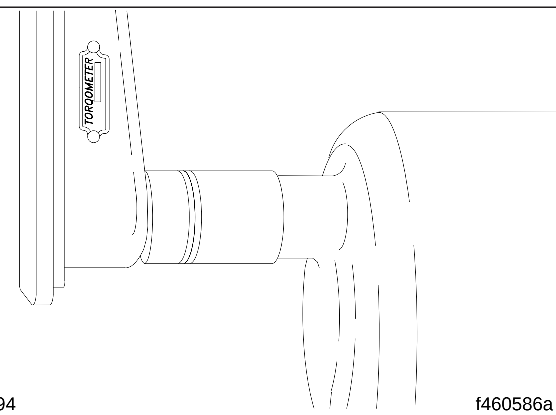

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Fig. 8, Tightening the Sealing Nut

WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in serious personal injury or property damage.

IMPORTANT: Once the poppet adjusting screw and sealing nut are in place and the poppet valves have been manually adjusted, the adjustment procedure must be repeated if steering travel is either increased or decreased in the future.

Removal

IMPORTANT: Before removing the steering gear, see **Section 46.06, Subject 300** to identify the problem.

1. Verify correct axle stop adjustment. For instructions, refer to **Group 33** in this manual. Ensuring correct axle stop adjustment now will eliminate the possibility of resetting steering gear poppet valves after the gear is reinstalled.
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. See **Fig. 1**.
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 TAS55 weights 60 lb (27 kg) dry, the TAS65 weights 80 lb (36 kg) dry, and the TAS85 weighs 110 lb (50 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 TAS55 weights 60 lb (27 kg) dry, the TAS65 weights 80 lb (36 kg) dry, and the TAS85 weighs 110 lb (50 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. 1**.

   Tighten the fasteners to the torque shown in **Table 1**.

Torque		
Description	**Bolt or Nut Size**	**Torque lbf·ft (N·m)**
Steering Gear Mounting Hexbolt Nut	7/8–14	278–352 (377–477)

Table 1, Torque

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.
3. Install the pitman arm.

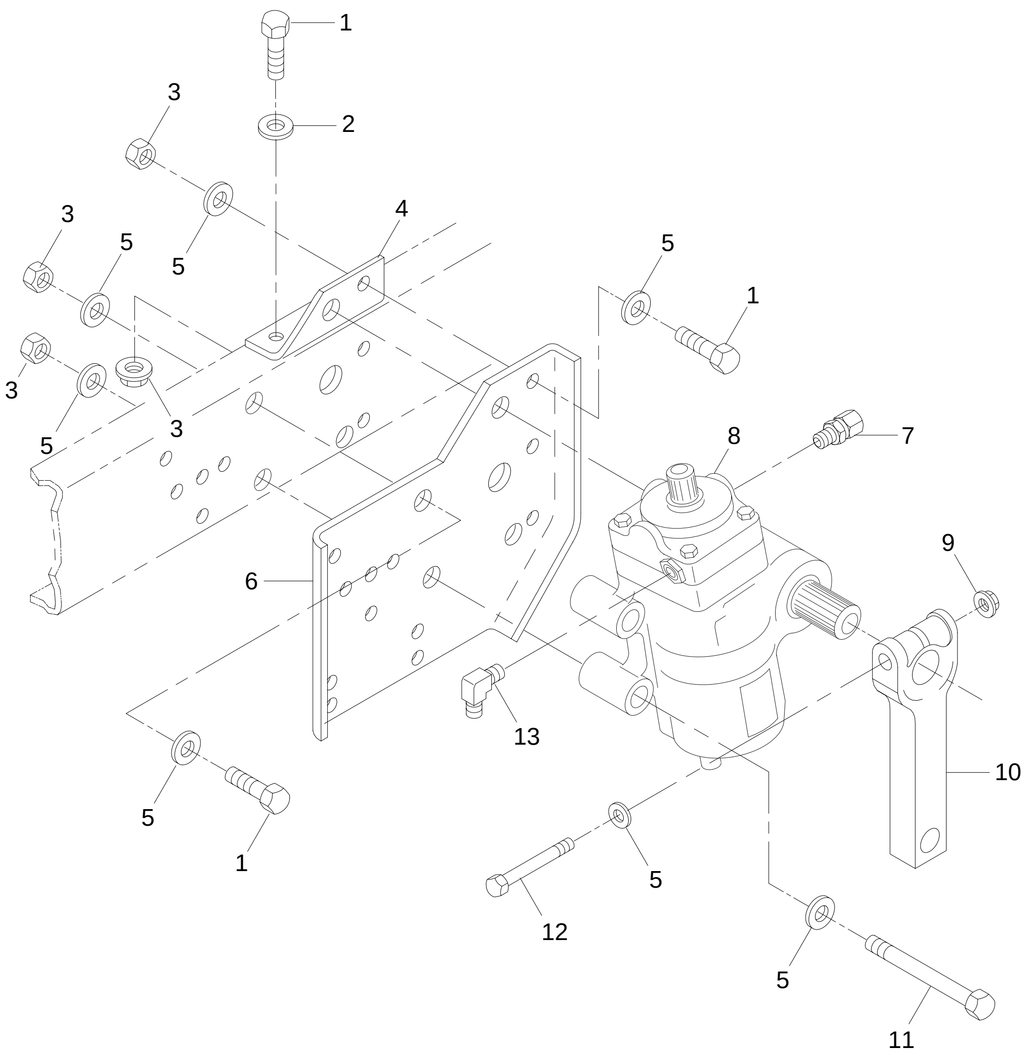
   3.1 Position the pitman arm on the steering gear, aligning the timing mark as shown in **Fig. 2**.

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 sectorshaft without spreading the slot in the arm. Use a ball-peen hammer to drive a chisel into the slot. Hold the chisel

Steering Gear Removal and Installation



1. Capscrew, 1/2–13, Grade 8
2. Washer, 1/2 x 1.06
3. Hexnut, 1/2–13
4. Steering Gear Angle Bracket
5. Washer
6. Steering Gear Mounting Plate
7. Straight Fitting
8. Steering Gear
9. Locknut, 3/4–16
10. Pitman Arm
11. Capscrew, 7/8–14, Grade 8
12. Capscrew, 3/4–16, Grade 8
13. 90-Degree Elbow Fitting

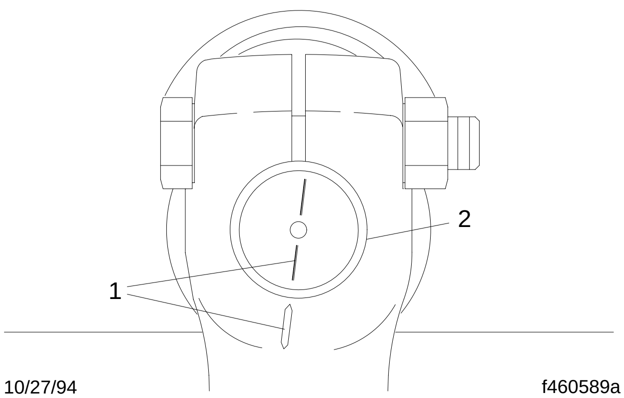
Fig. 1, Power Steering Installation

in place. Install the pitman arm on the sector shaft. Remove the chisel from the slot.

3.2 Install the pitman arm pinch bolt, washer, and a new nut. Tighten the locknut as shown in **Table 2**.

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.



1. Timing Marks
2. Steering Gear Sector Shaft

Fig. 2, Position the Pitman Arm on the Steering Gear

Torque		
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, Torque

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.

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 III 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 the 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 in **Subject 100**.

7. Refer 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 3 o'clock and 9 o'clock positions. If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.

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 to the letter. Failure to do so may result in the 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-dry them only.

Never steam clean or high-pressure wash the hydraulic steering components. Don't 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. Remove sector shaft/side cover assembly.

   4.1 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**.

   4.2 Tape the splines and the bolt groove of the sector shaft, using one layer of masking tape. See **Fig. 5**.

   4.3 Using a 3/4-inch socket, remove the jam nut from the sector shaft adjusting screw. See **Fig. 6**.

   4.4 Put a container under the side cover to catch any drainage, then remove the 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. Don't use a substitute; don't mix different types of bolts.

   4.5 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.
5. Disassemble the sector shaft/side cover assembly.

   5.1 Using a screwdriver, screw the sector shaft adjusting screw into the side cover and remove. See **Fig. 10**.

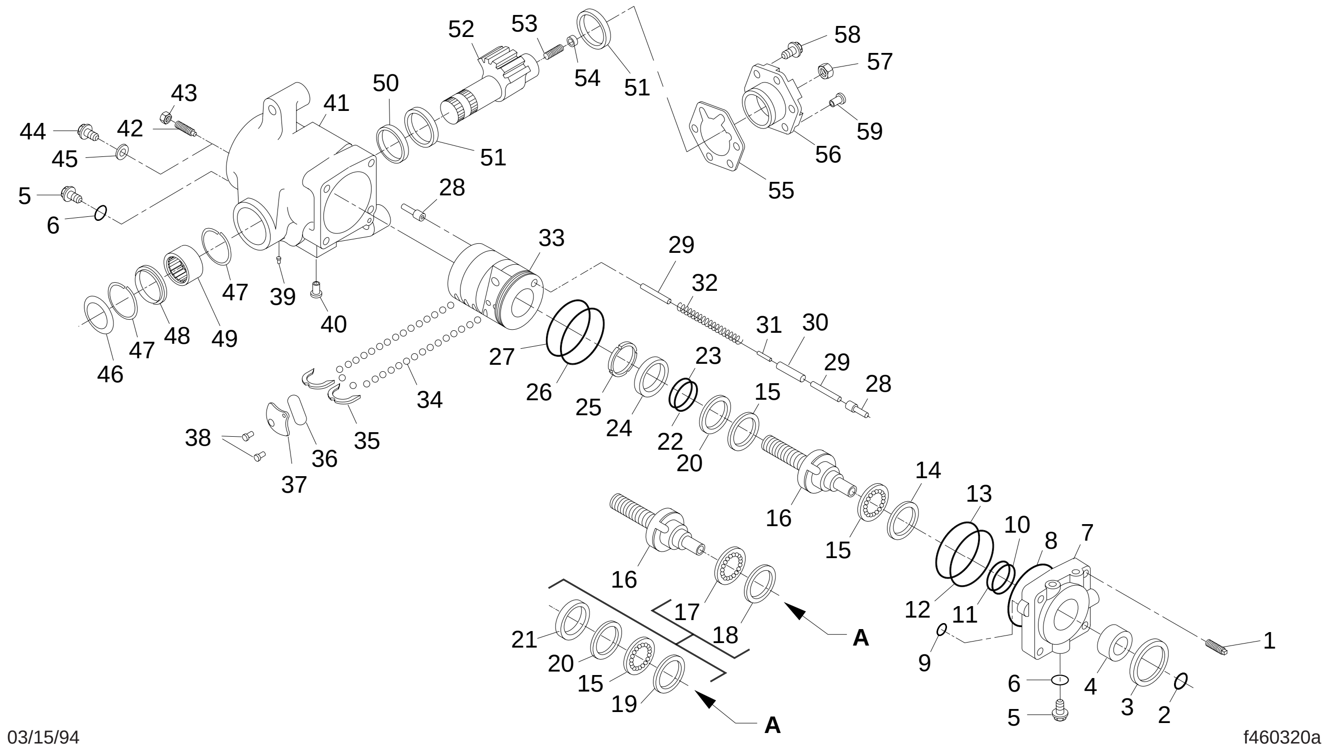
   5.2 Remove the sector shaft from the side cover.

   5.3 Remove the side-cover seal as follows:

   IMPORTANT: Be careful when you are removing the side-cover seal, or you may damage the side-cover bore, the "DU" bushing.

   5.4 Screw a 3-inch, 1/2–20 bolt into the hole in the side cover where the sector shaft adjusting screw was.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



NOTE: The side cover for TAS55 and TAS65 steering gears contains a bushing. The side cover for the TAS85 contains a bearing and is secured with eight special bolts.

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 Ball (32 or 34 qty.)
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 or 8 qty.)
59. Vent Plug, Side Cover

Fig. 1, Ross Steering Gear, Exploded View

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

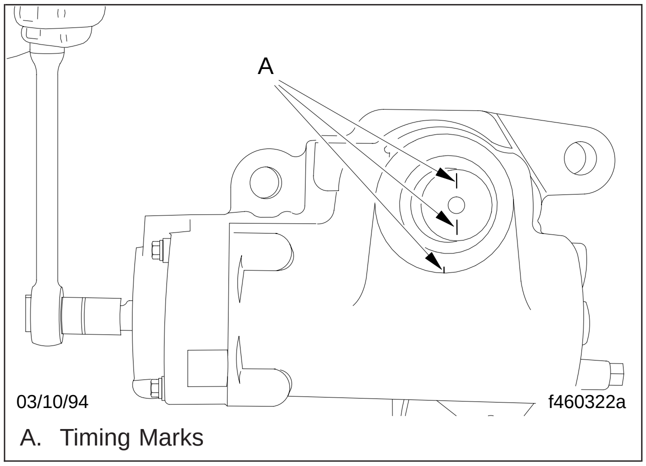


Fig. 2, Line Up the Timing Marks

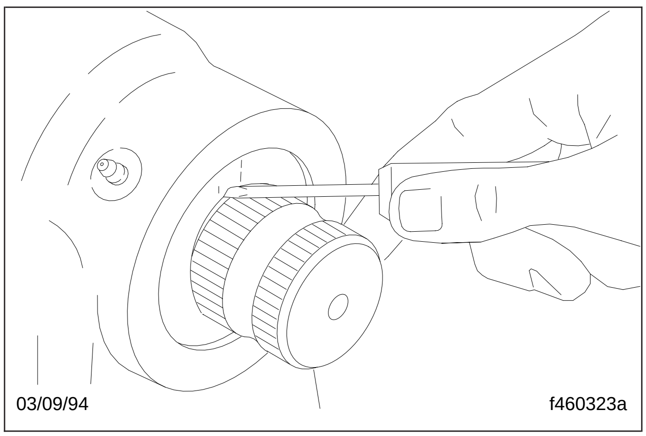


Fig. 3, Remove the Water Seal

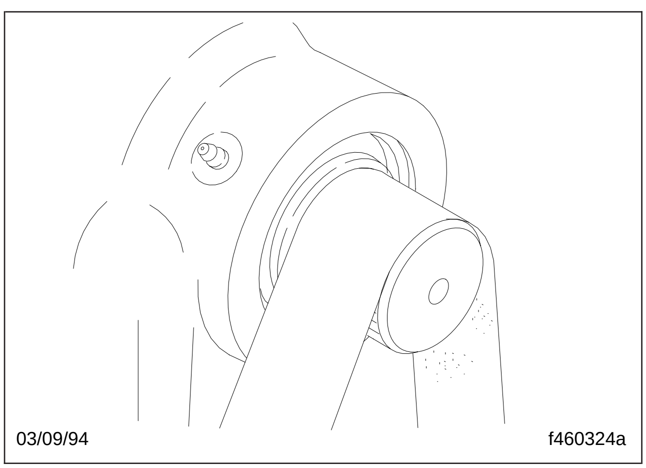


Fig. 4, Remove Dirt, Paint, or Corrosion

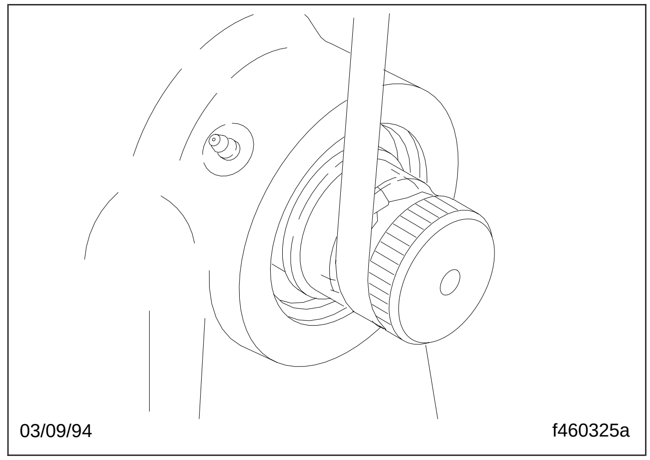


Fig. 5, Tape the Splines

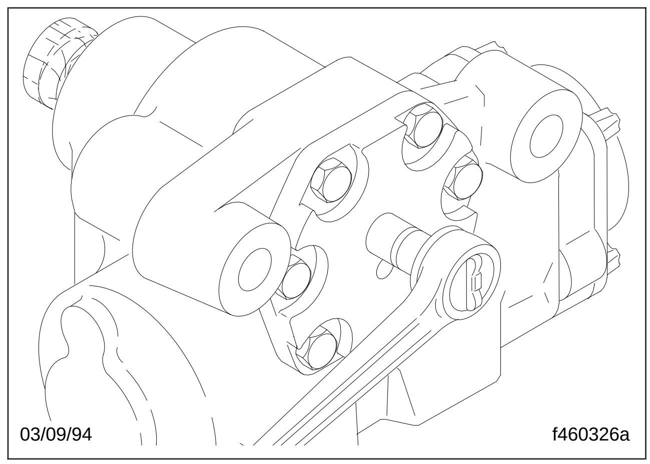


Fig. 6, Remove the Jam Nut

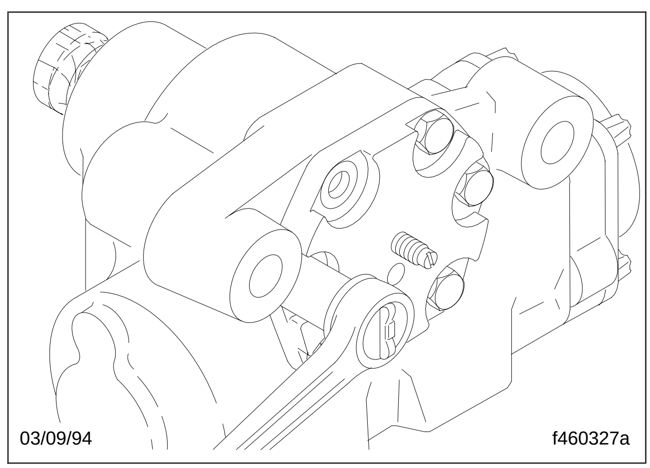
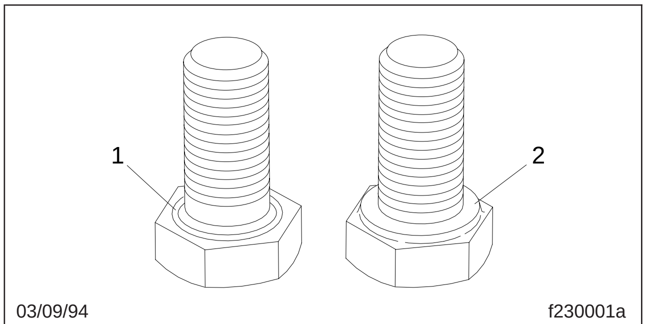


Fig. 7, Remove the Special Bolts

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



1. Ring
2. Washer

Fig. 8, Integral Ring and Washer

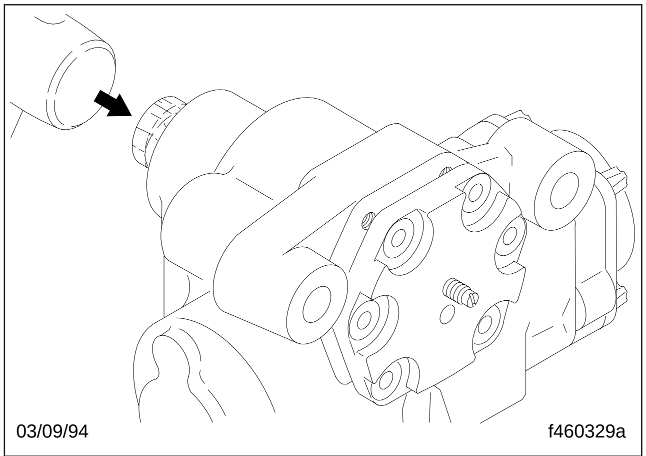


Fig. 9, Remove the Side Cover and Sector Shaft

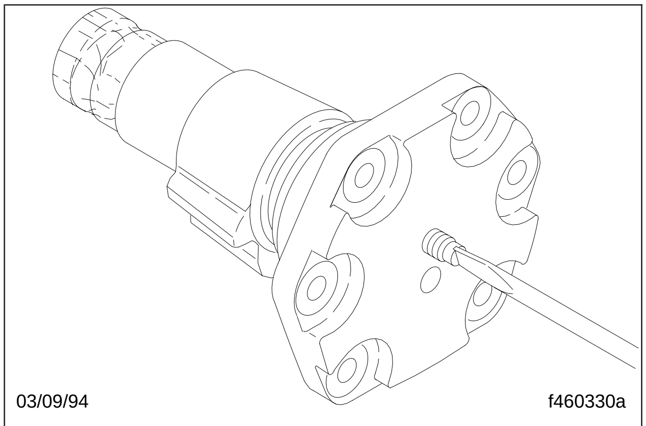


Fig. 10, Screw the Sector Shaft Adjusting Screw into the Side Cover

Make sure the bolt is in far enough so that it will support a rolling head (lady-foot) type pry bar. See **Fig. 11**.

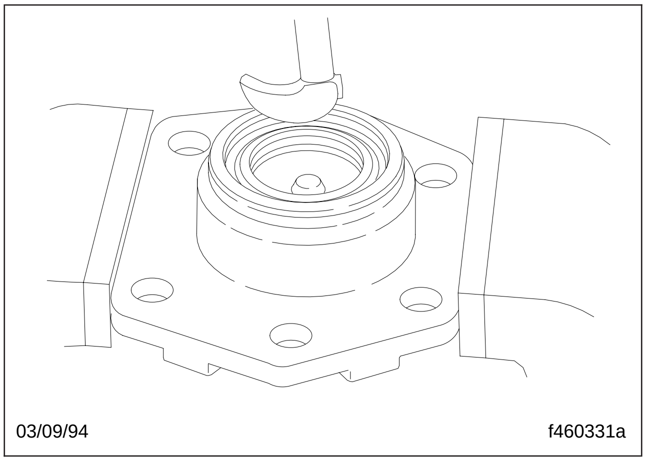


Fig. 11, Check the Bolt for Support

5.5 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.

5.6 Remove and discard the vent plug from the side cover.

6. Remove the adjusting screw if required. Removal is required only if deemed necessary after the inspection procedure.

   6.1 Put the sector shaft in a padded vise and, using a chisel, unstake the adjusting-screw retainer. See **Fig. 12**.

   6.2 Unscrew the retainer; remove it from the sector shaft.

   6.3 Remove the adjusting screw. Discard the retainer.

7. Remove the relief valve components, if equipped: remove the relief valve cap, O-ring, and the two-piece relief valve from the valve housing. Discard the O-ring.

8. Remove the input shaft, valve housing, and rack piston.

   8.1 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**.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

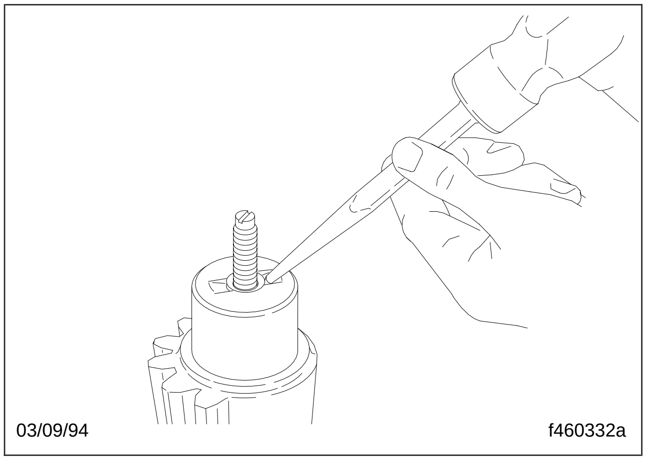


Fig. 12, Unstake the Adjusting-Screw Retainer

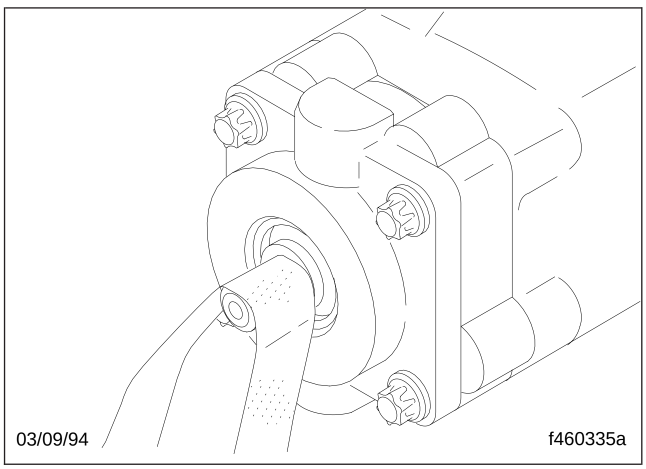


Fig. 13, Clean the Input Shaft

8.2 Using an E–16 Torx® socket wrench, remove the four valve housing bolts. See **Fig. 14**.

8.3 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.

8.4 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

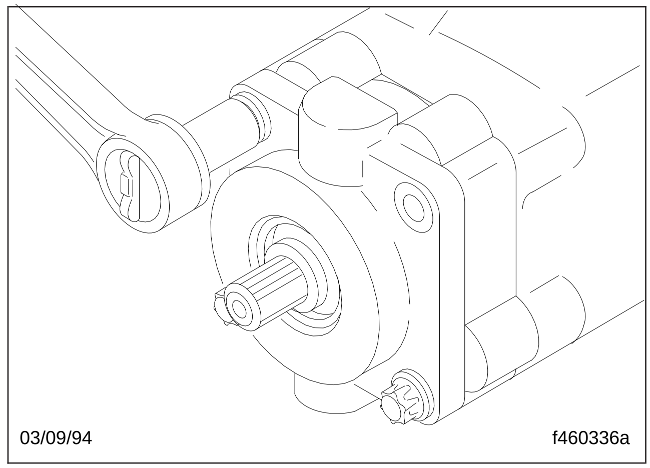


Fig. 14, Remove the Valve Housing Bolts

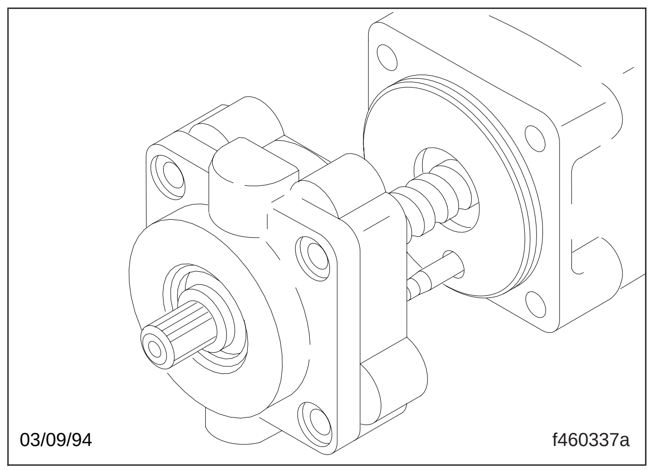


Fig. 15, Remove the Valve Housing

was removed, and note that the poppet valve adjustments are for that particular vehicle.

9. Remove the steel balls.

9.1 Remove the two sealing screws holding the ball return guide cap to the rack piston. See **Fig. 16**.

9.2 Remove the cap and its seal. See **Fig. 17**. Discard the two screws and the seal.

9.3 Remove the ball return guide halves from the rack piston by carefully prying up on them with a screwdriver. See **Fig. 18**.

9.4 Remove the 31 (TAS55), 32 (TAS65), or 34 (TAS85) steel balls from the rack pis-

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

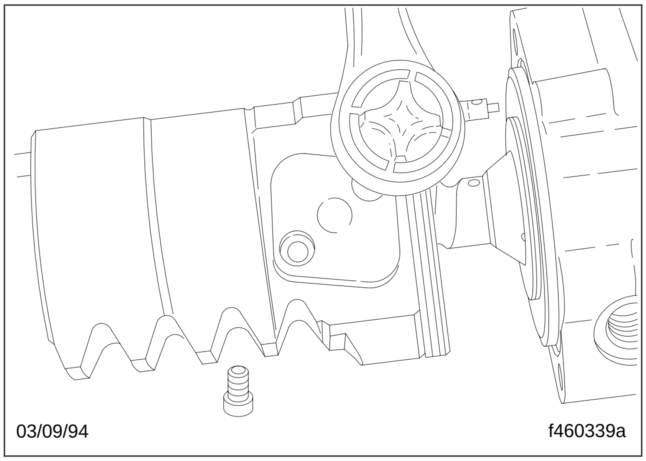


Fig. 16, Remove the Two Sealing Screws

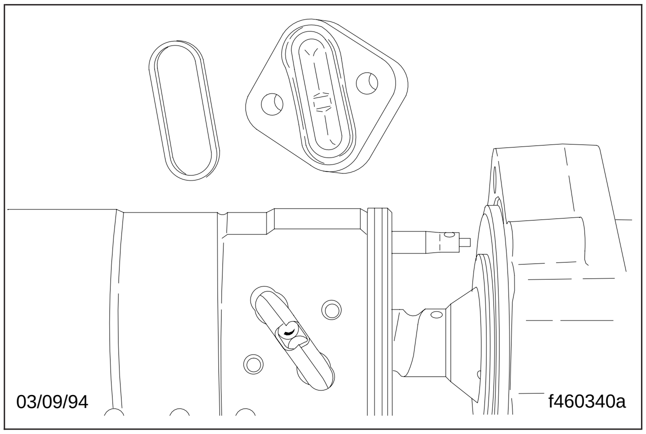


Fig. 17, Remove the Cap and Seal

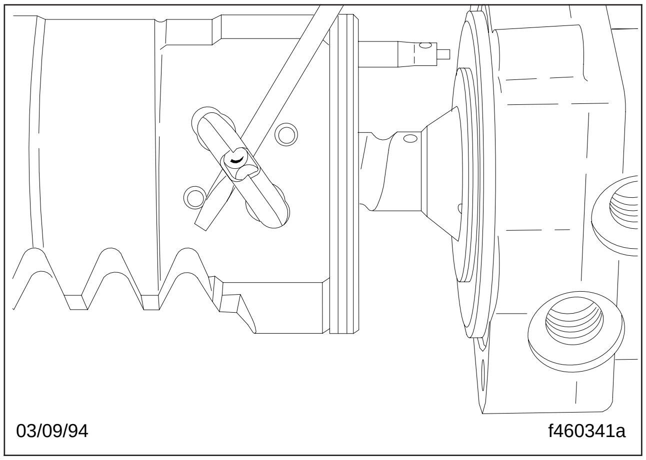


Fig. 18, Remove the Ball Return Guide Halves

ton by turning the worm shaft until all of them are out. See Fig. 19. Don't lose any of these balls, or you will have to replace the entire set.

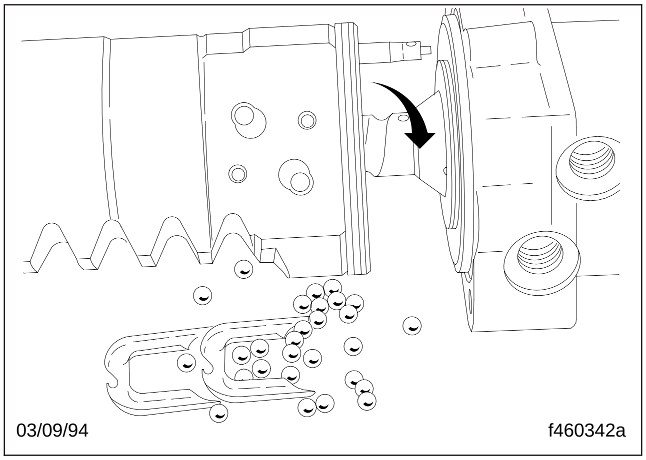


Fig. 19, Remove the Steel Balls

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.

10. Remove the worm shaft and valve housing assembly from the rack piston. See Fig. 20.

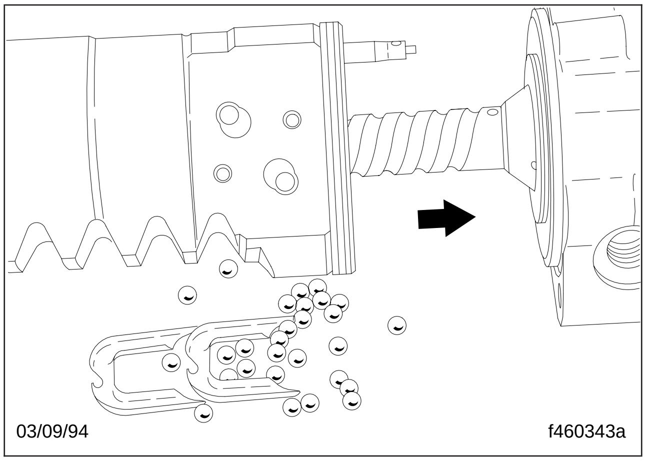


Fig. 20, Remove the Worm Shaft and Valve Housing Assembly

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

11. Cut and remove the Teflon seal ring and the O-ring from the rack piston. See **Fig. 21**.

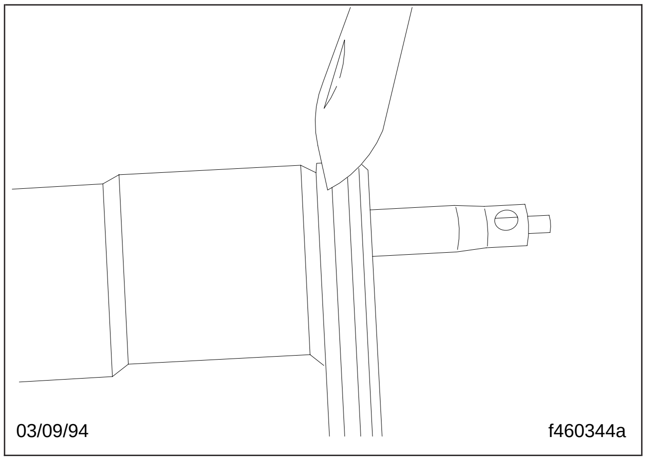


Fig. 21, Cut the Teflon Seal Ring

12. If replacing poppet assemblies, remove the poppet valve assemblies.

CAUTION

The poppet valve assemblies are installed with Loctite®. Be careful when removing them and use only special tool J36452 or J38713 (preferred). 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.

12.1 Put the rack piston in a padded vise.

12.2 Slide the special tool J38713 (preferred) or J36452 over the poppet adjuster seat. See **Fig. 22**. 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. 23**.

12.3 Using a breaker bar, unscrew the adjuster seat and sleeve assemblies from the rack piston. If the assembly will not loosen, hit the end of the tool several more times with a hammer.

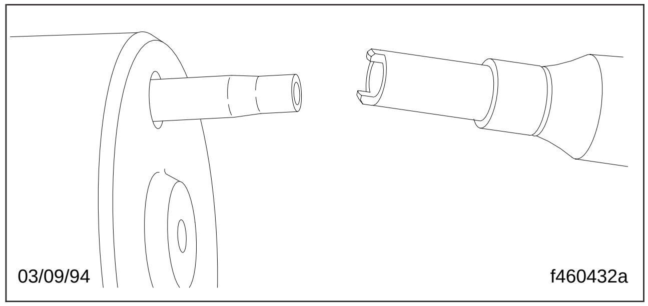


Fig. 22, Slide the Special Tool Over the Poppet Adjuster Seat

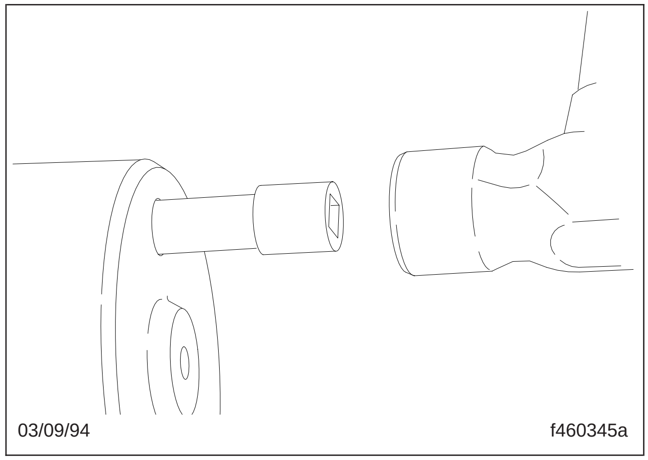


Fig. 23, Hit the End of the Tool with a Hammer

12.4 Remove both poppets, and the spring, spacer rod, and push tube. See **Fig. 24**.

Repeat the above steps for the other poppet adjuster seat and sleeve assembly.

13. Disassemble the valve housing, if needed.

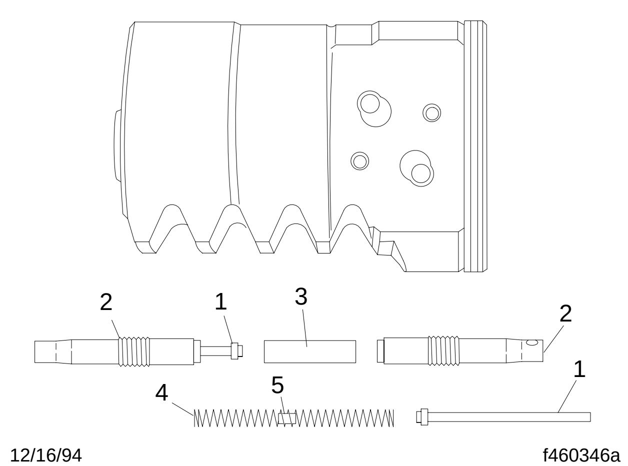
IMPORTANT: Don't disassemble the valve housing unless you find signs of extreme heat, internal leakage, bearing damage or roughness, or if the worm shaft preload adjustment is needed.

13.1 Put the worm shaft and valve housing assembly into a padded vise, with the worm shaft in a vertical position, as shown in **Fig. 25**.

13.2 Unstake the adjuster locknut, using a punch. See **Fig. 25**.

13.3 Using special tools J37464 and J37070 with a breaker bar, unscrew the adjuster

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. 24, Remove the Poppets, Spring, Spacer Rod, and Push Tube

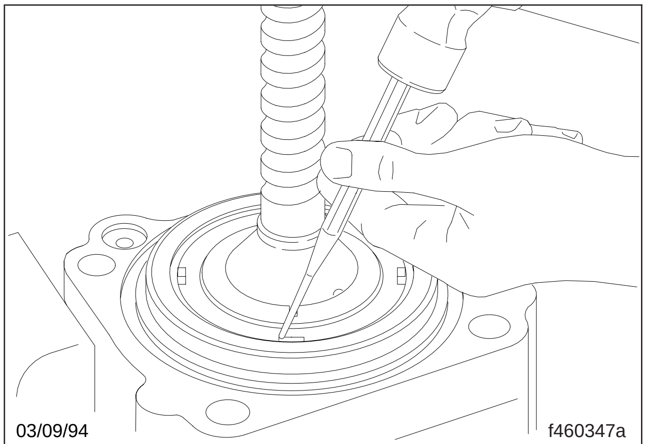


Fig. 25, Unstake the Adjuster Locknut

locknut, then the bearing adjuster from the valve housing. See **Fig. 26**.

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 removing and installing either style of bearing adjuster. See **Fig. 26**.

13.4 Remove and discard the seal ring and the O-ring from the bearing adjuster. See **Fig. 27**.

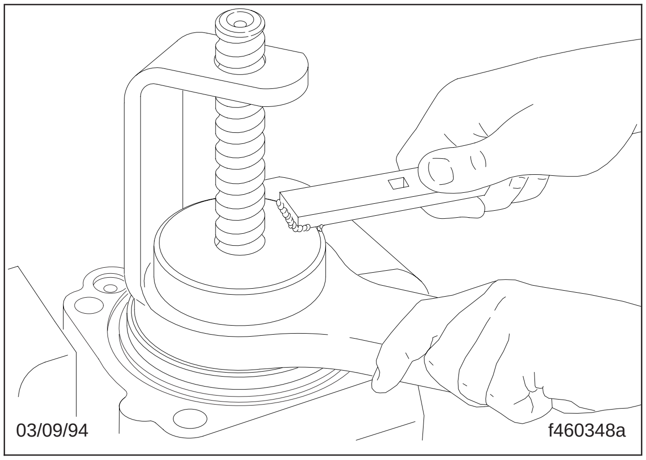


Fig. 26, Unscrew the Adjuster Locknut and Bearing Adjuster

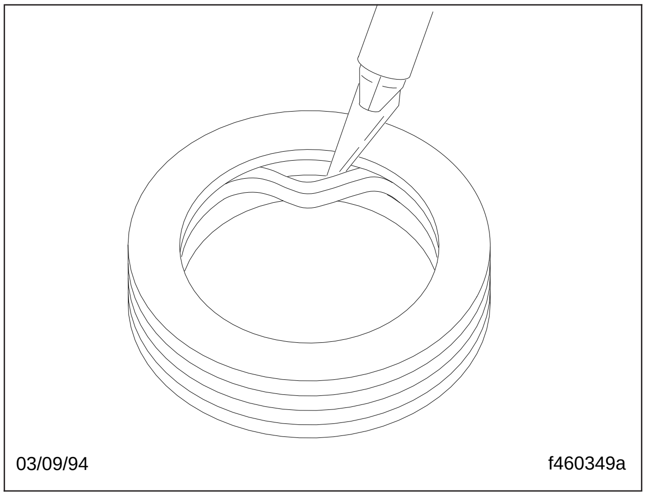


Fig. 27, Remove the Seal Ring and O-Ring

13.5 Remove the thin washer, thrust bearing, input shaft, rotary valve, and worm shaft assembly from the valve housing. See **Fig. 28**.

IMPORTANT: Don’t disassemble the input shaft or worm shaft assembly any further. These aren’t serviceable.

13.6 Remove the roller thrust bearing assembly and the thick thrustwasher from the valve housing. See **Fig. 29**.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

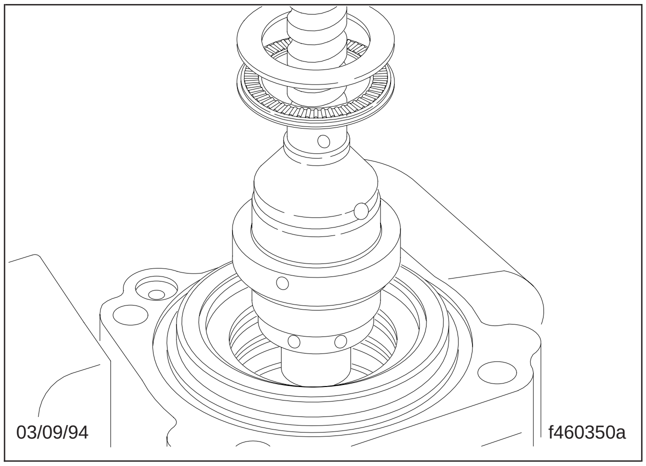


Fig. 28, Remove the Thin Washer, Thrust Bearing, Input Shaft, Rotary Valve, and Worm Shaft Assembly

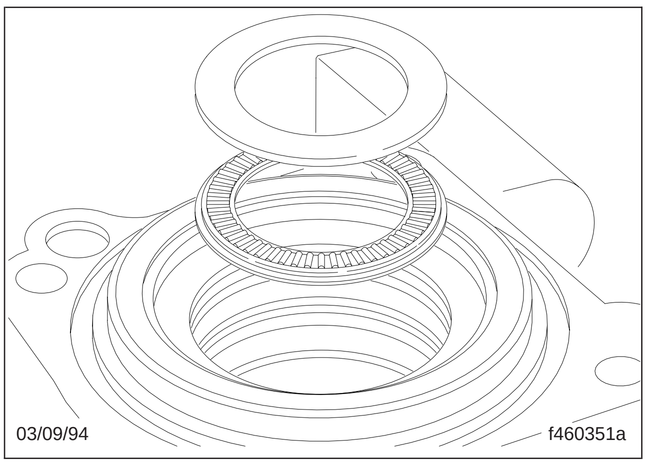


Fig. 29, Remove the Roller Thrust Bearing and Thick Thrustwasher

13.7 Using a small knife, a probe, or a pick, remove and discard the seal rings and O-rings from the valve housing. See **Fig. 30**.

CAUTION

In the next substep, 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.

13.8 Turn the valve housing over, and remove the retaining ring. See **Fig. 31**.

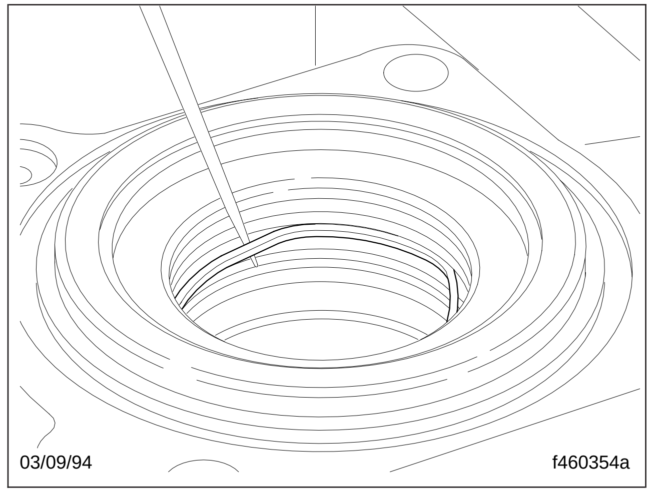


Fig. 30, Remove and Discard the Seal Rings and O-Rings from the Valve Housing

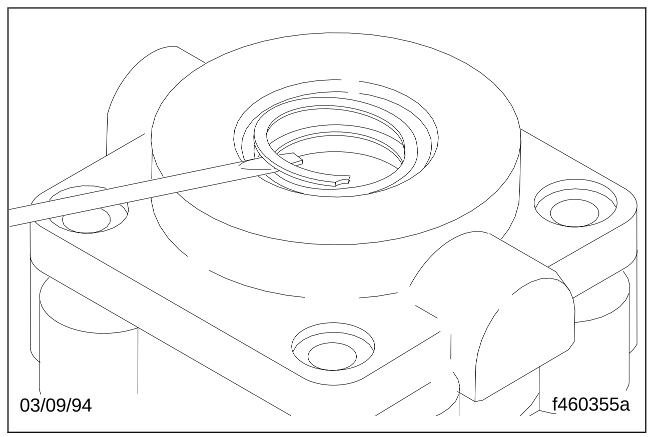


Fig. 31, Remove the Retaining Ring

13.9 Using a 1-1/8 inch socket, tap out the seal from the valve housing. See **Fig. 32**. Discard the seal.

13.10 If replacing either of the auxiliary port plugs, remove them. Be sure to remove and discard the O-rings.

14. Disassemble the housing.

NOTE: The steering gear is equipped with either a poppet fixed stopscrew, or an adjusting screw and sealing nut. See **Fig. 33**.

14.1 If the poppet fixed stopscrew needs replacement, remove it.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

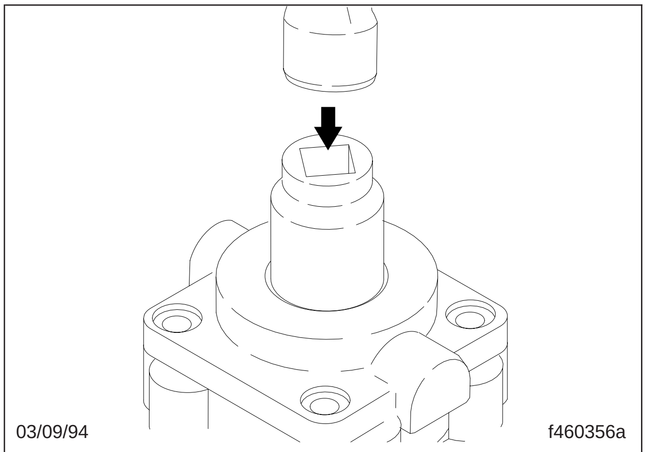
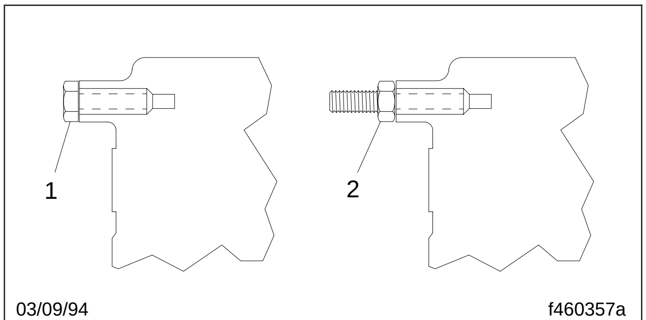


Fig. 32, Tap Out the Seal from the Valve Housing



1. Poppet Fixed Capscrew
2. Adjusting Screw and Sealing Nut

Fig. 33, Gear Equipped with a Poppet Fixed Stopscrew and Adjusting Screw and Sealing Nut

14.2 If the adjusting screw and sealing nut need replacing, remove them.

14.3 Remove the retaining ring from the output end of the housing trunnion. See **Fig. 34**.

14.4 Remove and discard the dirt seal. See **Fig. 35**.

14.5 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. 36**. Be careful not to damage the sealing area of the bore. Discard the seal.

14.6 If replacing the roller bearing in the housing, remove it, using special tool J37071 (TAS55/65) or J38779 (TAS85). Press the roller bearing out of the trunnion end of

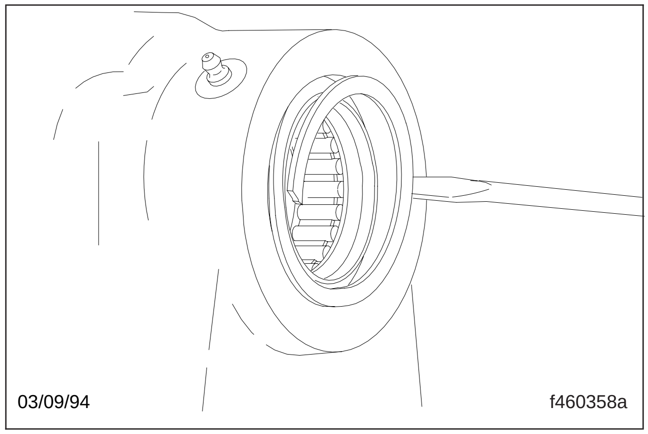


Fig. 34, Remove the Retaining Ring

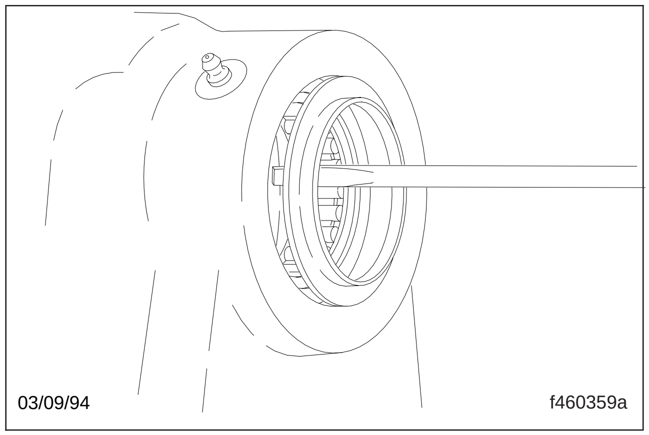


Fig. 35, Remove the Dirt Seal

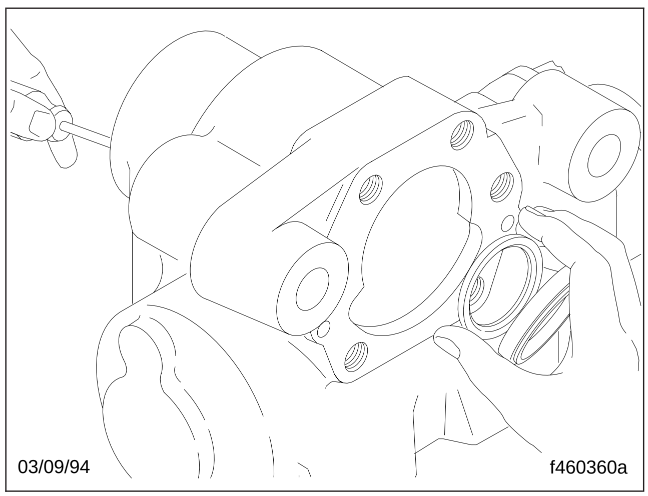


Fig. 36, Push the Seal and the Spacer Washer

the housing, from the side of the bore where the side cover was attached. See **Fig. 37**.

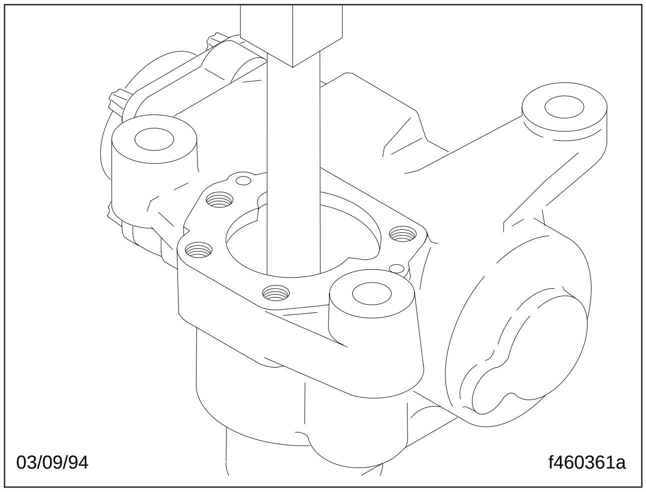


Fig. 37, Press Out the Roller Bearings

CAUTION

Be sure the retaining ring is not damaged when the roller bearing is pressed out.

14.7 If replacing the retaining ring, remove it through the trunnion end, opposite the end where the side cover was attached. See **Fig. 38**. Be careful not to damage the pressure seal bore area.

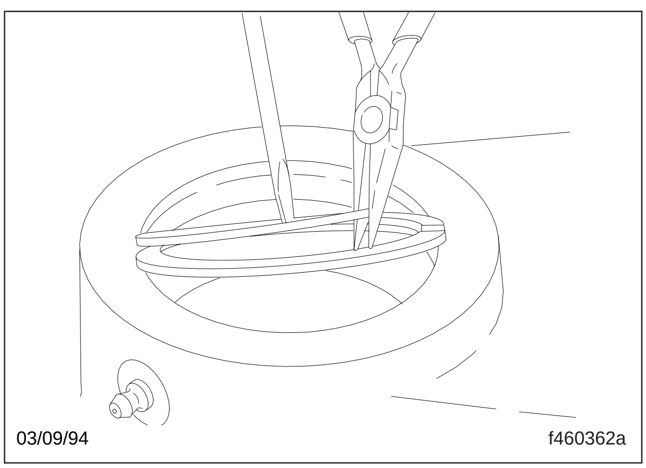


Fig. 38, Remove the Retaining Ring

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-dry them with air.

1. Inspect the rack piston teeth for cracks and wear. See **Fig. 39**. If a step can be detected by running your fingernail horizontally across the teeth surfaces, the rack piston, the sector shaft, and the set of steel balls must be replaced.

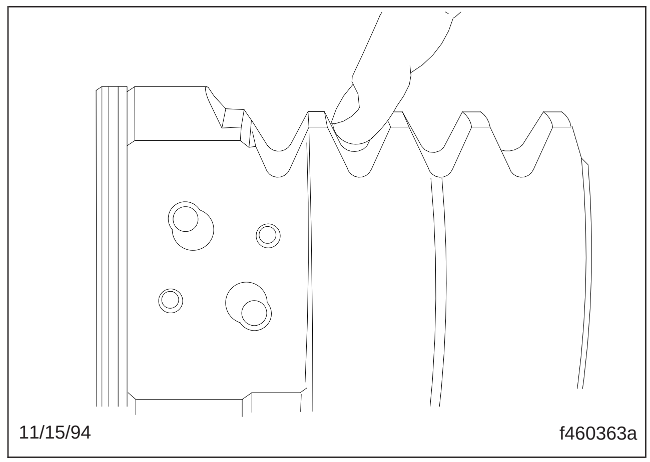


Fig. 39, Inspect the Rack Piston Teeth

2. Inspect the rack piston internal ball-track grooves for brinelling (dents) or spalling (flaking). See **Fig. 40**. If either condition exists, replace the following parts: the rack piston; the valve/worm shaft assembly, and the set of 31 (TAS55), 32 (TAS65), or 34 (TAS85) steel balls.
3. Inspect the worm shaft ball-track grooves for brinelling or spalling. See **Fig. 41**. 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. 42**.
4. Inspect the housing cylinder bore. See **Fig. 43**. Minor scoring marks running lengthwise through the bore are normal, and should not be compared to the scoring that might be found in the

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

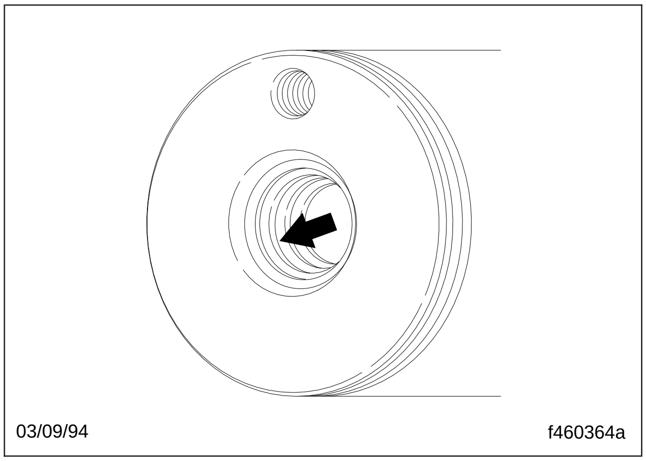


Fig. 40, Inspect the Rack Piston Internal Ball-Track Grooves

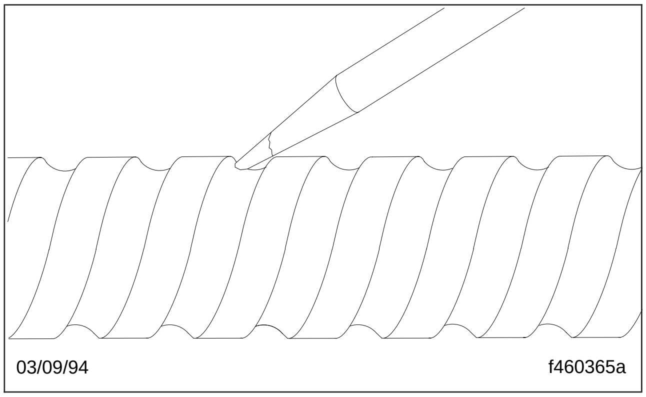


Fig. 41, Inspect the Worm Shaft Ball-Track Grooves

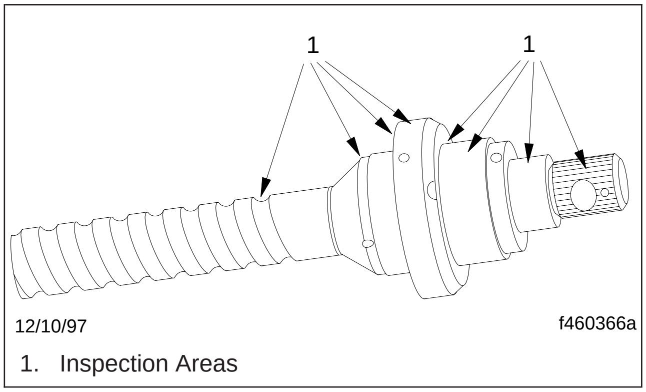


Fig. 42, Inspect the Upper Shaft-Seal Area

cylinder bores of an internal 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 procedure, see **Section 46.06, Subject 300**.

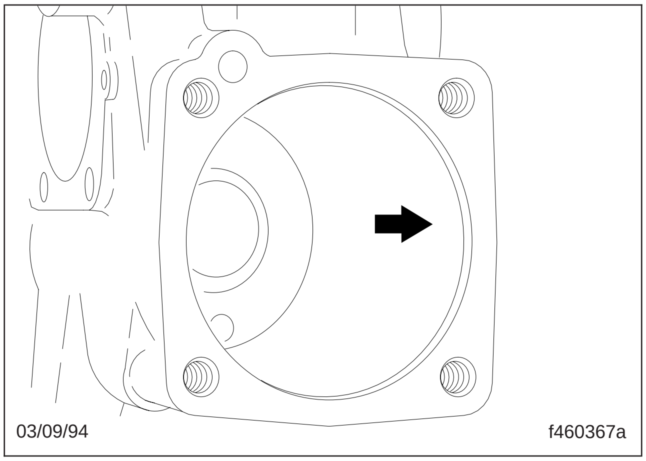


Fig. 43, Inspect the Housing Cylinder Bore

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. 44**. Replace the gear housing if these nicks cannot be easily removed with a fine-toothed flat file, without changing the dimensional characteristics.

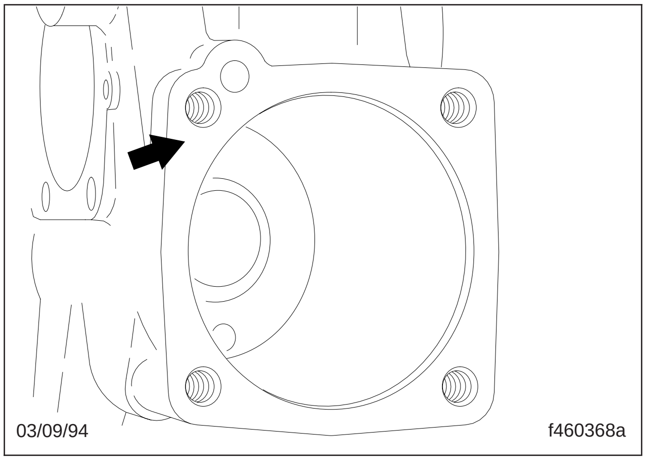


Fig. 44, Inspect the Housing Faces for Nicks

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

6. Inspect the housing roller bearing **Fig. 45** for brinelling or spalling. 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. 46**.

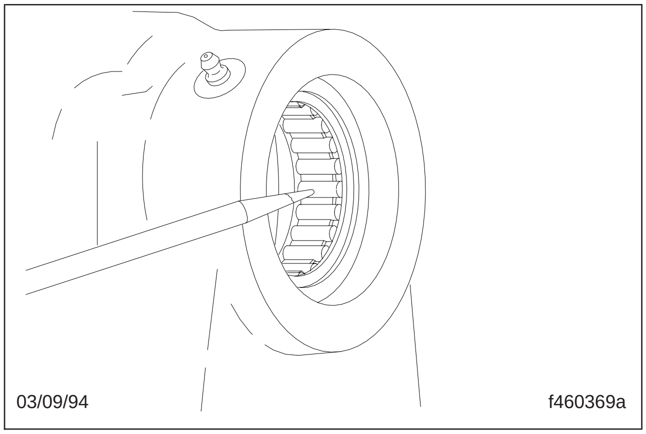


Fig. 45, Inspect the Housing Roller Bearing

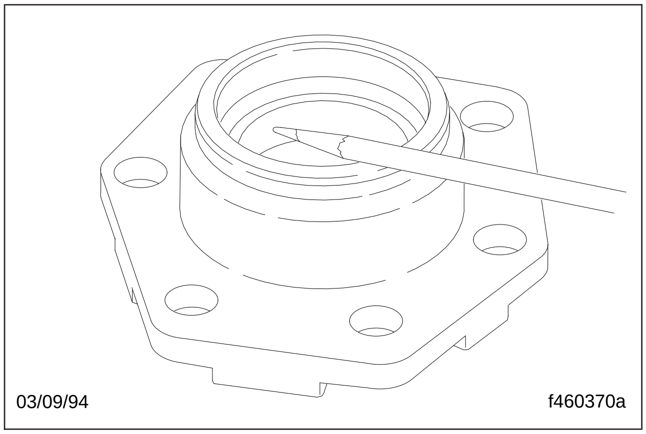
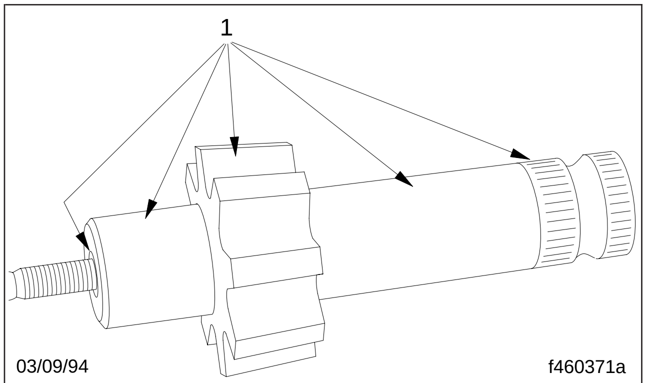


Fig. 46, Inspect the Side Cover Bushing

7. Inspect the sector shaft bearing sealing areas for brinelling or spalling. See **Fig. 47**. 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**, Ref. 48 and Ref. 50. Make sure the adjusting screw retainer is locked in place and has no cracks. The adjusting screw must turn by hand with no end play



1. Inspection Areas

Fig. 47, Inspect the Sector Shaft Bearing Sealing Areas

(lash). If the adjusting screw is damaged, replace it and its retainer.

9. Inspect the thrust bearing rollers for any deterioration. Inspect the thrustwashers for brinelling, spalling, or cracks. See **Fig. 48**. Replace any part if these conditions are detected.

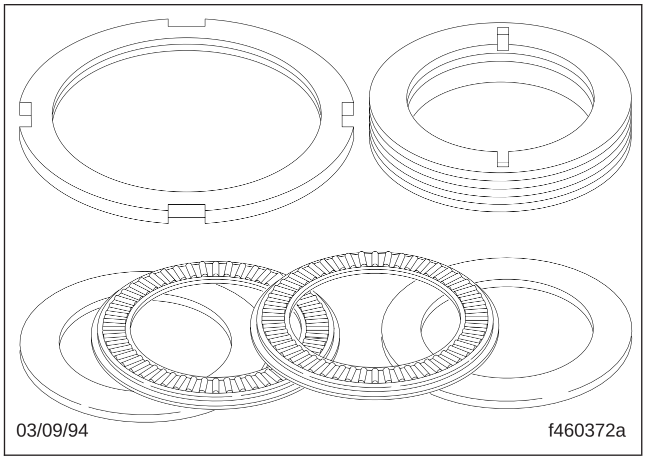


Fig. 48, Inspect the Thrust Bearing Rollers and Thrustwashers

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 parts are available from the Kent-Moore Tool Division, or an affiliated dealer.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

After inspection, clean all parts again in a clean petroleum-based solvent, and blow-dry them 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 required, install a new sector shaft roller bearing; otherwise, go on to the next step.

   1.1 Put the gear housing on its side, with the trunnion end of the bore facing up, as shown in **Fig. 49**.

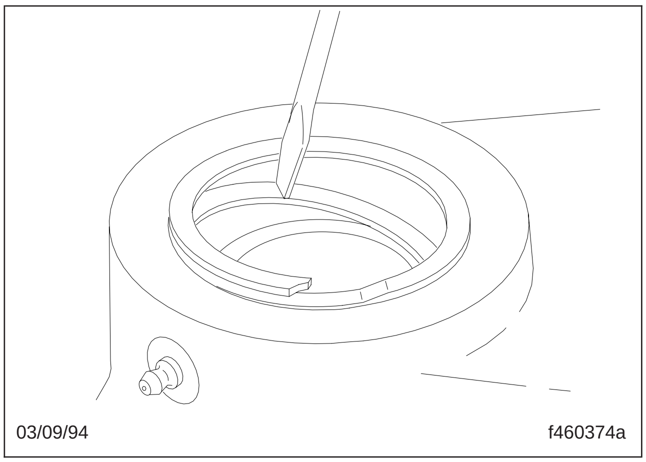


Fig. 49, Put the Gear Housing on its Side

   1.2 Install the retaining ring in the groove closest to the side-cover end of the bore. See **Fig. 49**. 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 J37071 (TAS55/65) or J38779 (TAS85) 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. 50**.

2. Install the sector shaft seals.

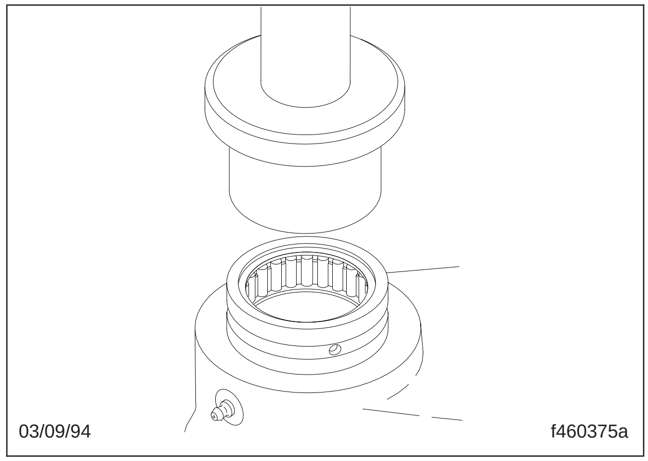


Fig. 50, Press the Roller Bearing into the Housing

   2.1 Put the gear housing on its side, with the side-cover end of the bore facing up, as shown in **Fig. 51**.

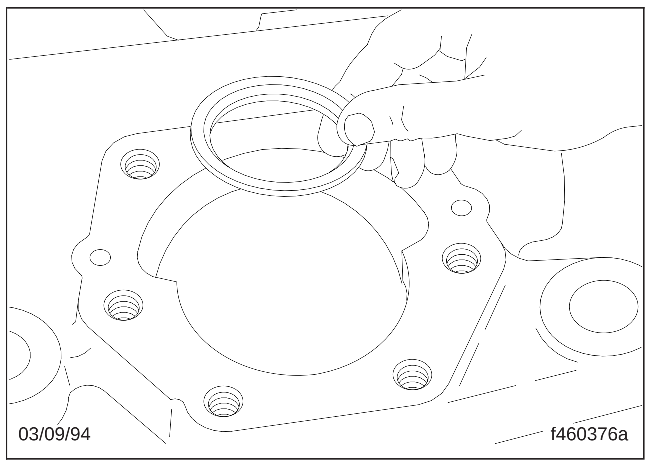


Fig. 51, Put the Gear Housing on its Side (with the side-cover end of the bore facing up)

   2.2 Install the washer in the bore, with the small diameter end of it facing the roller bearing retaining ring. See **Fig. 51**.

   2.3 Put the new seal on special tool so that the lip of the seal with the garter spring is toward the shoulder of the tool. See **Fig. 52**.

   2.4 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).

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

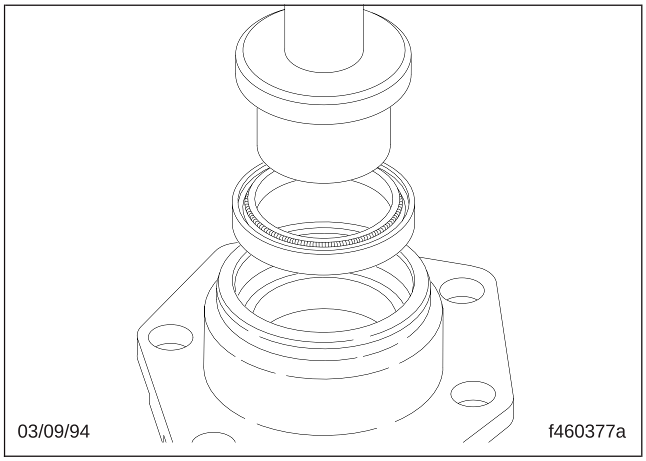


Fig. 52, Put the New Seal on Special Tool

2.5 Turn the gear housing over so that the trunnion end of the bore is up; install the new dirt seal against the roller bearing, with the lip facing up. See **Fig. 53**.

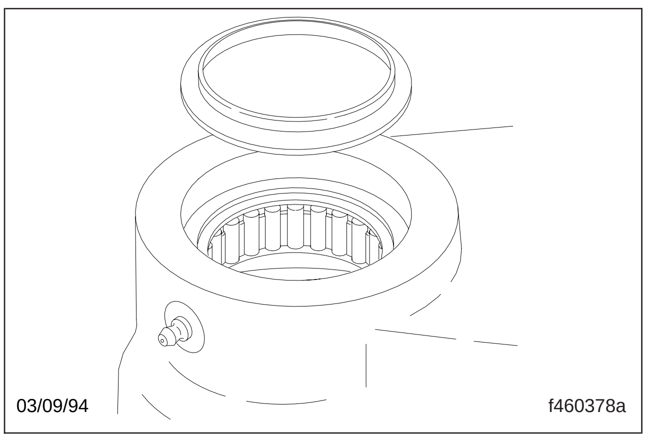


Fig. 53, Install the New Dirt Seal

2.6 Install the second retaining ring, seating it firmly into the groove in the bore. See **Fig. 54**.

2.7 Pack the area between the dirt seal and the pressure seal (including the roller bearing) with Mobil Temp® 1 grease, or equivalent. See **Fig. 55**.

3. Assemble the valve housing.

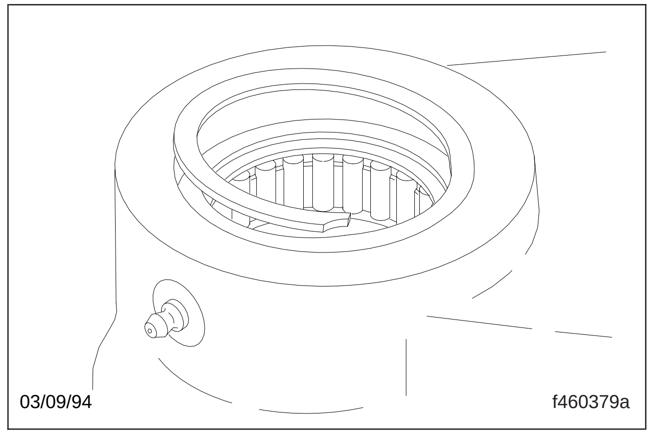


Fig. 54, Install the Second Retaining Ring

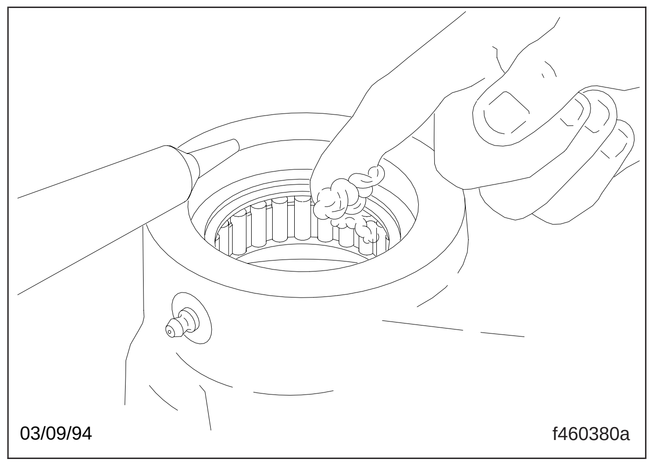


Fig. 55, Pack the Area between the Dirt Seal and the Pressure Seal with Grease

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 faces. To do so may damage these surfaces, which would require the replacement of the valve housing.

3.1 Put the valve housing in a vise so the input/worm shaft can be installed with the worm shaft up.

3.2 Lubricate and install a new O-ring in the valve housing. See **Fig. 56**.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

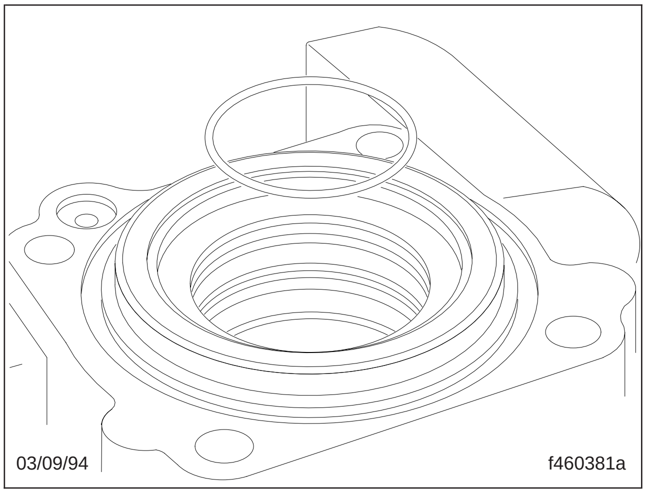


Fig. 56, Lubricate and Install a New O-Ring

3.3 Lubricate a new large diameter O-ring and a new seal ring, then install them in the valve housing. See **Fig. 56** and **Fig. 57**.

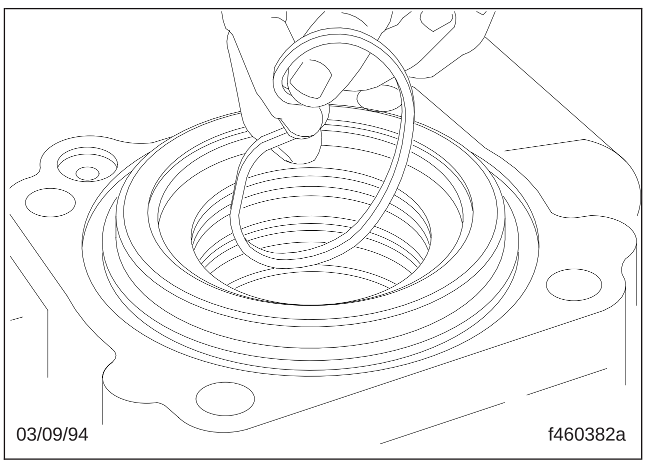


Fig. 57, Lubricate and Install a New Large Diameter O-Ring and a New Seal Ring

3.4 Install the roller thrust bearing and the thick thrustwasher on the input-shaft thrust face. See **Fig. 58**.

3.5 Install a new seal ring onto the input shaft, and against the thick thrustwasher. See **Fig. 1** Ref. 11.

3.6 Lubricate, then install the input-shaft/valve/worm assembly in the valve housing, seating it firmly. See **Fig. 59**.

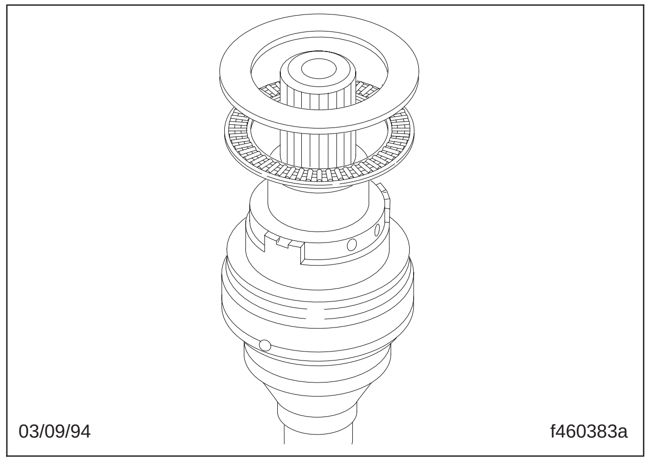


Fig. 58, Install the Roller Thrust Bearing and the Thick Thrustwasher

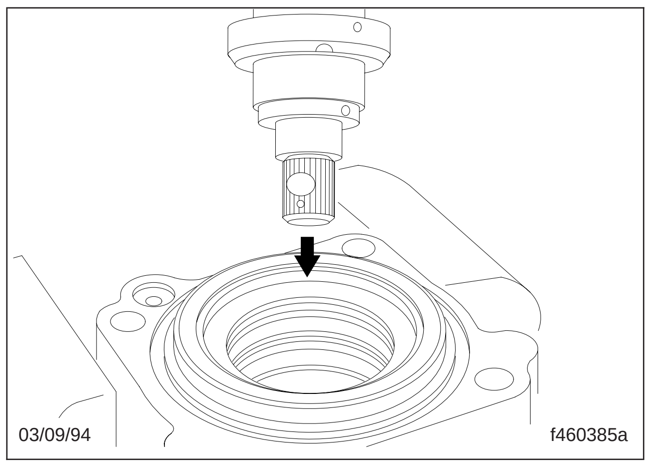


Fig. 59, Lubricate, then Install the Input-Shaft/Valve/Worm Assembly

3.7 Lubricate, then install a second thrust bearing and thin washer over the worm shaft. See **Fig. 60**.

3.8 Lubricate the new O-ring and seal ring. See **Fig. 1**, Refs. 18 and 19. Install the O-ring, then the seal ring in the groove of the bearing adjuster. See **Fig. 61**.

3.9 Making sure the bearing adjuster threads are clean and free of any stake burrs, lubricate and then install the bearing adjuster over the worm shaft, and into the valve housing.

3.10 Using a torque wrench and bearing adjuster tool J37070, tighten the valve ad-

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

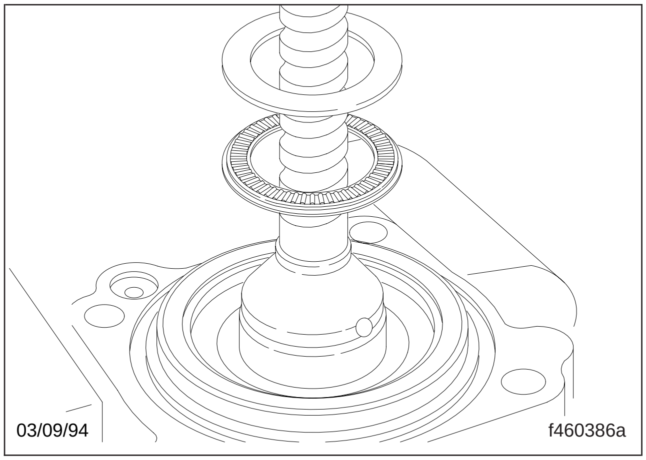


Fig. 60, Lubricate, then Install a Second Thrust Bearing and Thin Washer

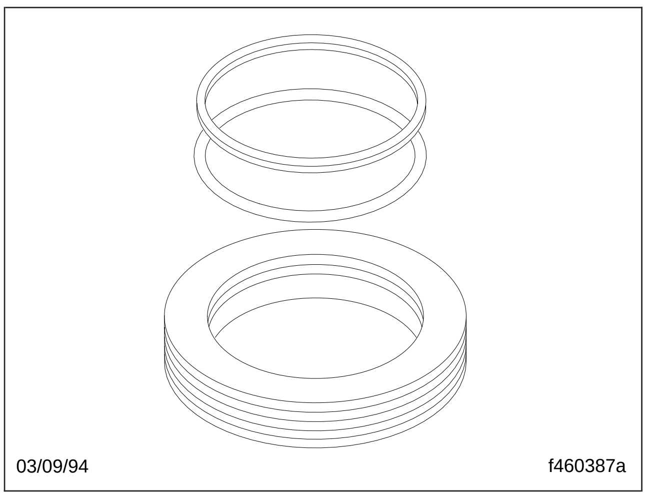


Fig. 61, Lubricate the New O-Ring and Seal Ring

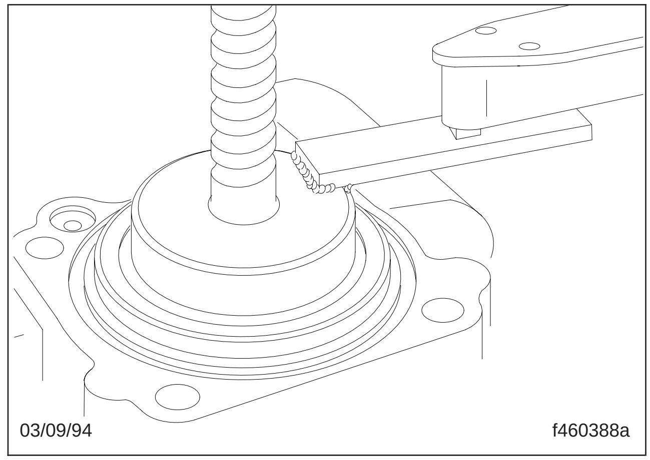


Fig. 62, Install the Bearing Adjuster over the Worm Shaft

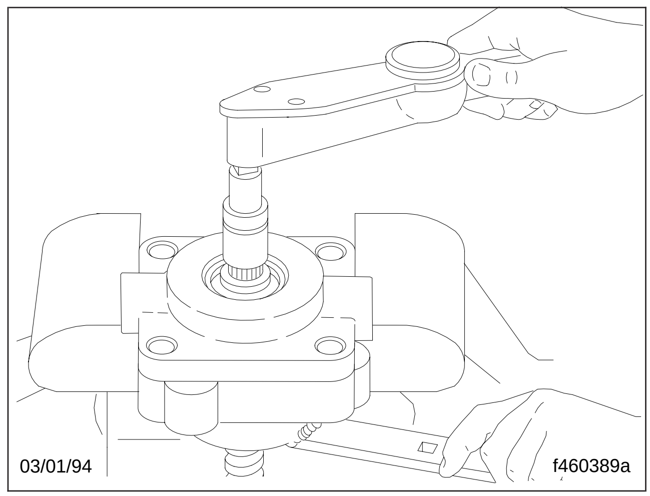


Fig. 63, Check the Torque

juster 11 to 15 lbf·ft (15 to 20 N·m), then back it off 1/4 to 1/2 turn. See **Fig. 62**.

3.11 Turn the valve housing over in the vise so that the worm shaft is facing down.

3.12 Using an inch-pound torque wrench, check the torque needed to turn the input shaft slowly 360 degrees clockwise and counterclockwise. Tighten the bearing adjuster until the torque needed to turn the input shaft increases by 5 to 10 lbf·in (60 to 120 N·cm). See **Fig. 63**.

3.13 Turn the valve housing over in the vise again, so that the worm shaft is facing up.

3.14 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. 64**.

3.15 Check the torque needed to turn the input shaft again. If the torque hasn't increased 5 to 10 lbf·in (60 to 120 N·cm), remove the locknut from the bearing adjuster, and repeat the steps above beginning with tightening the valve adjuster, then backing it off.

3.16 Using a punch, stake the locknut to the valve housing at two opposite slots in the

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

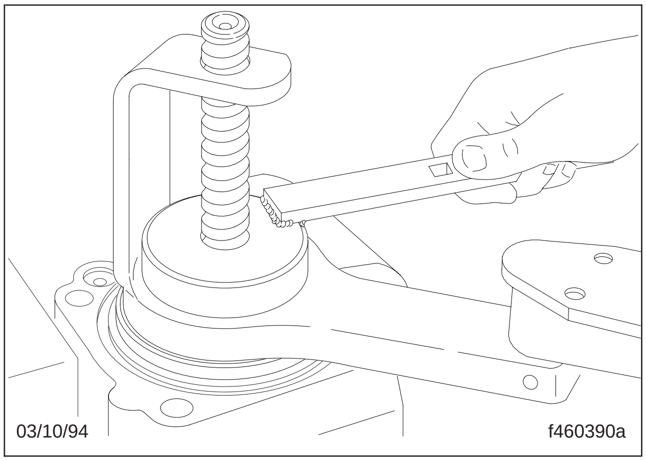


Fig. 64, Install the Locknut on the Bearing Adjuster

locknut. Stake each slot in the most clockwise corner, as shown in **Fig. 65**.

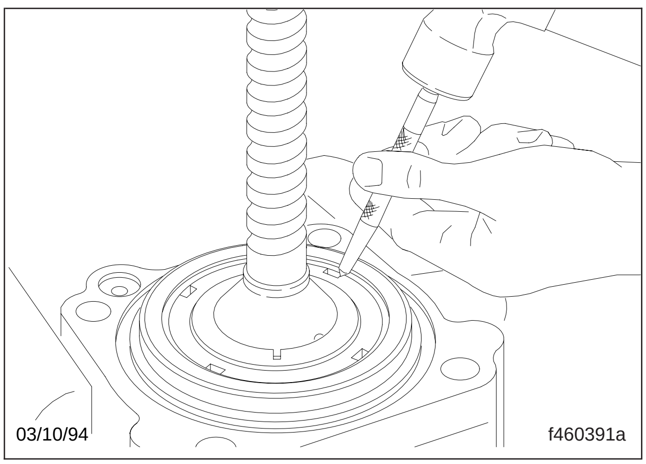


Fig. 65, Stake the Locknut to the Valve Housing and the Bearing Adjuster

3.17 Stake the locknut to the bearing adjuster at two places 180 degrees apart. See **Fig. 65**. Don't use a spot that was staked before.

3.18 Check the torque needed to turn the input shaft. If the torque isn't greater than 5 to 10 lbf·in (60 to 120 N·cm) the torque previously noted, unstake the locknut from the bearing adjuster, and repeat the steps above beginning with tightening the valve adjuster, then backing it off.

NOTE: The torque needed to turn the input shaft must not be more than 22 lbf·in (240 N·cm).

3.19 Oil the new seal rings, and install them in the valve housing. See **Fig. 66**.

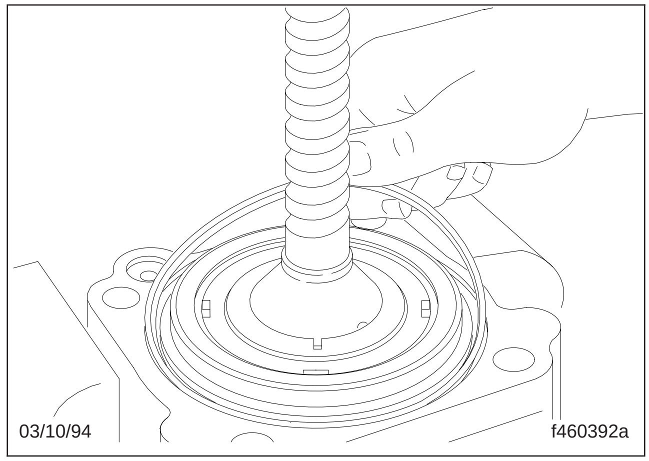


Fig. 66, Install the New Grease Seal Rings

4. Reset the automatic poppet valves.

IMPORTANT: Make sure the poppet adjuster seat and sleeve assemblies and the threaded holes in the rack piston are free of Loctite. Use 7/16–20 UNF thread chasers to remove the Loctite.

4.1 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. 67**.

4.2 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. 68** and **Fig. 69**.

4.3 Remove the adjuster seat and sleeve assembly from the rack piston.

4.4 Repeat the previous steps for the other poppet adjuster seat and sleeve assembly.

5. Install the rack piston seal: install a new backup O-ring and new Teflon seal ring on the rack piston. See **Fig. 70**. Don't stretch them more than necessary when installing them.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

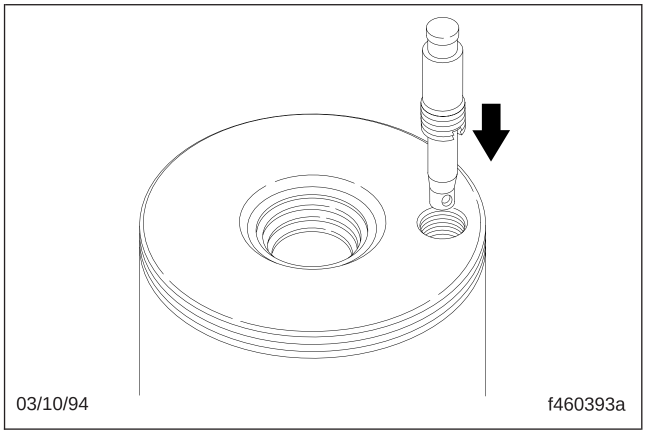


Fig. 67, Screw the Poppet Adjuster Seat and Sleeve Assembly into the Rack Piston

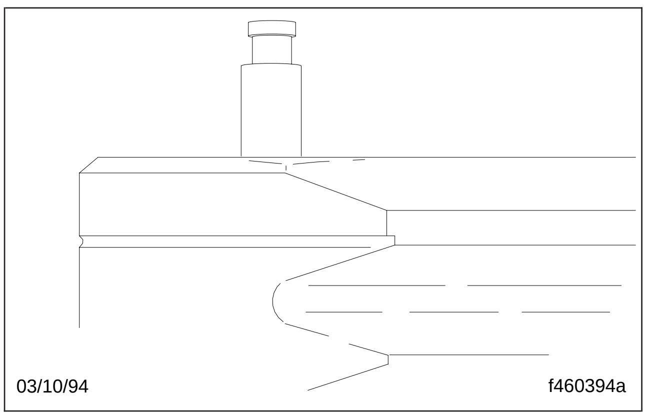


Fig. 68, Adjuster Seat/Adjuster Sleeve in the Rack Piston

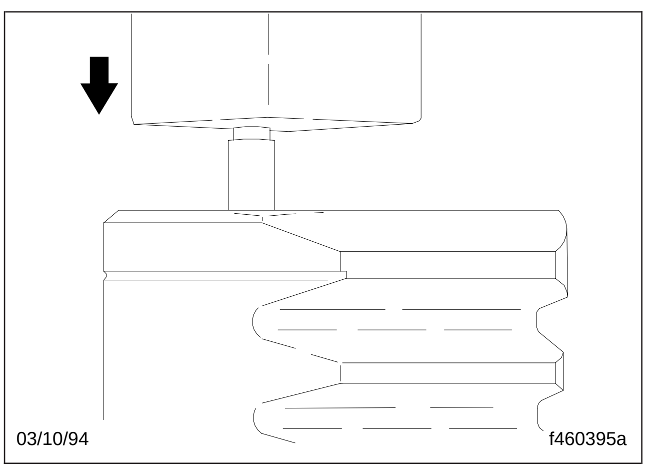


Fig. 69, Press the Adjuster Seat Into the Adjuster Sleeve

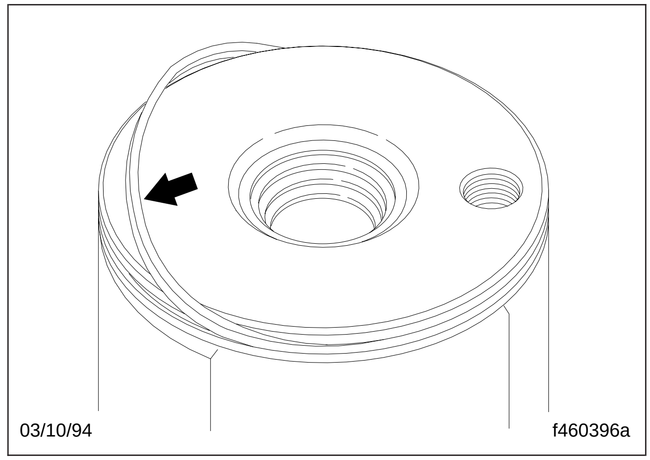


Fig. 70, Install a new Backup O-Ring and new Teflon Seal Ring

6. Install the automatic poppets.

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 is not needed.

6.1 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. 71**.

6.2 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. 72**.

WARNING

Wear eye protection while assembling the poppets. The poppets are spring-loaded and could be ejected, which could result in serious eye injury.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

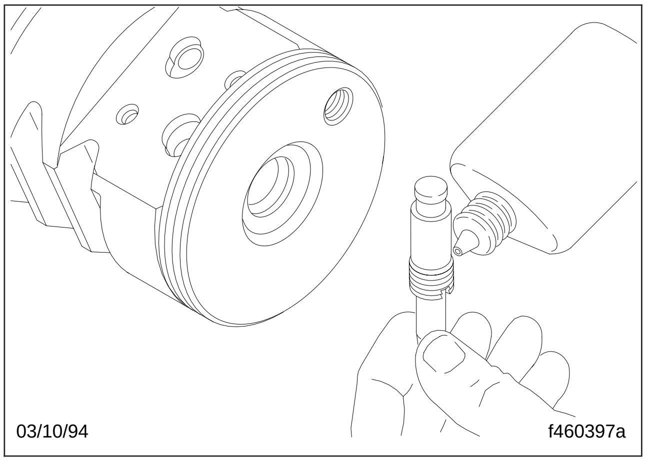


Fig. 71, Apply Locquic Primer T

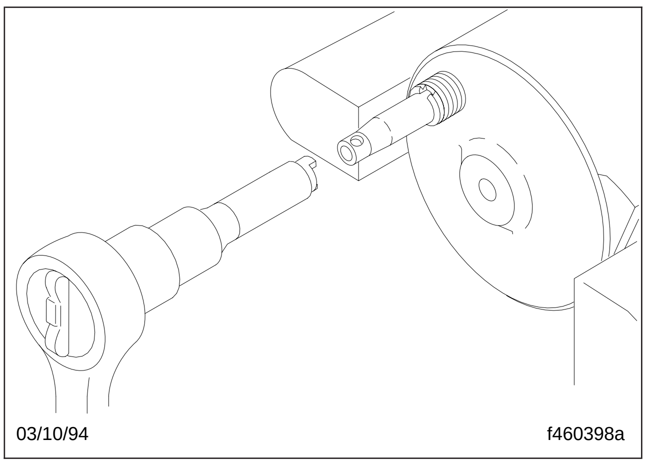


Fig. 72, Install a Poppet Adjuster Seat and Sleave Assembly

6.3 In the other end of thehole, install the poppet assembly parts in the following order. See **Fig. 73**: one poppet, the poppet spring, the nylon spacer rod, the push tube, the other poppet, and the other poppet adjuster seat and sleeve assembly.

6.4 Using special tool J36452 or J38713 (preferred), tighten both poppet adjuster seat and sleeve assemblies as follows. See **Fig. 74**:

TAS55/65 steering gear, 10 lbf·ft (14 N·m);

TAS85 steering gear, 18 lbf·ft (24 N·m).

7. Install the worm shaft and valve housing assembly into the rack piston.

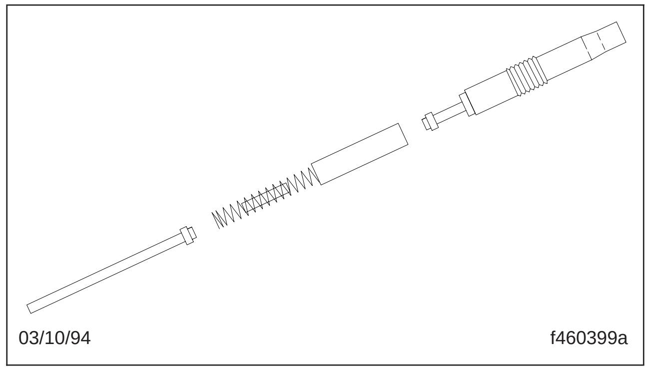


Fig. 73, Install the Poppet Assembly Parts

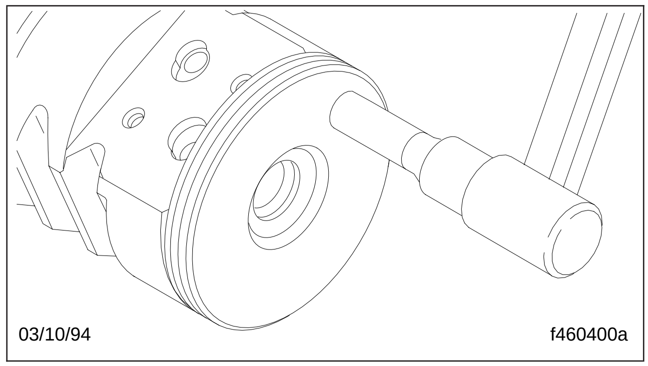


Fig. 74, Tighten both Poppet Adjuster Seat and Sleeve Assemblies

7.1 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.

7.2 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. 75**.

7.3 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 as shown in **Fig. 75**, or the rack piston is put on a V-block, so that the valve housing and worm shaft can turn freely.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

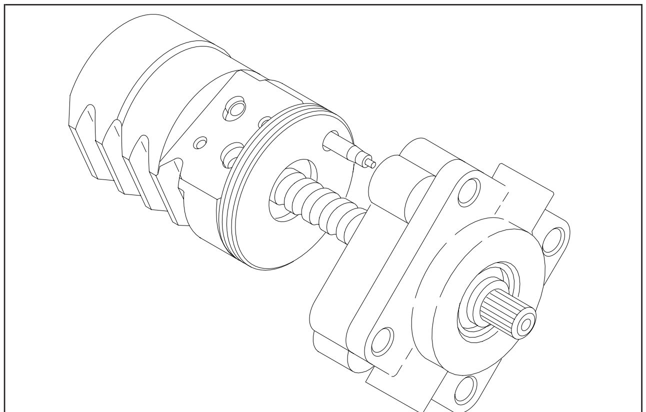


Fig. 75, Insert the Worm Shaft and Input Shaft Assembly

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.

8. Install the steel balls.

   8.1 Install new ball return guide halves in the rack piston. See **Fig. 76**. Make sure they are correctly seated.

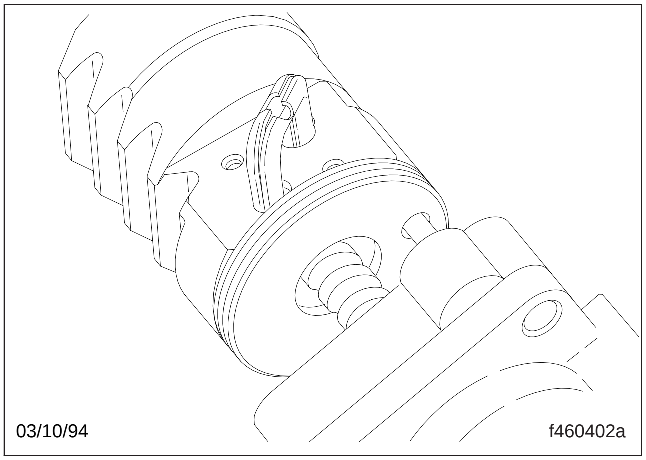


Fig. 76, Install New Ball Return Guide Halves

CAUTION

If you are installing a new rack piston or a new input-shaft/valve/worm assembly, do not install the existing steel balls. Use a new set of steel balls or damage to the steering gear may result.

NOTE: The worm gear may have to be rotated slightly to seat guide halves. Left-hand ball return guide halves are copper-plated, and right-hand 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.

   8.2 Insert the steel balls in the ball return guide hole, as shown in **Fig. 77**. As the balls are dropped into the guide, turn the worm shaft so that the balls are pulled down into its grooves.

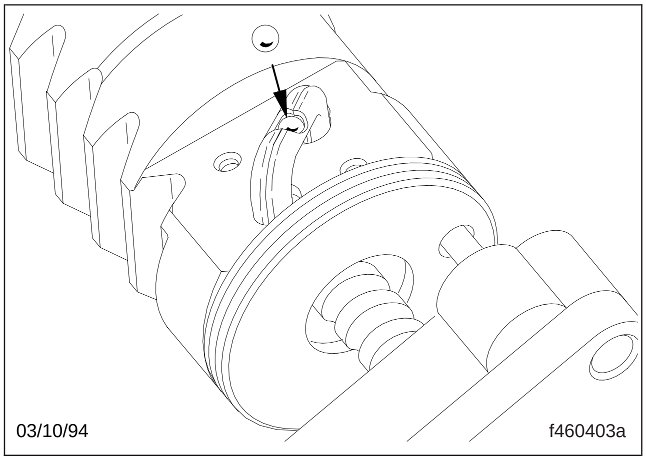


Fig. 77, Insert the Steel Balls

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.

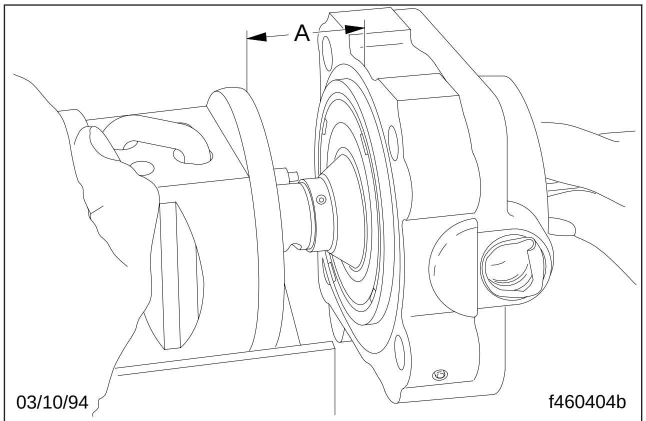
   8.3 If the ball guide halves rise up at any time during or after the installation of the steel

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

balls, remove all of the balls, and the input-shaft/valve/worm assembly from the rack piston. Repeat the previous steps beginning with inserting the worm shaft and input shaft assembly into the worm end of the rack piston.

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. 78**. If this happens, the poppet adjuster could be incorrectly preset or the worm could be backed out beyond the closed ball loop.

8.4 Lubricate the new seal for the ball return guide cap, and install it in the groove in the cap. See **Fig. 79**.



A. 2.7 inches (69 mm)

Fig. 78, Check the Valve Housing Pilot Face

8.5 Using a 5/32-inch allen socket and two new 5/32-inch allen screws (or a T–30 Torx socket 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).

8.6 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 without moving the valve housing pilot face more than 2.7

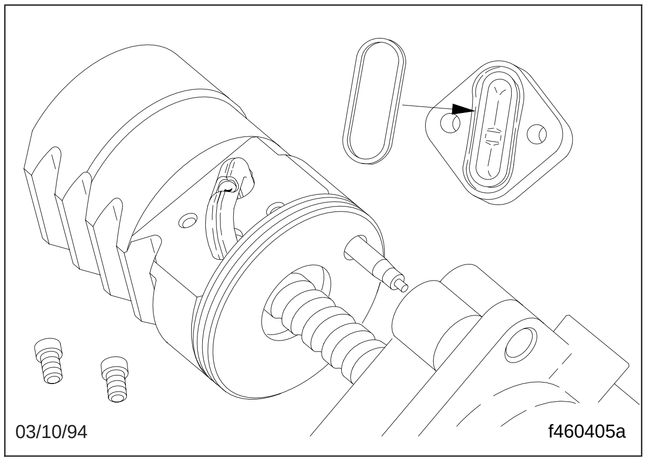


Fig. 79, Install the Seal

inches (69 mm) from the input end (upper end) of the rack piston. See **Fig. 78**.

8.7 If the worm shaft doesn't turn, remove all of the steel balls, and install them again.

9. Install the poppet stopscrew. If the poppet stopscrew is being replaced, install the new one and its washer in the gear housing. See **Fig. 80**. Tighten it 38 to 42 lbf·ft (52 to 57 N·m).

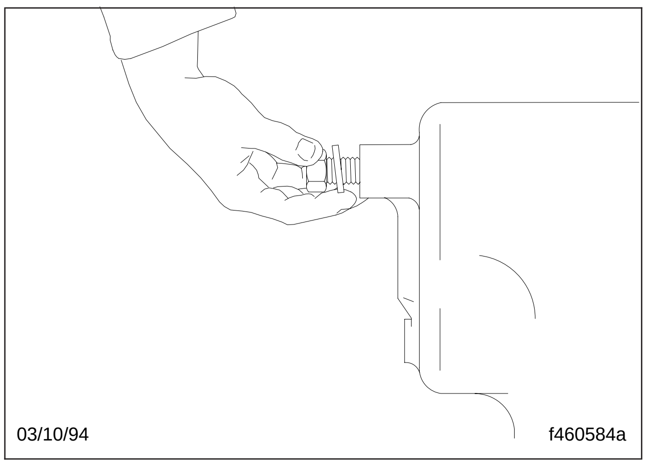


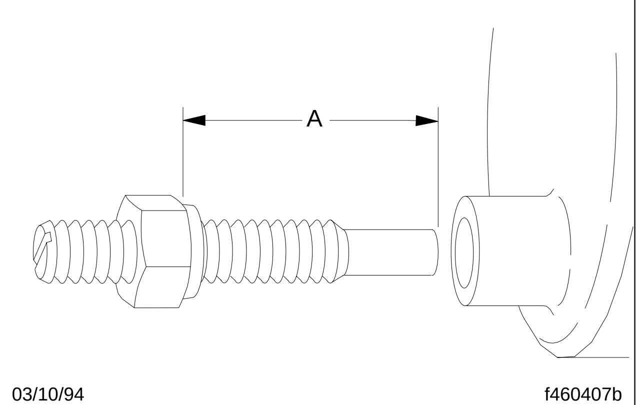
Fig. 80, Install a new Poppet Stopscrew

10. Preset the poppet adjusting screw, if equipped.

10.1 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

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

from the bottom of the jam nut. See **Fig. 1**, Ref. 38 and Ref. 39 and **Fig. 81**.



A. 1.03 to 1.09" (26 to 28 mm)

Fig. 81, Check the Distance from the Bottom of the Jam Nut

10.2 Install the assembly into the gear housing. Tighten the jam nut 33 to 37 lbf·ft (45 to 50 N·m).

11. Install the rack piston/valve housing assembly into the gear housing.

11.1 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.

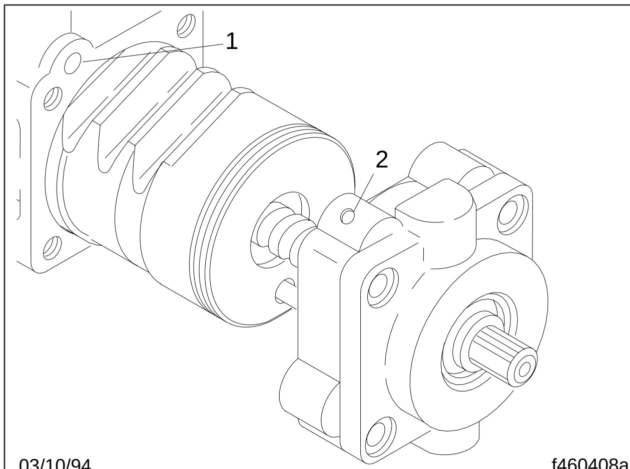
CAUTION

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.

IMPORTANT: This gap is to ensure that the poppets don't make contact with anything while the steering gear is being assembled.

11.2 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 the rack teeth toward the sector shaft hole in the housing. See **Fig. 82**. 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. 82, Install the Piston with the Rack Teeth toward the Sector Shaft Hole

11.3 Using an E–16 Torx socket wrench, install and tighten the four valve housing bolts as follows: See **Fig. 83**.

TAS55/65 steering gear, 75 to 85 lbf·ft (102 to 115 N·m).

TAS85 steering gear, 108 to 128 lbf·ft (146 to 174 N·m).

12. Install the relief valve components, if equipped.

12.1 Assemble a new O-ring on the relief valve cap.

12.2 Assemble the small end of tapered spring onto the pin on the other part of the relief valve and insert the assembly, tapered spring end first, into the relief valve cap cavity. See **Fig. 84**.

12.3 Turn the relief valve cap as assembled into the valve housing and torque it to 30 lbf·ft (41 N·m). See **Fig. 85**.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

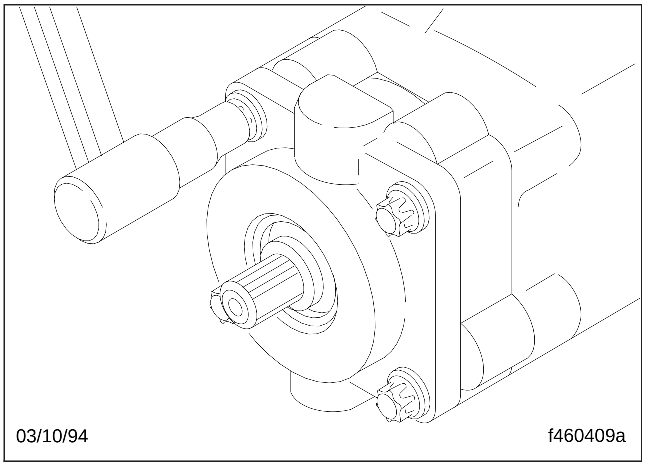


Fig. 83, Install the Valve Housing Bolts

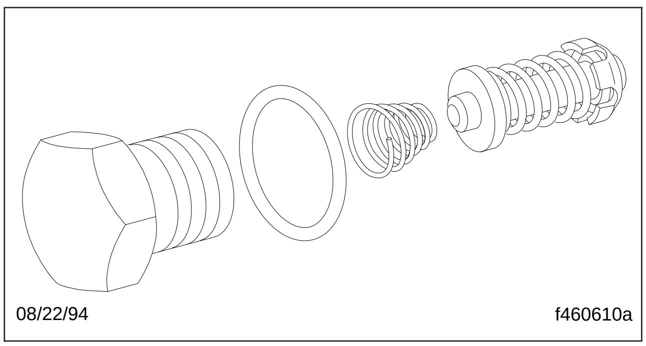


Fig. 84, Install the Tapered Spring

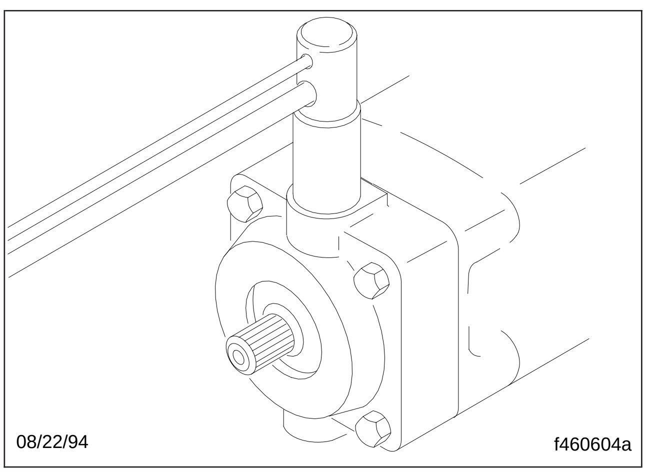


Fig. 85, Turn the Relief Valve Cap into the Valve Housing

13. If the sector shaft adjusting screw is being replaced, do the following; otherwise go to the next step and install the sector shaft/side cover components.

    13.1 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.

    13.2 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 accidentresulting in personal injury or property damage. Replace a broken or cracked sector-shaft screw retainer.

    13.3 Stake the sector-shaft screw retainer to the slots in the sector shaft. See **Fig. 86**. Check the adjusting screw again for free movement and end play.

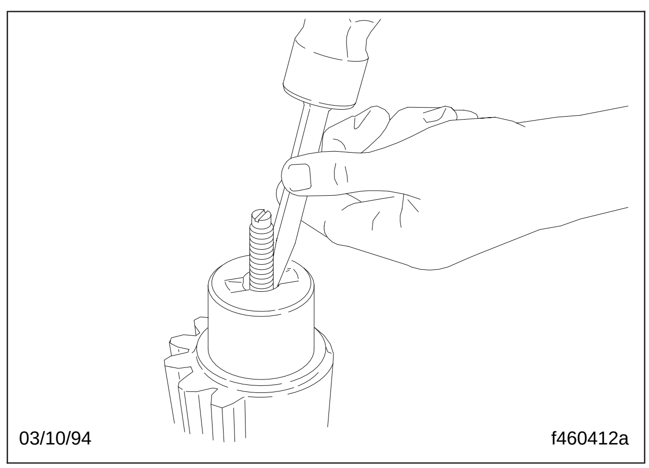


Fig. 86, Stake the Sector-Shaft Screw Retainer

14. Install the sector shaft/side cover components.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

14.1 For a TAS55/65 steering gear, lightly oil the side-cover "DU" bushing. Don't grease it. See **Fig. 87**.

For a TAS85 steering gear, heavily grease the side-cover bearing with Mobile Temp 1 or 2 grease. Don't oil it.

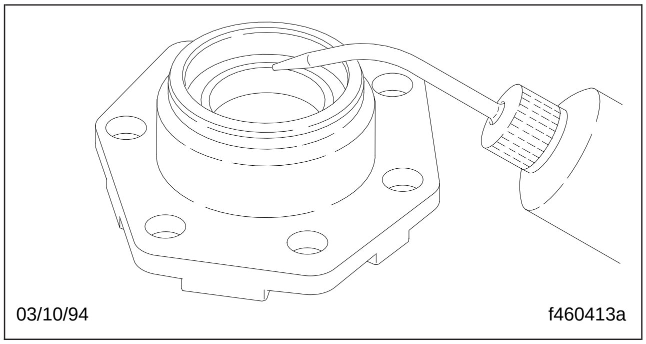


Fig. 87, Applying Oil to the DU Bushing

14.2 Put a new seal on special tool J37071 (TAS55/65) or J38779 (TAS85) so that the garter spring is against the shoulder of the tool. See **Fig. 88**. 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 counter-bore.

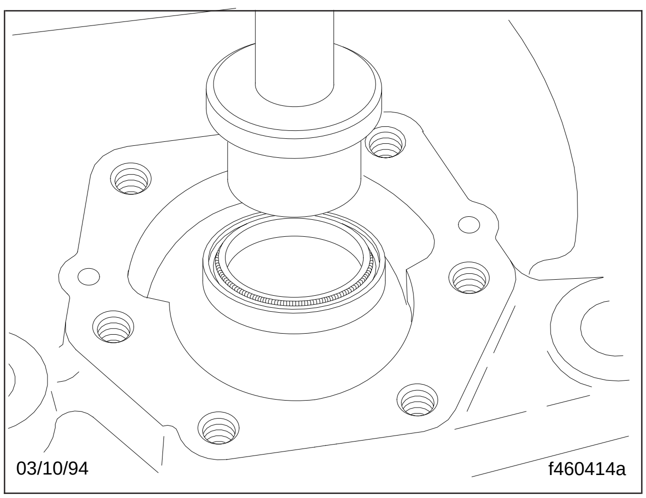


Fig. 88, Press in the New Seal

14.3 For a TAS55/65 steering gear, lightly oil the short bearing end of the sector shaft.

For a TAS85 steering gear, heavily grease the short bearing end of the sector shaft.

Insert the sector shaft into the side cover. Screw the sector shaft adjusting screw counterclockwise into the side cover, until the screw seats. See **Fig. 89**. Then rotate the adjusting screw clockwise one turn, so that the side cover rotates freely on the sector shaft.

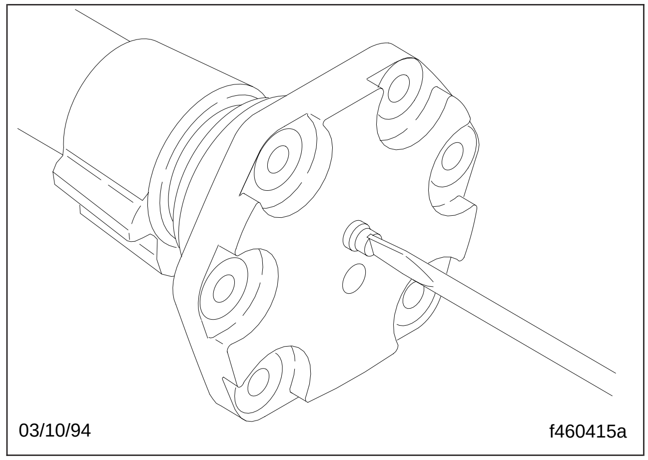


Fig. 89, Install the Sector Shaft Adjusting Screw

14.4 Install the sector-shaft adjusting screw jam nut onto the sector-shaft adjusting screw a few threads. See **Fig. 90**. Final adjustment will be made later.

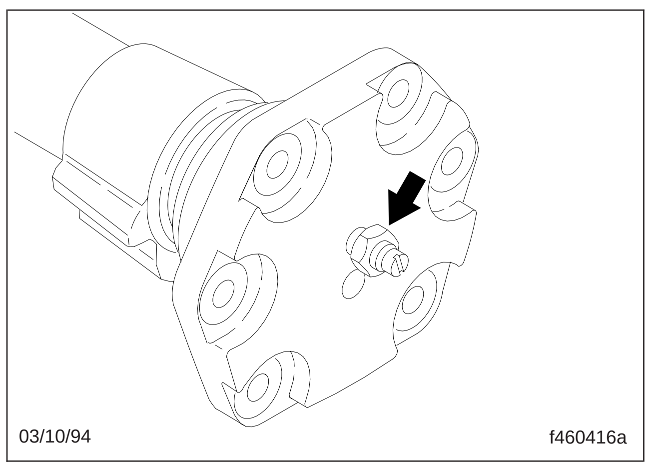


Fig. 90, Loosely Install the Sector-Shaft Adjusting Screw Jam Nut

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

14.5 Press a new rubber plug into the hole provided in the side cover, until the plug is flush. See **Fig. 91**.

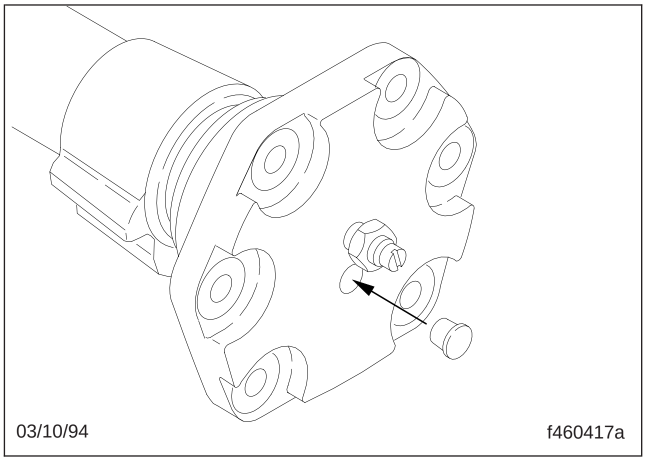


Fig. 91, Press in a New Rubber Plug

WARNING

Do not weld or plug this hole permanently. This is a safety vent which functions only if the side cover output shaft seal does not work. If the seal does not 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.

15. Install the sector shaft/side cover assembly.

15.1 Apply clean grease to a new side cover gasket, and install it on the side cover. See **Fig. 92**. Apply enough grease to hold the gasket in place.

15.2 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. 93** (it is the third space between the second and the third tooth), is in the center of the sector shaft opening. See **Fig. 94**. This will center the rack piston in the opening.

15.3 Remove all tape from the sector shaft splines. Retape the splines and the bolt groove with one layer of masking tape.

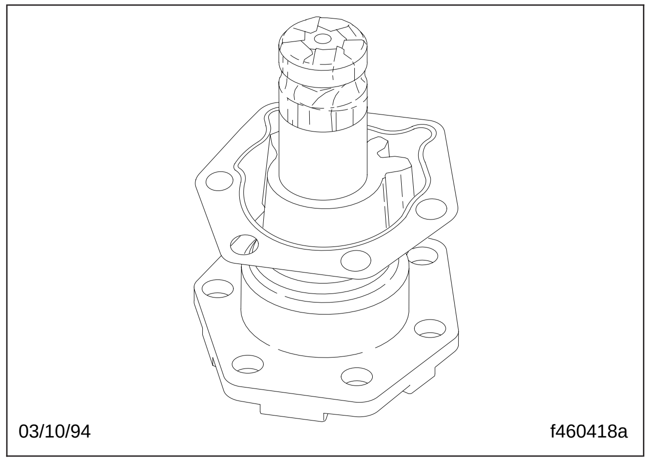


Fig. 92, Install the Side Cover Gasket

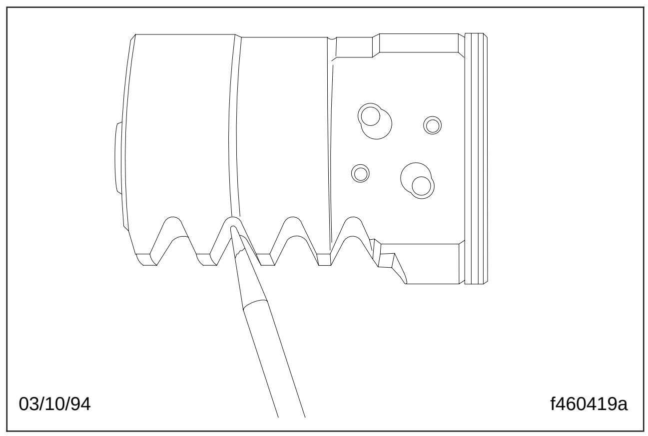


Fig. 93, Check the Tooth Space

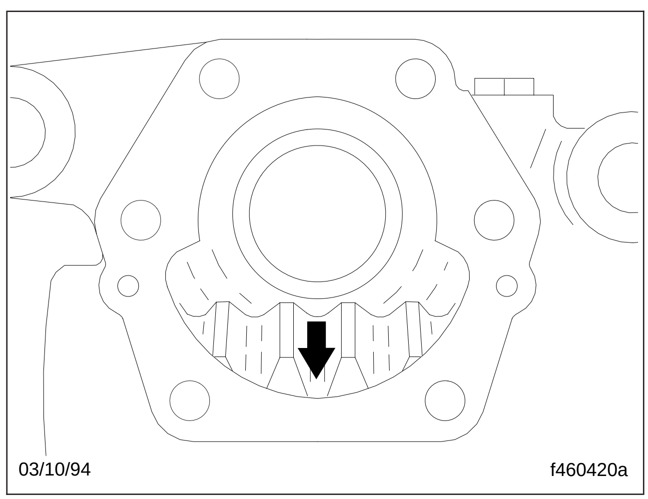


Fig. 94, Check the Tooth Position

CAUTION

If the splines on the sector shaft are not taped correctly, the spline will damage the housing seal during assembly, causing the seal to leak.

15.4 Install the sector shaft and side cover, as an assembly, in the gear housing. See **Fig. 95**. Make sure the center tooth of the sector engages the center space (between the second and third teeth) of the rack piston.

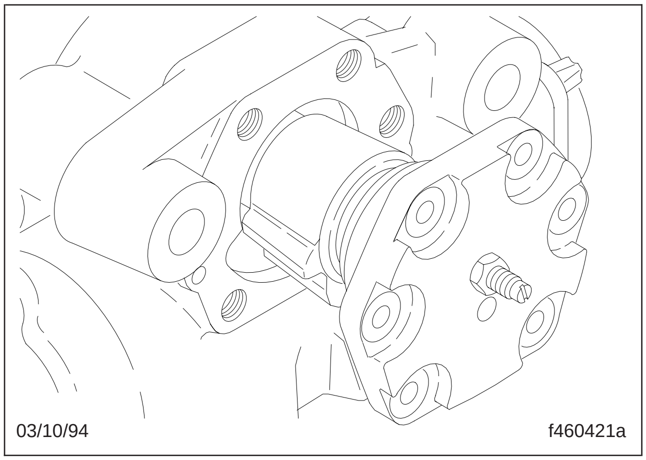


Fig. 95, Install the Sector Shaft and Side Cover

15.5 Install the special side cover bolts in the side cover. Using the torque pattern shown in **Fig. 96** or **Fig. 97**, tighten as follows:

Dry bolts 230 lbf·ft (312 N·m); lubricated bolts 170 lbf·ft (230 N·m). See **Fig. 98**.

16. Install the sector shaft seal.

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 equivalent. Put grease on the new trunnion dirt seal, and install it over the sector shaft and into the trunnion bore. See **Fig. 99**.

17. Install the input shaft seals and retaining ring.

IMPORTANT: Make sure the input shaft seal is installed squarely in the seal bore.

17.1 Apply clean grease to the new input shaft seal; then place it, garter spring side first,

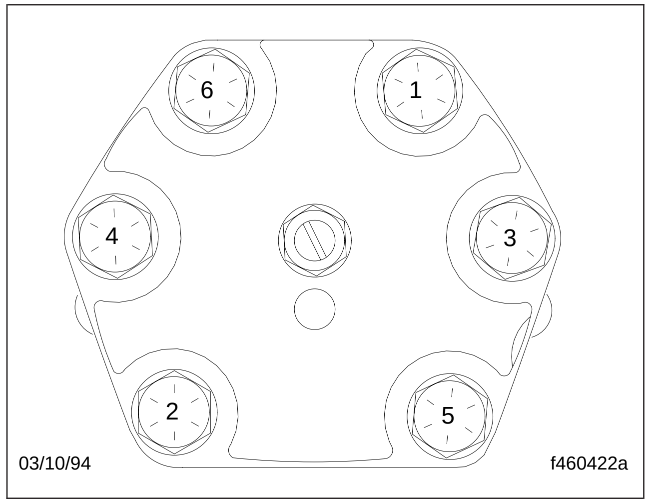


Fig. 96, Six-Bolt Tightening Sequence

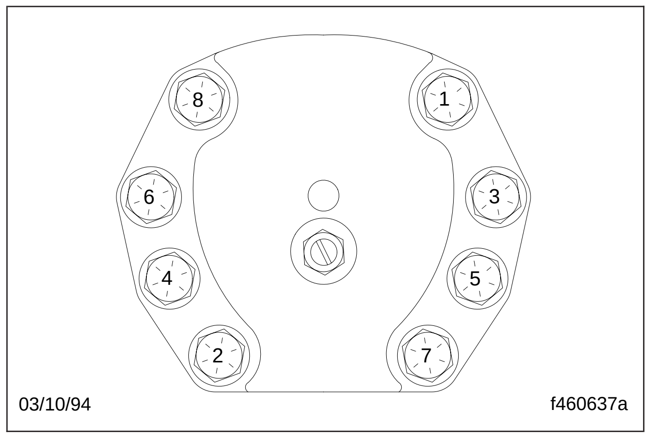


Fig. 97, Eight-Bolt Tightening Sequence

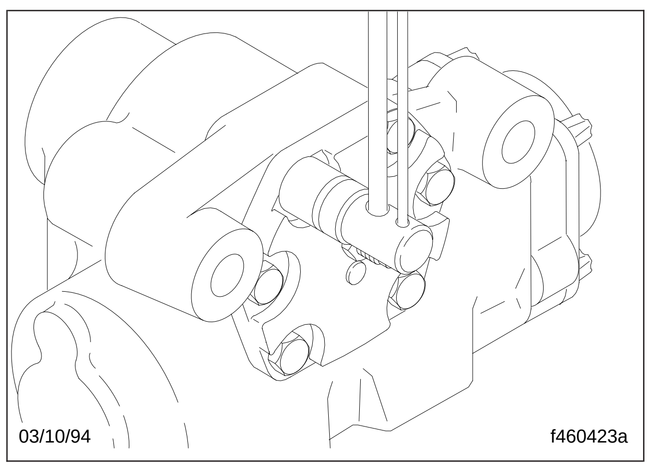


Fig. 98, Install the Special Side Cover Bolts

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

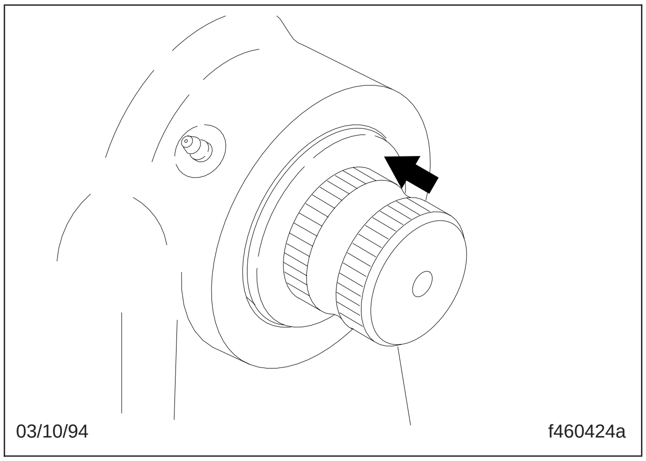
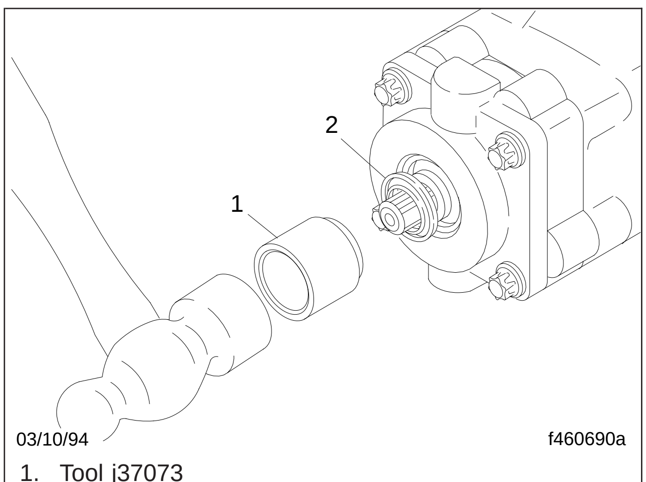


Fig. 99, Install a New Trunnion Dirt Seal

over the input shaft. Using special tool J37073 and a mallet, tap the seal installer tool until the tool shoulder is square against the valve housing. See **Fig. 100**. Remove any seal material that may have sheared off in the retaining groove.

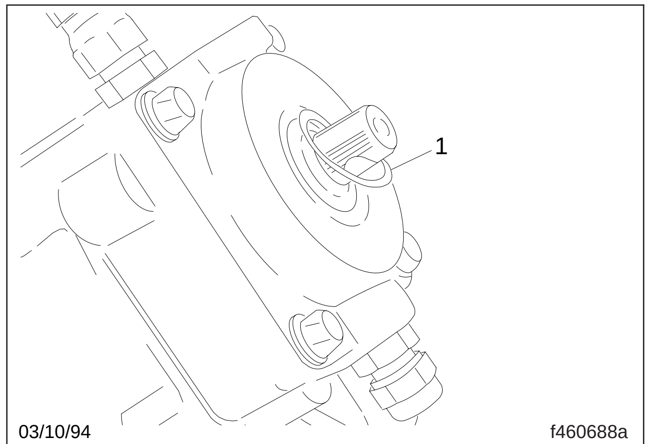


1. Tool j37073
2. Seal

Fig. 100, Tap the Seal Into the Valve Housing Bore

17.2 Install a new retaining ring into its groove in the valve housing. See **Fig. 101**.

17.3 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 serra-



1. Retaining Ring

Fig. 101, Install a New Retaining Ring

tions of the input shaft, and against the valve housing. See **Fig. 102**.

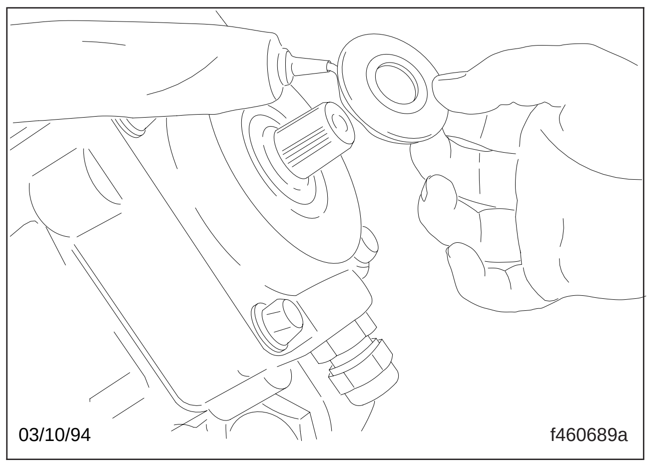


Fig. 102, Install the Dirt-and-Water Seal

18. Install the grease fitting and auxiliary port plug.

18.1 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. 103**. Tap the new grease fitting in place.

18.2 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).

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

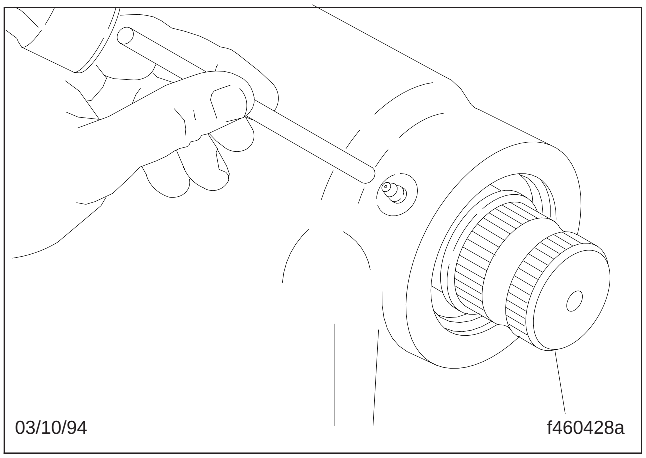


Fig. 103, Install a New Grease Fitting

Final Adjustments

Before installing the steering gear on the vehicle, make these adjustments:

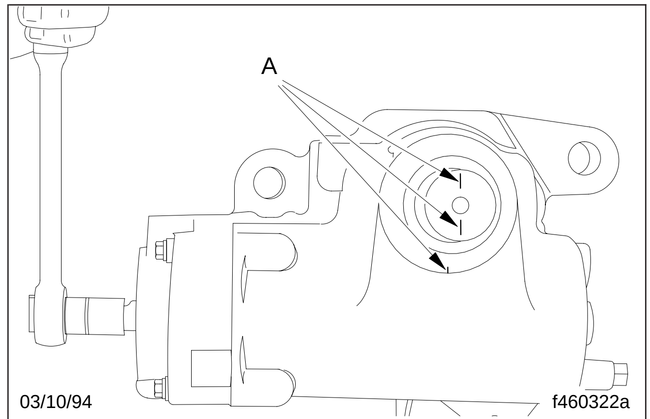
NOTE: Worm shaft preload adjustment was done when the input shaft was installed in the valve housing during the assembly procedure.

1. Adjust the sector shaft preload.

CAUTION

When the steering gear is not connected to the steering system, do not 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.

1.1 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. 104**. 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. 104, 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.

1.2 With the adjusting screw nut loose, 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 45 to 50 lbf·in (500 to 560 N·cm). See **Fig. 105**. Use a 12-point socket and an inch-pound torque wrench to turn the input shaft.

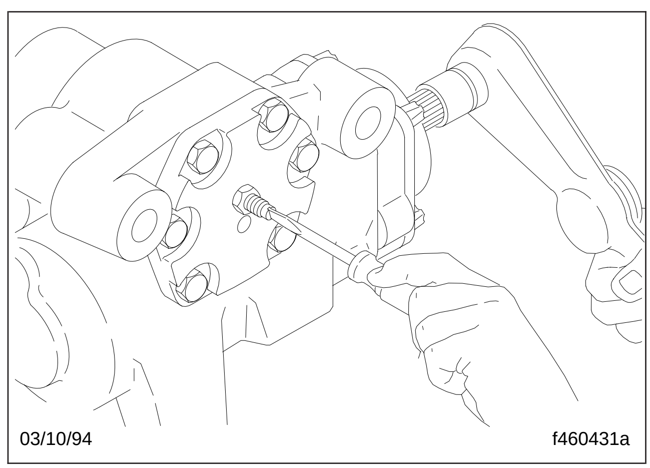


Fig. 105, Adjust the Sector Shaft Adjusting Screw

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

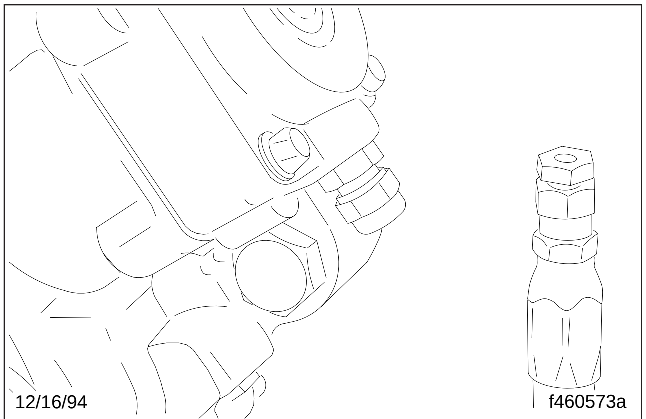
1.3 Back out the sector shaft adjusting screw one-half turn. Note the torque needed to turn the input shaft through 180 degrees each side of center.

1.4 Tighten the sector shaft adjusting screw so that the torque noted in the above substep is increased by 6 to 8 lbf·in (60 to 100 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).

2. Check the torque needed to turn the input shaft. If it is more than 40 lbf·in (452 N·cm), readjust the input shaft.

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.



A. Cap the return line and the return port.

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

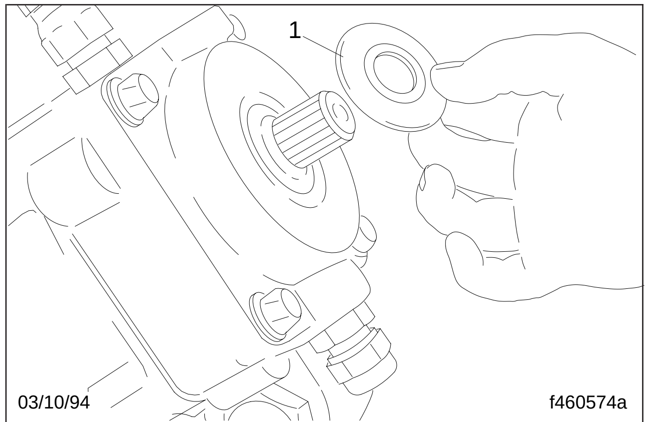
Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   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**.

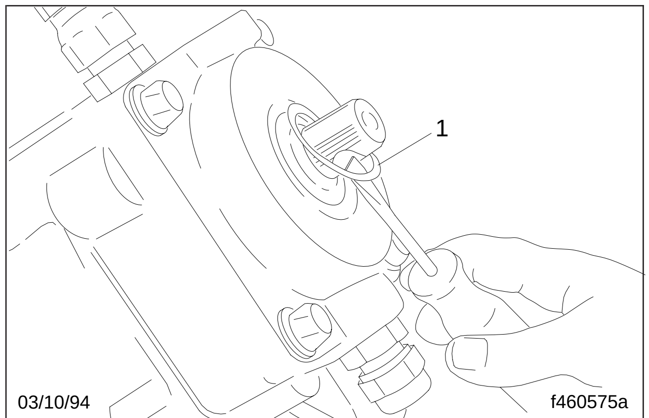
4. Wipe out the grease and then remove the spiral retaining ring. See **Fig. 3**. Use a screwdriver inserted into the notch formed in the end of the ring.

5. Slip the input yoke back onto the input shaft with the pinch bolt installed, but not tightened. See **Fig. 4**.



1. Dirt-and-Water Seal

Fig. 2, Remove the Dirt-and-Water Seal



1. Retaining Ring

Fig. 3, Remove the Retaining Ring

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**.

7. Add Dexron III type ATF as necessary to the fill line on the dipstick.

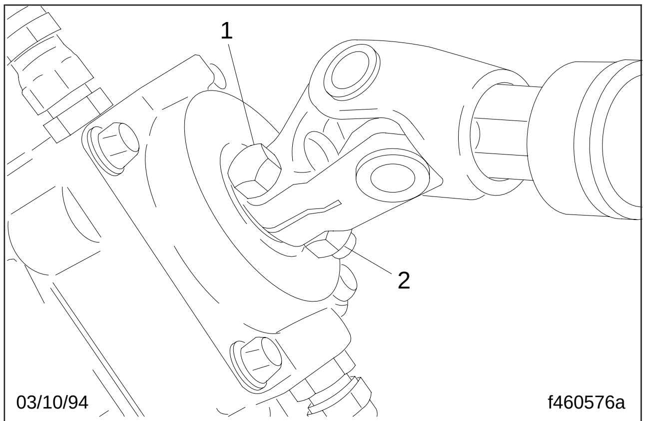
8. With the vehicle in neutral, momentarily turn the starter (quickly turn off the engine if it starts).

9. Remove the shop towel, pinch bolt, and input yoke.

10. Remove the seal. See **Fig. 6**.

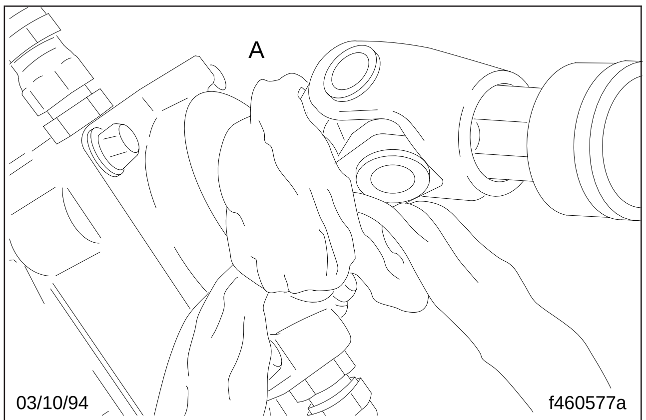
11. Check the seal area of the valve housing for any seal fragments. Remove any that are found.

Input Shaft Seal Removal and Installation



1. Pinch-Bolt
2. Pinch-Bolt Nut

Fig. 4, Install the Pinch Bolt



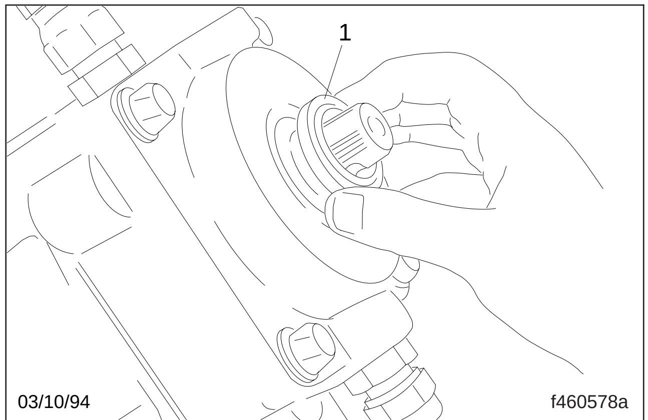
A. Cover the Input Shaft Area

Fig. 5, Shop Towel Covering the Input Shaft

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. Refer to the appropriate section in **Troubleshooting 300** to determine and fix the cause of excessive heat in the vehicle.

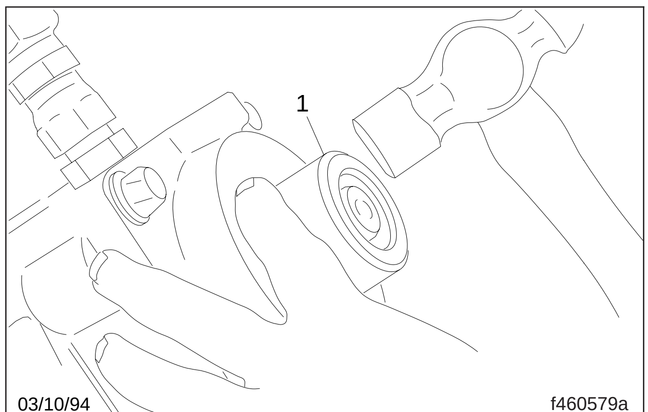
Installation

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. Input Shaft Seal

Fig. 6, Install the Input Shaft Seal

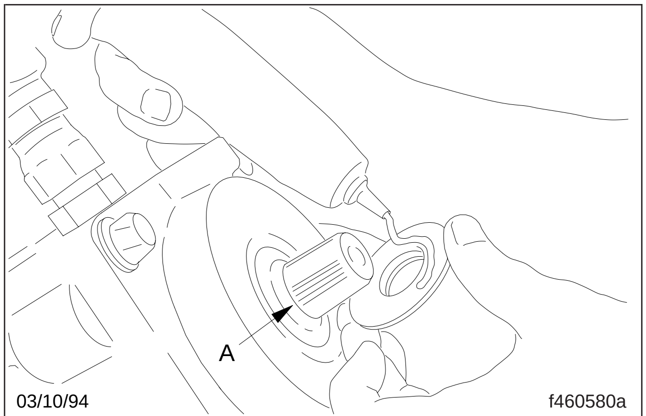


1. Seal Installer Tool

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.

Input Shaft Seal Removal and Installation



A. Seat the seal here.

Fig. 8, Install the Dirt-and-Water Seal

4.1 Clean the input shaft and the inside of the driveline yoke.

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 III 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.

Post-Service Checks

After power steering components have been worked on, and before the vehicle is placed into service, the following items must be checked.

WARNING

Failure to check the following items could result in damage to the power steering system. This could cause a loss of hydraulic assist, which could cause personal injury or property damage.

1. 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. With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop, while checking the power steering reservoir for frothing or a change in the fluid level (a sign that air is trapped in the system). If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as necessary. Bleed the air from the system.
2. With the engine turned off and warm, check the power steering reservoir fluid level, using the instructions in the steering section in the vehicle maintenance manual.
3. At full-left and full-right wheel cuts, be sure the axle stops (on the rear-side of the spindle) are set so there is at least 1/2 inch (13 mm) clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be 3/4 inch (19 mm). If clearance is less than the above, reset the axle stops.
4. Check that the poppet plungers 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 46.06, Subject 300**, and perform the steering system hydraulic tests as instructed; otherwise, go to the next step.
6. Test drive the vehicle, or take a ride with the driver. Check the steering wheel spoke position. If, during straight-ahead driving on a level road, the steering wheel spokes are not within ±10 degrees of the 3 o'clock and 9 o'clock positions, remove the steering wheel and reposition it.

Refer to **Fig. 1** for a plumbing diagram of the steering system with hydraulic brakes. Refer to **Fig. 2** for a plumbing diagram of the steering system with air brakes.

Kent-Moore Tools		
Kent-Moore Part Number		Tool
TAS55/65	TAS85	
J37070	J37070	Adjuster Tool
J37464	J37464	Adjuster Locknut Tool
J37071	J38779	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

Steering Gear Torque Values			
Description	Bolt or Nut Size	Grade	Torque: lbf·ft (N·m)
Valve Housing Bolt:			
TAS55/65	—	—	75–85 (102–115)
TAS85			108–128 (146–174)
Auxiliary Port Plug	—	—	25–35 (34–47)
Poppet Adjuster Sleeve and Seat Assembly:			
TAS55/65	—	—	10 (14)
TAS85			18 (24)
Ball Return Guide Bolt	—	—	14–22 (19–30)
Sector Shaft Adjusting Screw Jam Nut	—	—	40–555 (54–7)
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		90–170 (122–230)
	7/8–14		160–300 (217–407)
Steering Driveline Lower End Yoke Pinch-Bolt Nut	7/16–20	C	55–65 (75–88)

Specifications

Steering Gear Torque Values			
Description	**Bolt or Nut Size**	**Grade**	**Torque: lbf·ft (N·m)**
Pitman Arm Pinch-Bolt Nut	5/8–18 3/4–16	C	120–140 (163–190) 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.

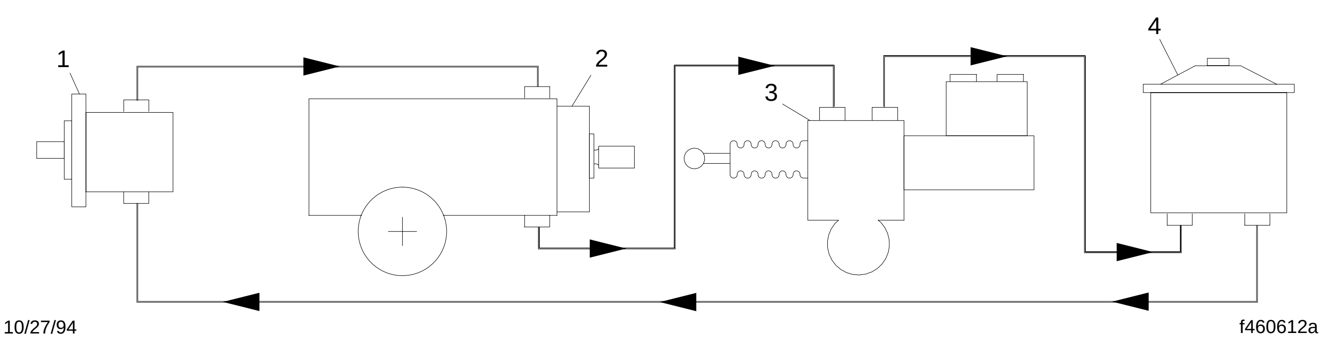
Table 2, Steering Gear Torque Values

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 III

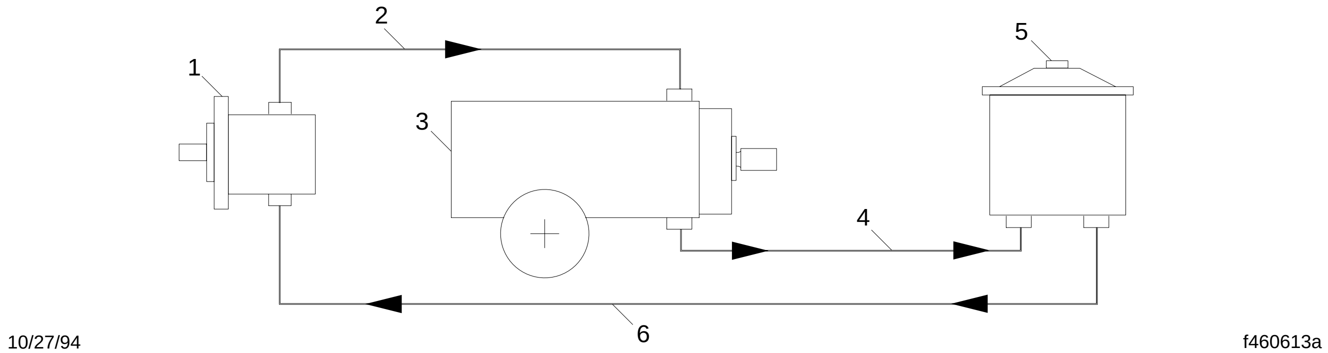
Table 3, Recommended Power Steering Fluid



1. Steering Pump
2. Steering Gear
3. Brake Booster
4. Reservoir

Fig. 1, Steering System With Hydraulic Brakes

Specifications



1. Steering Pump
2. Pressure Line
3. Steering Gear
4. Return Line
5. Reservoir
6. Supply Line

Fig. 2, Steering System With Air Brakes

General Information

General Description

The Vickers VT10 power steering pump supplies fluid for the operation of the power steering gear and the hydraulically-assisted service brakes.

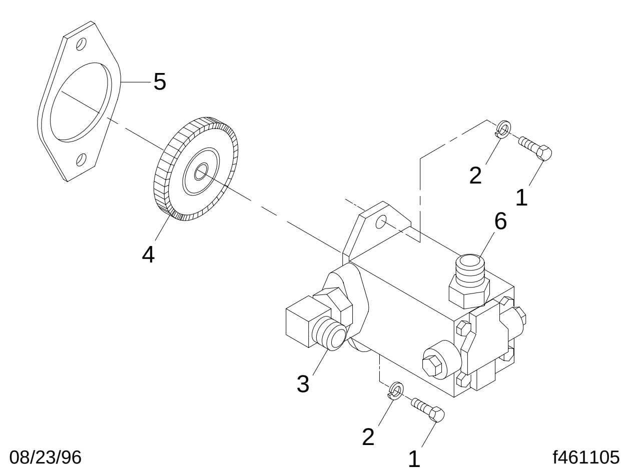
The pump is mounted on the passenger's side of the engine, at the rear of the air compressor, and is powered by the same drive gear in the engine that powers the air compressor.

Steering Pump Removal and Installation

Removal

1. Apply the parking brakes, chock the tires.
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 hose from 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 bolts that attach the pump to the air compressor. See **Fig. 1**. Slide the pump out of the drive gear, and remove the pump from the engine.



1. Mounting Capscrew
2. Lockwasher
3. Supply (inlet) Port
4. Drive Gear
5. Gasket
6. Return (outlet) Port

Fig. 1, Vickers 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's accessory drive mounting. Turn the pump or shaft as needed to mesh with the shaft of the drive gear. Seat the pilot of the pump mounting flange in the accessory drive mounting, without applying unneccessary force. Install the lockwashers and mounting bolts. Tighten the bolts 35 lbf·ft (47 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.
6. Turn the steering wheel from full-left to full-right two or three times with the engine running at idle. Repeat this step, and add fluid as necessary until there are no bubbles in the reservoir.
7. Remove the chocks from the tires.

Specifications

CAUTION

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.

Steering System Hydraulic Fluid	
Fluid Type	**Recommended Fluid**
Automatic Transmission Fluid	Dexron III

Table 1, Steering System Hydraulic Fluid

General Information

The SmartWheel Steering Wheel Control System offers control of the horn, headlamp and marker lamp interrupt, cruise control, and wiper functions from switches mounted in the steering wheel. The system consists of two components: the PC209 and PC210 steering wheel, or PC217 steering wheel and the SM209 master control. Communication between the steering wheel and the master control is accomplished through two wires. The two wires carry a multiplexed communication signal and power for the steering wheel electronics. Some systems include two additional wires to provide power to backlight the steering wheel switches.

Since February 2001, steering columns equipped with clock springs have been widely used in motor homes. The clock spring is a device in the steering column that allows continuous electrical connections through the rotation of the column without sliding contacts. Steering wheel item numbers PC210x and PC217x utilize four wires for this purpose. The controls on these wheels are backlit.

Troubleshooting

CAUTION

Clock springs can be damaged if they are not handled and installed properly. Failure to follow the proper procedure can result in the clock spring being damaged, although the damage may not be immediately apparent.

The most common problem with any electrical device is usually related to interconnections: wires and connectors.

1. If the system does not function correctly, check that all connectors and wires are properly installed and fully seated, making good contact.
2. If the system is partially functional, for example, the horn, cruise control, and lights work but the wipers do not, then the problem is likely not with the multiplex system but with the wiring between the master control and the wipers, or the wiper system itself.
3. If the system is completely nonfunctional, start by checking the power, ground, and wiring to the master control and from the master control to the steering wheel.
4. If the system functions intermittently, the problem is most likely with the wiring in general or with connections in the steering column.

   If the SmartWheel Steering Wheel Control System does not operate correctly, use the following troubleshooting procedures to identify and repair the problem. See **Fig. 1** for the VIP master controller chassis wiring diagram.

Initial In-Vehicle Tests

See **Fig. 2** for the Multiplex IPX master controller.

Proceed with the following instructions in the order in which they are listed prior to attempting any other in-vehicle tests.

1. Turn the ignition to the OFF position.
2. Disconnect connectors J5, J9, J10, and J12 from the master control.
3. Make sure that +12Vdc power is present at J2.5, J2.6 and connector J6 on the master control. If +12Vdc power is not present, check the supply fuses or breakers and wiring.
4. Measure the DC voltage at J1.1 (multiplex SIG) on the master control. It should measure in the range of 7 to 10 volts. If it doesn't, check the continuity between J1.2 and chassis ground. If continuity exists, replace the master control.

NOTE: The steering wheel does not have to be completely removed from the column to perform the following tests.

5. Remove the center pad from the steering wheel and disconnect the steering wheel from the clock spring. The center pad can be removed by loosening a 5 mm Allen-head screw. The screw is accessible through a hole on the bottom of the steering wheel below the horn bar. The Allen-head screw does not have to be completely removed for the center pad to be released.
6. Measure the DC voltage between the wires in the column that were connected to the yellow and brown wires on the steering wheel. It should also measure in the range of 7 to 10 volts. If it does not, check the wiring in the column and to the master control for continuity. If it does, reconnect the steering wheel to the column wiring.

In-Vehicle Tests

Perform the above initial in-vehicle tests before attempting to perform the following tests. Select these tests if problems are observed with a particular function. Make sure that connectors J5, J9, J10, J11, and J12 are disconnected from the master control.

Horn Test

Connect the low-current test light between a +12Vdc source and J2.1 (horn output) on the master control. Press the horn bar on the steering wheel and make sure the test light illuminates. If it does not, the horn output on the master control is damaged. Replace the master control.

IMPORTANT: For the lamp flash tests below, the ignition switch on the vehicle should be turned to the "ACCESSORY" or "RUN" position, causing +12Vdc to be present at J2.4 on the master control.

Troubleshooting

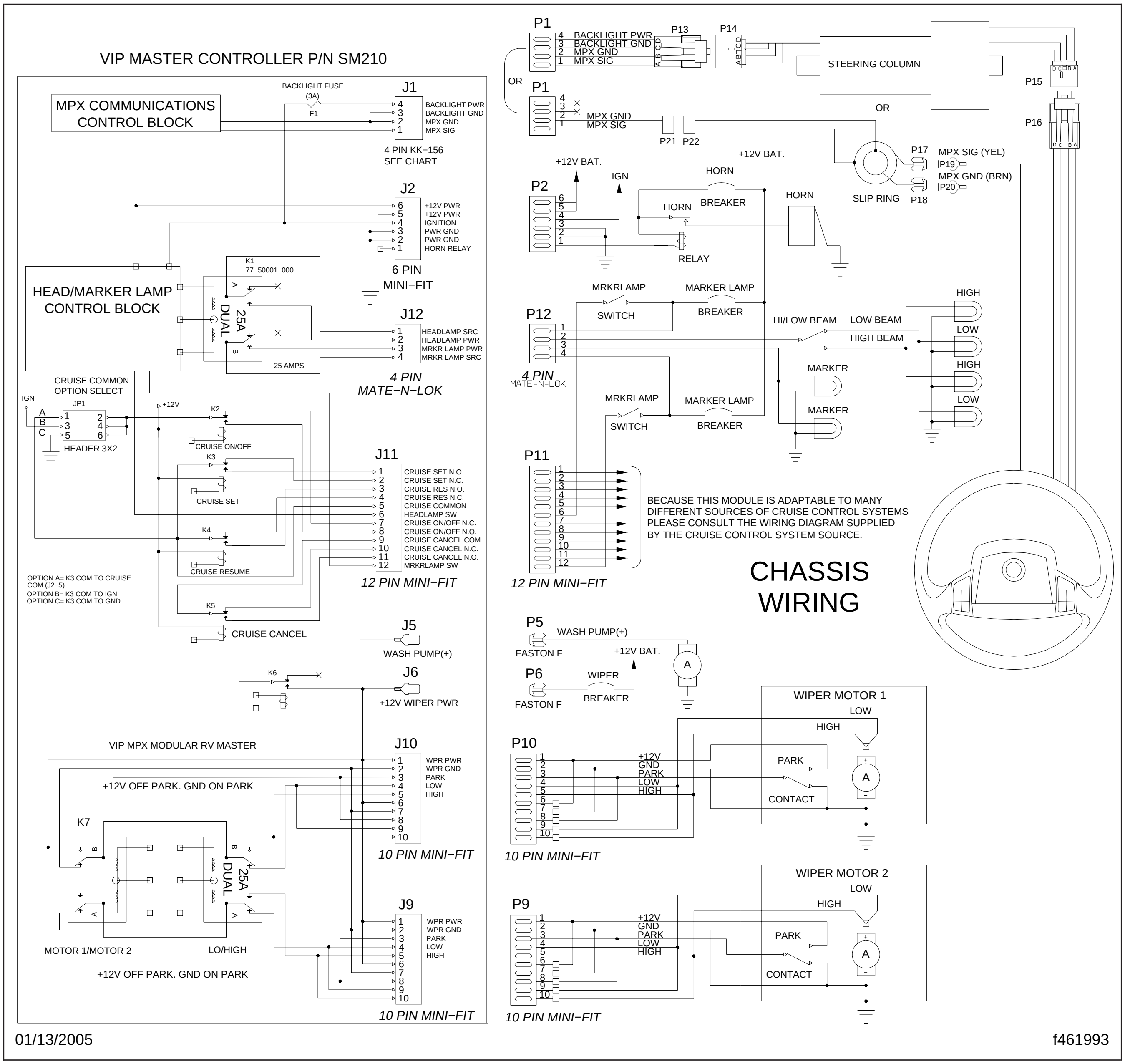


Fig. 1, VIP Master Controller Chassis Wiring Diagram

Headlamp "OFF" Test

With no switches pressed on the steering wheel and the dash headlamp switch in the "OFF" position, check for continuity between J12.1 and J12.2 on the master control. If continuity does exist, the headlamp "OFF" circuitry on the master control is damaged. Replace the master control.

Headlamp "ON" Test

With the headlamp flash switch on the steering wheel pressed and the dash headlamp switch "OFF", check

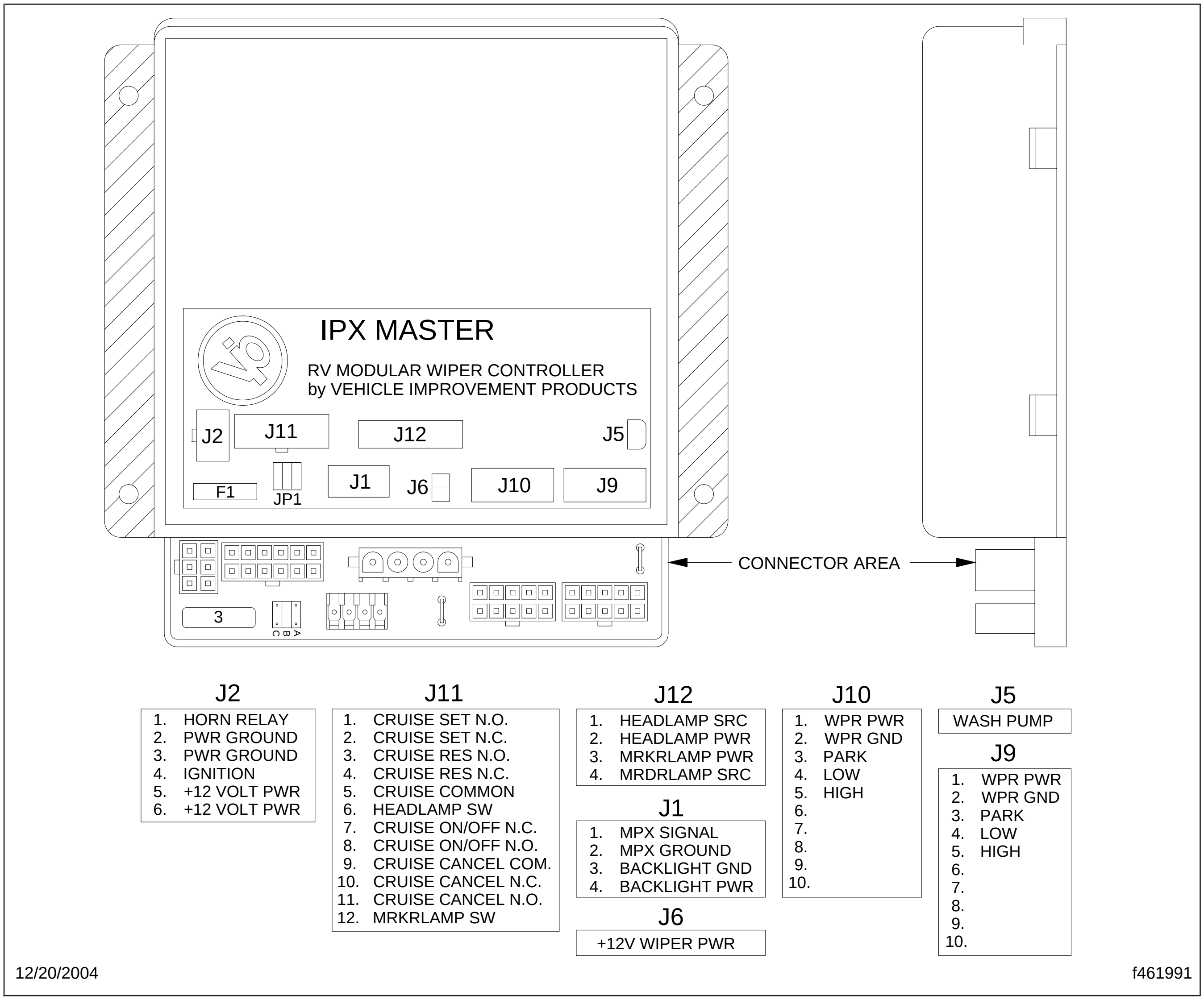


Fig. 2, Multiplex IPX Master Controller

for continuity between J12.1 and J12.2 on the master control. If continuity does not exist, the headlamp "ON" circuitry on the master control is damaged. Replace the master control.

Master Lamp "OFF" Test

With no switches pressed on the steering wheel and the dash headlamp switch "OFF", check for continuity between J12.3 and J12.4 on the master control. If continuity does exist, the marker lamp "OFF" circuitry on the master control is damaged. Replace the master control.

Marker Lamp "ON" Test

With the marker lamp interrupt switch on the steering wheel pressed and the dash headlamp switch "OFF", check for continuity between J12.3 and J12.4 on the master control. If continuity does not exist, the marker lamp "ON" circuitry on the master control is damaged. Replace the master control.

Troubleshooting

IMPORTANT: For the cruise and wiper tests below, the ignition switch on the vehicle should be turned to the "ACCESSORY" or "RUN" position, causing +12Vdc to be present at J2.4 on the master control. Note the position of the jumper on the configuration header JP1 so that the unit can be returned to that configuration after the tests have been completed. After that position is noted, place the jumper in position "A" so that "CRUISE COMMON" is the source.

NOTE: The J11 harness must be unplugged to perform the cruise tests. All tests need to be performed at the master controller, not the harness.

Cruise "ON" Test

Press the cruise "ON" switch on the steering wheel. Once the switch is released, the cruise function should be active. Check for continuity between J11.5 and J11.8 on the master control. If continuity does not exist, the cruise "ON" circuitry on the master control is damaged. Replace the master control.

Cruise "OFF" Test

Press the cruise "OFF" switch on the steering wheel. Once the switch is released, the cruise function should be active. Check for continuity between J11.5 and J11.7 on the master control. If continuity does not exist, the cruise "OFF" circuitry on the master control is damaged. Replace the master control.

Cruise "SET" Test

With the cruise "SET" switch on the steering wheel not pressed, check for continuity between J11.5 and J11.2 on the master control. If continuity does not exist, the cruise "SET" circuitry on the master control is damaged and must be replaced. With the cruise "SET" switch on the steering wheel pressed, check for continuity between J11.5 and J11.1 on the master control. If continuity does not exist, the cruise "SET" circuitry on the master control is damaged. Replace the master control.

Cruise "RESUME" Test

With the cruise "RESUME" switch on the steering wheel not pressed, check for continuity between J11.5 and J11.4 on the master control. If continuity does not exist, the cruise "RESUME" circuitry on the master control is damaged and must be replaced. With the cruise "RESUME" switch on the steering wheel pressed, check for continuity between J11.5 and J11.3 on the master control. If continuity does not exist, the cruise "RESUME" circuitry on the master control is damaged. Replace the master control.

Cruise "CANCEL" Test

With the cruise "CANCEL" switch on the steering wheel not pressed, check for continuity between J11.9 and J11.10 on the master control. If continuity does not exist, the cruise "CANCEL" circuitry on the master control is damaged and must be replaced. With the cruise "CANCEL" switch on the steering wheel pressed, check for continuity between J11.9 and J11.11 on the master control. If continuity does not exist, the cruise "CANCEL" circuitry on the master control is damaged. Replace the master control.

Wiper "WASH" Test

With the wiper "WASH" switch on the steering wheel pressed, check for +12Vdc at J5. If +12Vdc is not present at J5, the wash pump output circuitry on the master control is damaged and must be replaced. In addition, check for the presence of +12Vdc at J9.4 and J10.4. If +12Vdc is not present, the low speed wiper wash circuitry on the master control is damaged. Replace the master control.

Wiper "LO/HI" Test

Press the wiper "LO/HI" switch on the steering wheel. The function should remain active after the switch is released. Check for the presence of +12Vdc at J9.4 and J10.4 on the master control. If +12Vdc is not present, the continuous low-speed wiper circuitry on the master control is damaged and must be replaced. Press the wiper "LO/HI" switch again and check for the presence of +12Vdc at J9.5 and J10.5 on the master control. If +12Vdc is not present, the continuous high-speed wiper circuitry on the master control is damaged. Replace the master control.

Wiper "OFF" Test

Press the wiper "OFF" switch on the steering wheel. The function should remain active after the switch is released. Check for no output at J9.4, J9.5, J10.4, and J10.5 on the master control. If +12Vdc power is present on any of these output pins, the wiper "OFF" circuitry on the master control is damaged. Replace the master control. In order to check the dynamic braking circuitry after the wiper "OFF" switch is pressed, check for continuity between J9.2 and J9.4 and also between J10.2 and J10.4. If continuity does not exist, the dynamic braking circuitry on the master control is damaged. Replace the master control.

Wiper "VARIABLE" Test

Connect the wiper motor(s) at the master (J9 and J10) and verify correct operation. Operation of this switch initially causes the low speed wiper outputs (J9.4 and J10.4) to be connected to 12Vdc wiper power (J6) for one wipe. If the switch is pressed again within approximately 30 seconds, the low speed wiper function will be activated again and will repeat at an interval determined by the time between the last two operations of the switch. Additional switch operations will shorten the cycle. Activation of any other wiper mode cancels the variable mode. If the operation is not performed as described, the variable delay circuitry on the master control is damaged. Replace the master control.

Steering Wheel

If 7 to 10 volts are present on the yellow and brown wires on the steering wheel, and the master control is not responding to any button presses in the above tests, replace the steering wheel.

Backlit Steering Wheel

On steering wheels mounted on clock spring-equipped steering columns, the steering wheel switch pads are backlit by light emitting diodes (LEDs). If the backlighting is not working, remove the center pad from the steering wheel as described previously. Measure the DC voltage between the black and green wires on the steering wheel. There should be 12 volts present when the ignition is on. If not, check the 3 amp fuse on the master control. If the fuse is good, check for 12 volts on J1.4 on the master control. If there are 12 volts present at J1.4 on the master control and not at the steering wheel then check the wiring between the master control and the steering wheel. If there are 12 volts present at the steering wheel and the backlighting is not working, replace the steering wheel.

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.

<table>
<tr><th colspan="13">Steering Complaint and Troubleshooting Steps Checklist</th></tr>
<tr><th rowspan="2">LH</th><th rowspan="2">RH</th><th rowspan="2">Both</th><th rowspan="2">Complaint</th><th colspan="9">Troubleshooting Steps</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th></tr>
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<tr><td></td><td></td><td></td><td>Low assist</td></tr>
<tr><td></td><td></td><td></td><td>Binding</td></tr>
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<tr><td></td><td></td><td></td><td>Occasional loss of assist</td></tr>
<tr><td></td><td></td><td></td><td>Reduced wheel cut</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>•</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Pulling to one side*</td><td>•</td><td></td><td>•</td><td></td><td></td><td>•</td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td>Excessive heat</td></tr>
</table>

* 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.

Troubleshooting Procedures

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.

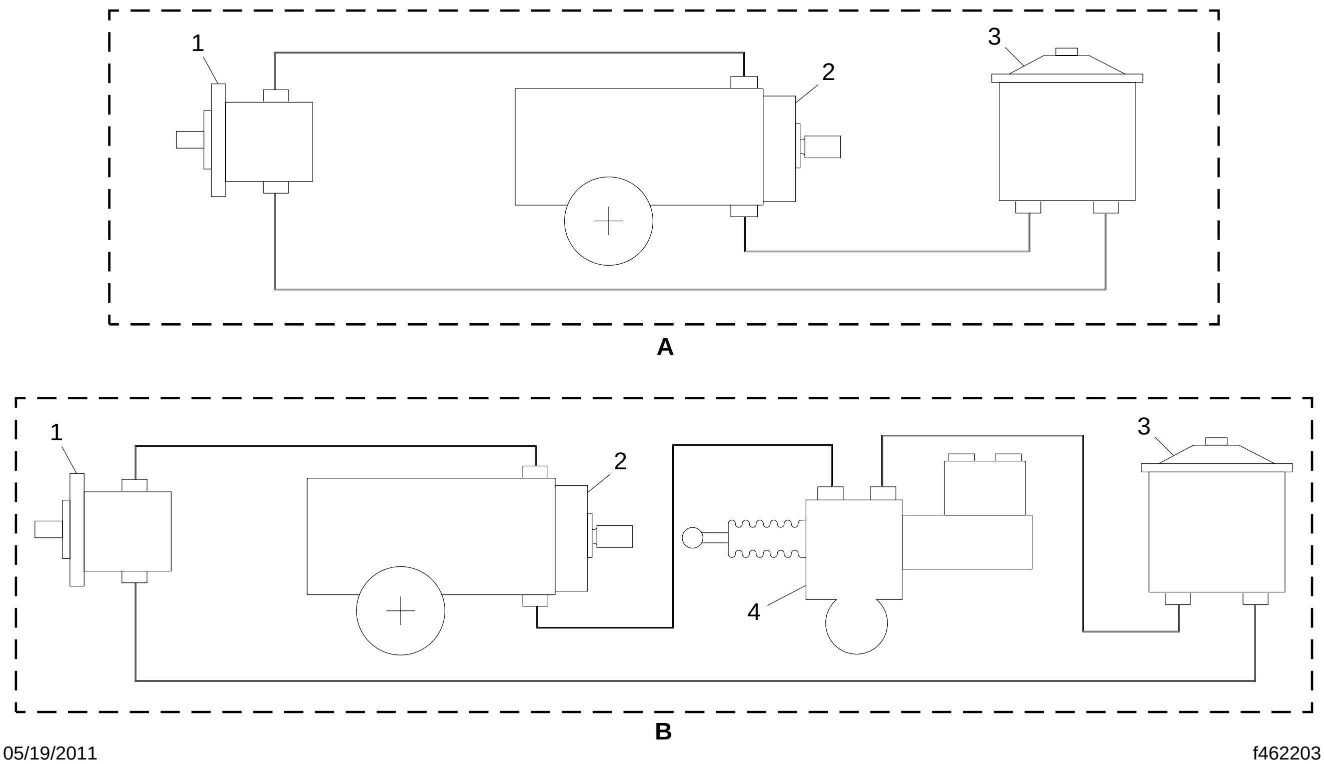
  If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to step 6.

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
B. Vehicles With Hydraulic Brakes

1. Steering Pump
2. Steering Gear
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.

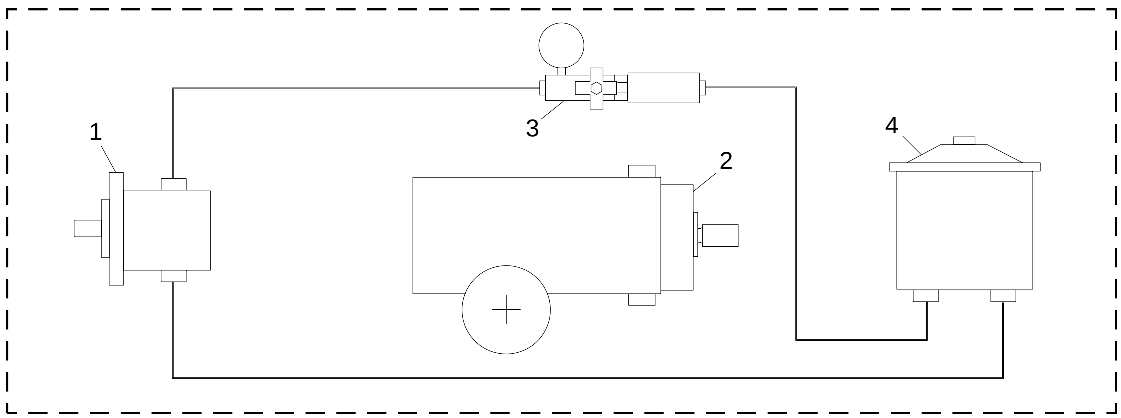
  If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.

- 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.



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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.

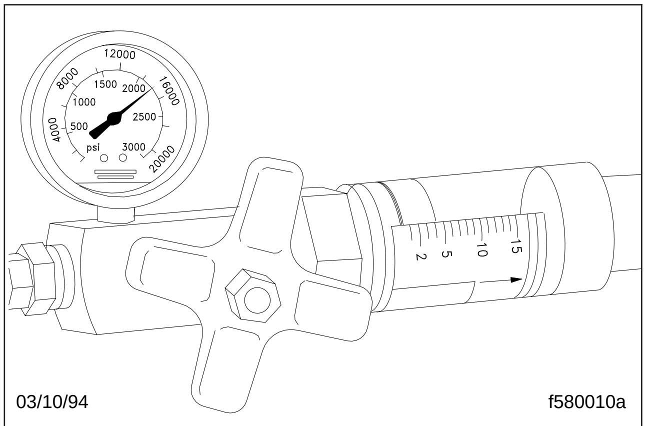


Fig. 3, Power Steering System Analyzer

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.

Troubleshooting Procedures

NOTICE

Do not leave the PSSA shutoff valve fully closed for longer than five seconds. Doing so could damage the power steering system.

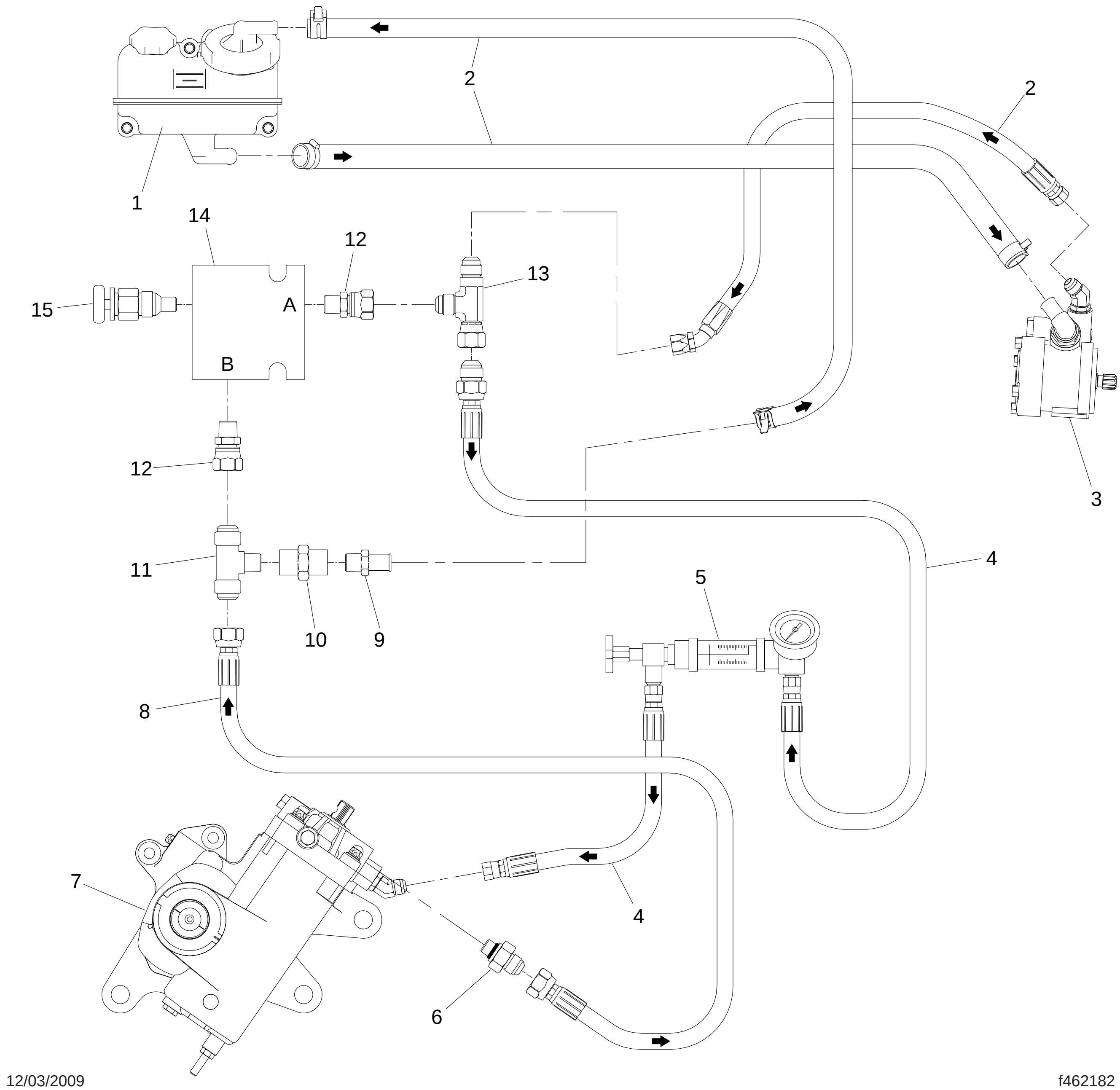
8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve (**Fig. 4**, Item 15) until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal leakage test (step 9 of the **Troubleshooting Steps** heading above).

Internal Leakage Test Components			
Part	**Available From**	**Part Number (Vendor P/N)**	**Item #, Fig. 4**
Power Steering System Analyzer (PSSA)	SPX Kent-Moore	J-26487	5
PSSA Adaptor Kit	SPX Kent-Moore	J-28593	—
Relief Valve Plug	SPX Kent-Moore	J-37130	—
Connector, Straight Thread with O-Ring	Daimler Trucks PDC	23-11470-088	6
Power Steering Hose, 42"	Daimler Trucks PDC	14-12694-042	8
Connector, 3/8" Male NPT to 5/8" Beaded Hose Barb	Daimler Trucks PDC	23-11321-001	9
Pipe Coupling, 3/8" NPT	Parker Hannifin	PH 3/8 GG S (3/8 GG-S)	10
Tee, Male JIC with Male NPT Branch*	Parker Hannifin	PH 8STXS (8 STX-S)	11
Swivel Adaptor, 3/8" Male NPT to Female 37 degree JIC (qty 2)	Weatherhead	WH 9100X8X6 (9100x8x6)	12
Swivel Nut Run Tee	Parker Hannifin	PH 8 R6X S (8 R6X-S)	13
3/8" Female NPT Aluminum Relief Valve Threaded Cartridge Body	Parker Hannifin	B10-2-A6P (PH B102A6P)	14
Aluminum Hydraulic Threaded Cartridge Relief Valve with Knob	Parker Hannifin	PH RAH101K30 (RAH101K30)	15

* Use steel 37 degree JIC fittings only.

Table 5, Internal Leakage Test Components

Troubleshooting Procedures



A. High-Pressure Input Port
B. Low-Pressure Output Port

1. Power Steering Fluid Reservoir
2. Existing Power Steering Fluid Lines (Qty 3)
3. Power Steering Pump
4. PSSA Fluid Lines (Qty 2)
5. PSSA
6. Connector, Straight Thread with O-Ring
7. Power Steering Gear (TAS85 shown)
8. Power Steering Hose, 42"
9. Connector, Male NPT to Beaded Hose Barb
10. Pipe Coupling
11. Tee, Male JIC with Male NPT Branch
12. Swivel Adaptor (Qty 2)
13. Swivel Nut Run Tee
14. Relief Valve Threaded Cartridge Body
15. External Relief Valve, Threaded Cartridge Type

Fig. 4, Internal Leakage Test Component Installation

General Information

The TRW PS Series power steering pump supplies fluid for the operation of the power steering gear. See **Fig. 1**.

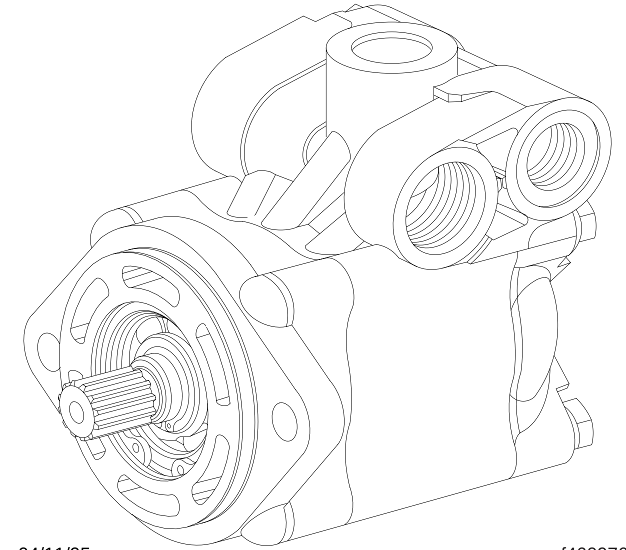


Fig. 1, TRW PS Series Power Steering Pump

The main parts of the power steering pump are the housing, input shaft, cam ring, rotor, vanes, control valve, and cover assembly.

Principles of Operation

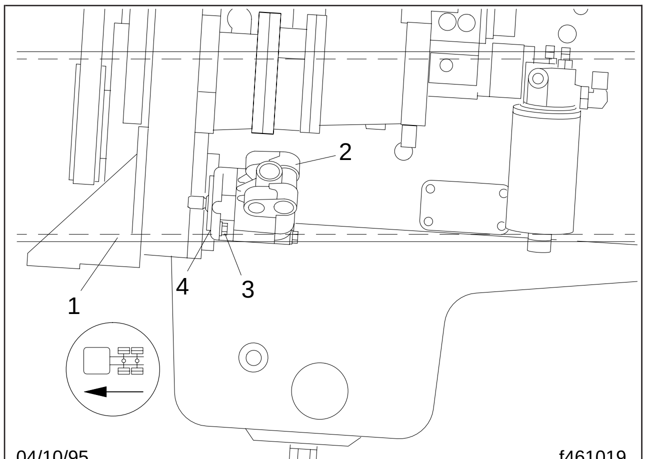
The input shaft, powered by the adaptor gear in the engine gear case, or by the crankshaft pulley, turns the rotor, which is inside the cam ring. As the rotor turns, centrifugal force pushes the vanes out toward the surface of the cam ring. As fluid enters the cam ring through the inlet port, the rotor 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.

If the system pressure gets too high, a relief valve 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 relief valve 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.

Steering Pump Removal and Installation

Removal

1. Apply the parking brake, chock the tires.
2. Clean all outside dirt from around the fittings and hose connections.
3. Put a container under the pump, then disconnect the hoses from the fittings on the pump. Plug the hoses and cap the fittings to keep out dirt and to prevent fluid from leaking.
4. Remove the mounting capscrews and lockwashers that attach the pump to the engine accessory drive mounting flange. See **Fig. 1**. Hold the pump as you remove the second mounting bolt.



1. Frame Rail
2. Steering Pump
3. M10 x 35 Capscrew and 7/16-inch Lockwasher
4. Gasket

Fig. 1, TRW PS Series Power Steering Pump Mounting

5. Pull the pump straight out from the engine. Keep it level to avoid spilling fluid.
6. Turn the pump upside down over a container and let the fluid drain out.
7. Discard the gasket from the pump mounting flange.

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 engines accessory drive mounting flange.
3. Install the lockwashers and capscrews, and tighten them 35 lbf·ft (46 N·m).
4. Connect the inlet hose (from the power steering reservoir) to the inlet port. Tighten it 26 lbf·ft (35 N·m).
5. Connect the outlet hose (from the power steering gear) to the outlet port.
6. Bleed the power steering system.
   - 6.1 Check the fluid level in the power steering reservoir and if needed, fill it to the correct level. For the approved steering system fluid, see **Specifications, 400**.
   - 6.2 Start the engine and let it idle for several minutes.
   - 6.3 Turn the wheels to a full-left and full-right turn. Repeat three times.
   - 6.4 Check the fluid level in the power steering reservoir. Add fluid as necessary to the full line on the reservoir dipstick.
   - 6.5 Shut down the engine.
7. Remove the chocks.

Steering Pump Disassembly, Inspection, and Assembly

CAUTION

Be careful when working on the pump housing; it is aluminum, and can be easily damaged. When putting the pump in a vise, pad the vise jaws and clamp only the cover; tighten the vise just enough to hold the pump.

Disassembly

NOTE: Prepare for fluid drainage before disassembling the pump.

1. Remove the power steering pump from the engine, following the instructions in **Subject 100**.
2. Carefully remove the end plug from the pump housing. See **Fig. 1** and **Fig. 2**. Remove the spring, if it didn't come out with the end plug. See **Fig. 3**.
3. Remove and discard the O-ring from the plug.

IMPORTANT: TRW does not recommend disassembly of the control valve spool assembly.

4. Remove the control valve spool assembly by hand, or by pushing it with a small rod. See **Fig. 4**. Don't push on the small screen in the relief valve seat assembly.
5. Using a solvent-proof marker, make a mark across the housing and the cover. See **Fig. 5**. Remove the four screws and washers that hold the housing and the cover together. See **Fig. 6**. Using a twisting motion, separate the housing from the cover.
6. Remove the spring. See **Fig. 7**.
7. Using a solvent-proof marker, draw a line across the top plate and the bottom plate. See **Fig. 8**.
8. Holding the cam ring in place, remove the top plate. See **Fig. 9**. Remove and discard the O-ring and backup O-ring.
9. Holding the bottom plate in place, remove the cam ring. Note and record whether the dots near the locating pin holes on the cam ring are up or down. See **Fig. 10**.
10. Look for wear on the outside edge of the vanes. Note and record the direction of the wear for assembly. Carefully remove the rotor and vanes, as the vanes will slip from their slots in the rotor. See **Fig. 11**.
11. Remove the locating pins. See **Fig. 12**. Make marks on the outside of the cover (not on the sealing surface) to note from which holes the locating pins were removed.
12. Remove the bottom plate. See **Fig. 13**.
13. Turn the cover over and remove the large retaining ring. See **Fig. 14**.
14. Press out the input shaft and ball bearing assembly. See **Fig. 15**.
15. Remove the spacer from the cover. See **Fig. 16**.
16. Using care not to damage the bore, remove the shaft seal. See **Fig. 17**.

Inspection

1. Clean all the parts, using a solvent compatible with the steering system hydraulic fluid. Then, using filtered compressed air, dry all the parts.

NOTE: Replace any parts that are damaged or worn.

2. Inspect the housing for cracks, stripped threads, a damaged valve bore, and damaged sealing areas. See **Fig. 18**.
3. Inspect the cover for nicks in the O-ring seal grooves. Make sure that the seal drain hole is open, and that the seal bore is free of nicks and other damage. See **Fig. 19**.

   Make sure that the surface on which the bottom plate rests is flat and free of nicks and other damage.
4. Check that the needles roll freely in the needle bearing. If needed, replace the needle bearing, as follows.

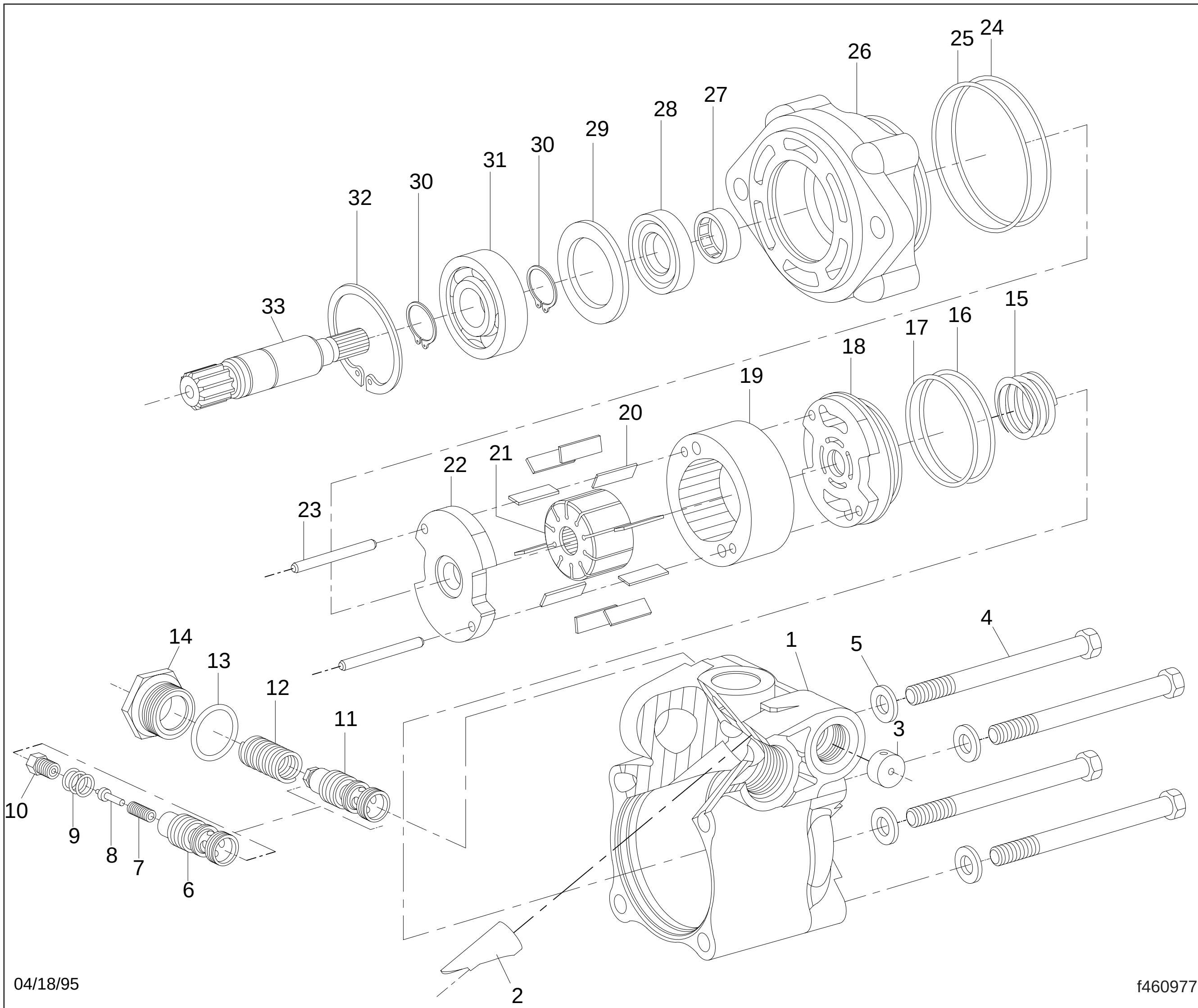
   4.1 Place the cover in a press with the flange side down. Using an 11/16-inch socket, press the needle bearing out of the cover. See **Fig. 20**.

CAUTION

Make sure that the press is clean and free of debris. Debris could damage the face of the cover, which will affect pump operation.

   4.2 Put the cover in a clean press with the flange side up. Make sure that the lettered

Steering Pump Disassembly, Inspection, and Assembly



1. Pump Housing
2. Boost Tube
3. Orifice
4. Mounting Bolt
5. Washer
6. Spool
7. Spring
8. Poppet
9. Shims
10. Relief Valve Seat Assembly
11. Control Valve Spool Assembly
12. Spring
13. O-Ring
14. Plug
15. Spring
16. O-Ring
17. Backup O-Ring
18. Top Plate
19. Cam Ring
20. Vane
21. Rotor
22. Bottom Plate
23. Locating Pin
24. Small O-Ring
25. Large O-Ring
26. Cover
27. Needle Bearing
28. Shaft Seal
29. Spacer
30. Small Retaining Ring (2 qty.)
31. Ball Bearing
32. Large Retaining Ring
33. Input Shaft

Fig. 1, Steering Pump, Exploded View

Steering Pump Disassembly, Inspection, and Assembly

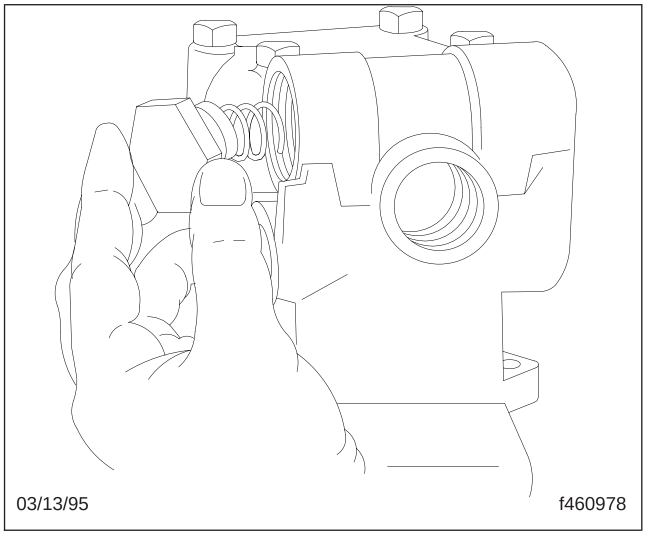


Fig. 2, Removing the End Plug

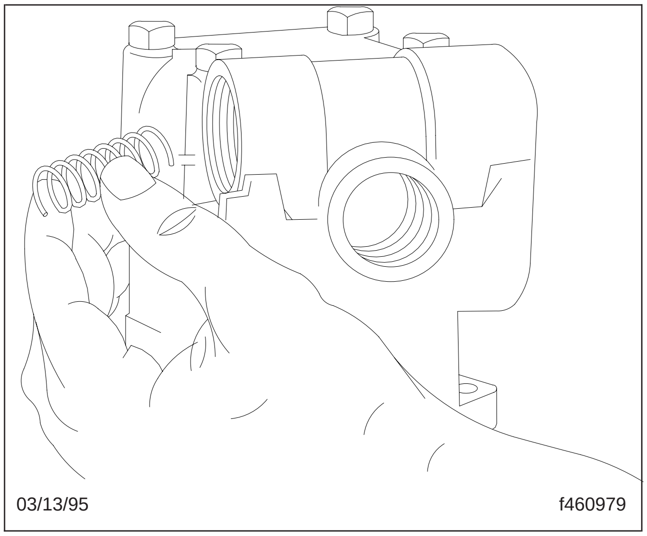


Fig. 3, Removing the Spring

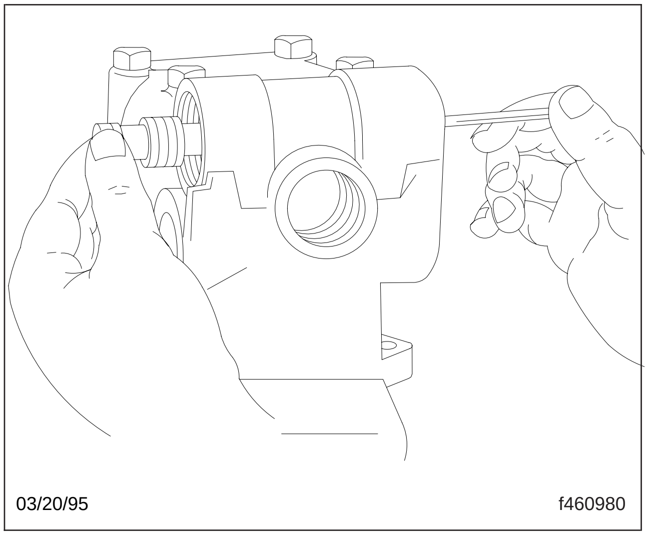


Fig. 4, Removing the Control Valve Assembly

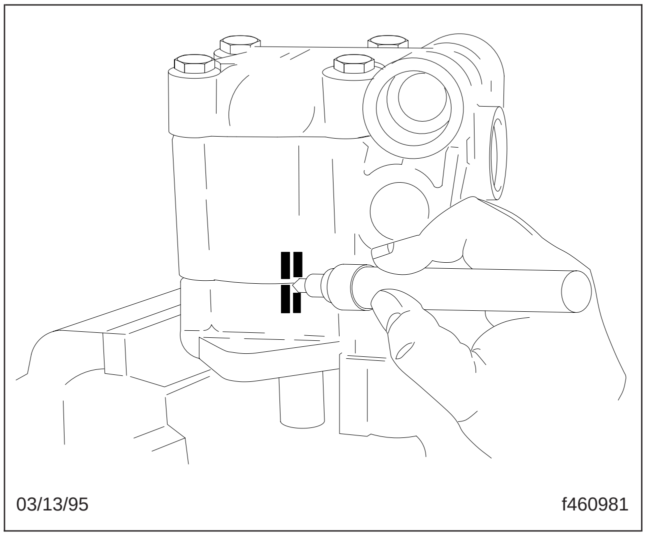


Fig. 5, Marking the Housing and the Cover

side of the needle bearing is facing toward the press.

4.3 Using a 7/8-inch deep socket, press the new needle bearing into the cover until it is flush with the inside surface of the cover. See **Fig. 21**.

5. Inspect the top plate for seal area nicks, and abnormal wear or erosion. A polished pattern from the rotor and vanes is normal; grooves you can feel with your fingernail are not normal.

6. Look for abnormal wear, erosion, or surface damage on the inside of the cam ring.

7. Check the vanes on the rotor for damage or too much play in the rotor slots. See **Fig. 22**. If you can move the vanes from side-to-side in the slots, replace the whole rotor assembly.

NOTE: If the vanes are removed, make sure they are installed with the rounded edge out.

8. Check the bottom plate for abnormal wear patterns.

Steering Pump Disassembly, Inspection, and Assembly

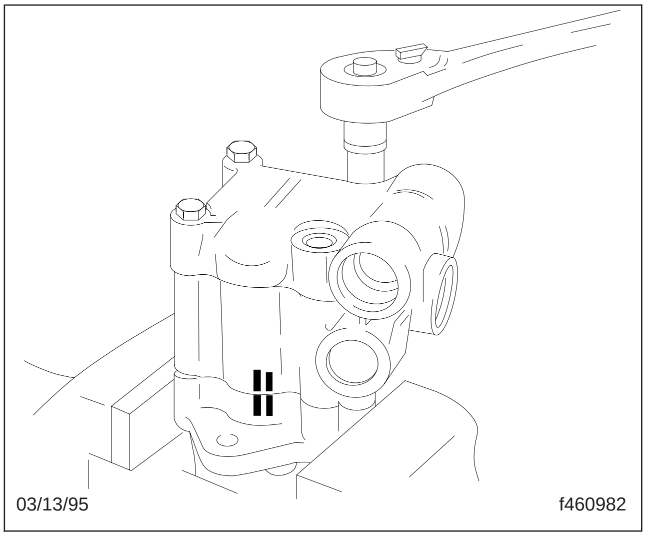


Fig. 6, Removing the Screws and Washers

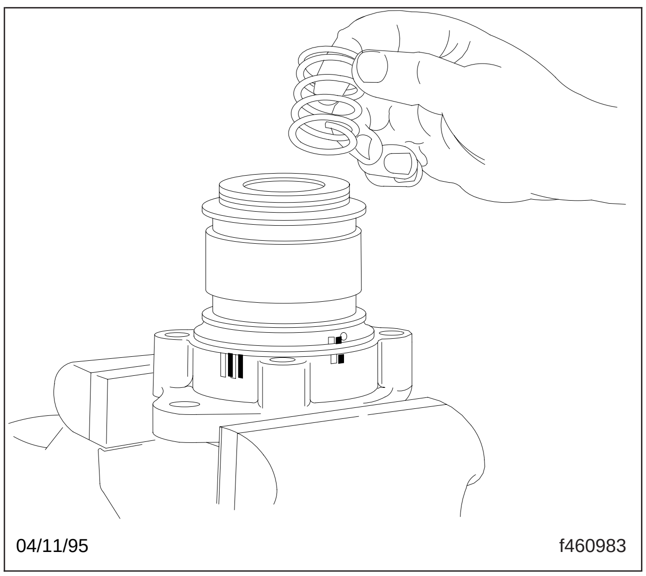


Fig. 7, Removing the Spring

9. Check the input shaft for damaged splines and abnormal wear grooves around the seal area. See **Fig. 23**. If there are grooves that can be detected with your fingernail, replace the input shaft, as follows.

    9.1 Remove the retaining ring (engine drive end) from the shaft. See **Fig. 24**.

    Remove the woodruf key, if equipped.

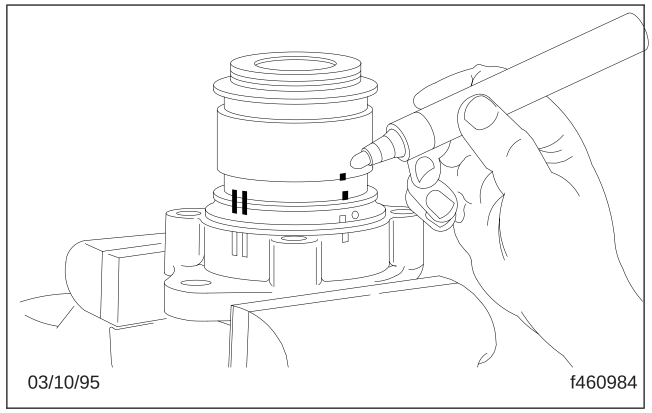


Fig. 8, Marking the Top Plate and the Bottom Plate

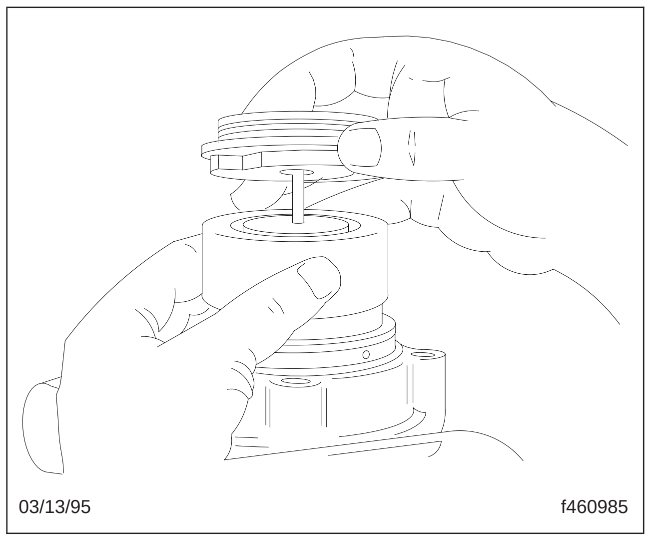


Fig. 9, Removing the Top Plate

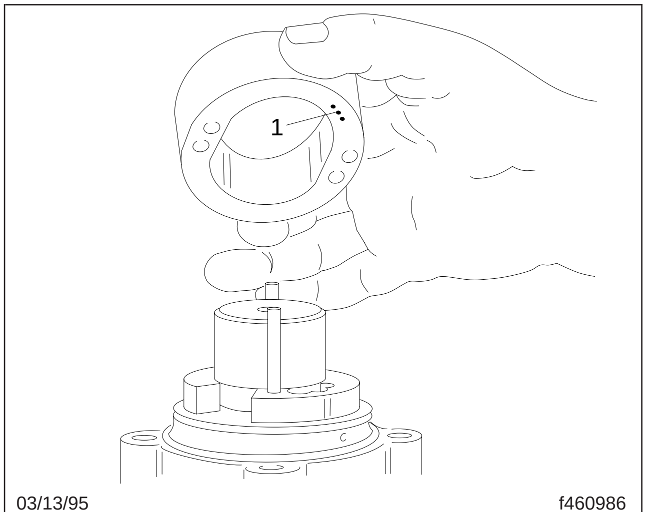
    9.2 Applying pressure to the engine drive end of the input shaft, press the input shaft from the ball bearing. See **Fig. 25**.

    9.3 Press the new input shaft (from the small splined end) into the ball bearing until the shaft bottoms out on the retaining ring. See **Fig. 26**.

    9.4 Install the retaining ring on the input shaft with the sheared edge pointing away from the bearing. Make sure that the retaining ring is properly seated.

IMPORTANT: TRW does not recommend disassembly of the control valve spool assembly.

Steering Pump Disassembly, Inspection, and Assembly



1. Dots

Fig. 10, Checking Whether the Dots are Up or Down.

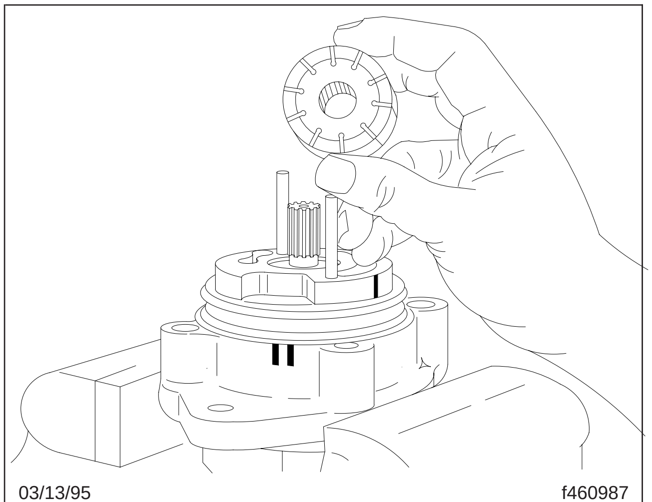


Fig. 11, Removing the Rotor and Vanes

10. Check the control valve spool assembly for wear or chipping. If needed, back-flush with air and solvent. Check the assembly for nicks or burrs.

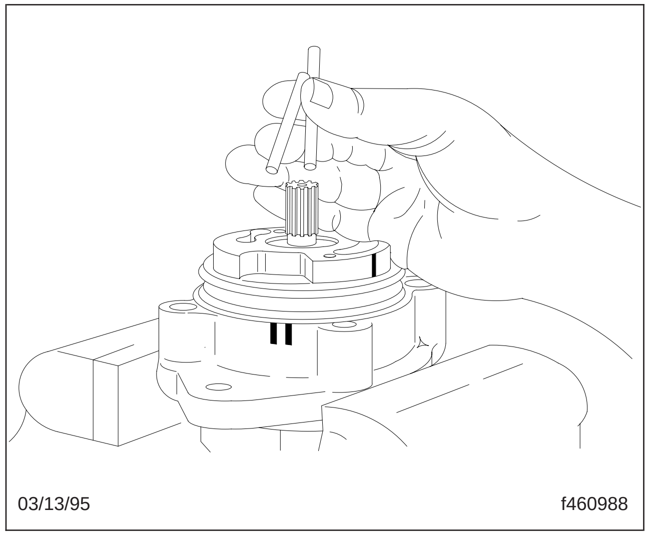


Fig. 12, Removing the Locating Pins

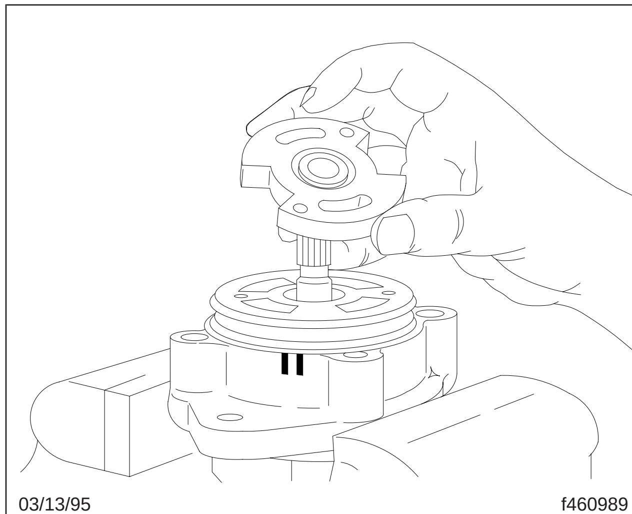


Fig. 13, Removing the Bottom Plate

Assembly

CAUTION

Make sure that the press is clean and free of debris. Debris could damage the face of the cover, which will affect pump operation.

1. Coat the outside surface of the shaft seal with a petroleum-based chassis grease. With the lettered side facing toward the needle bearing, press the seal into the cover. See **Fig. 27**. The

Steering Pump Disassembly, Inspection, and Assembly

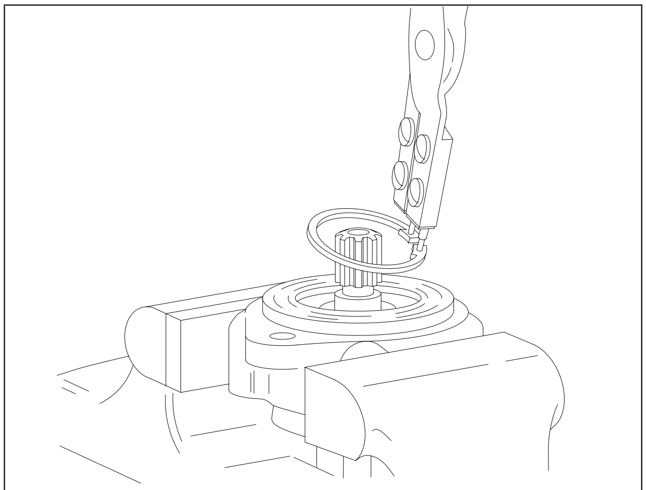


Fig. 14, Removing the Large Retaining Ring

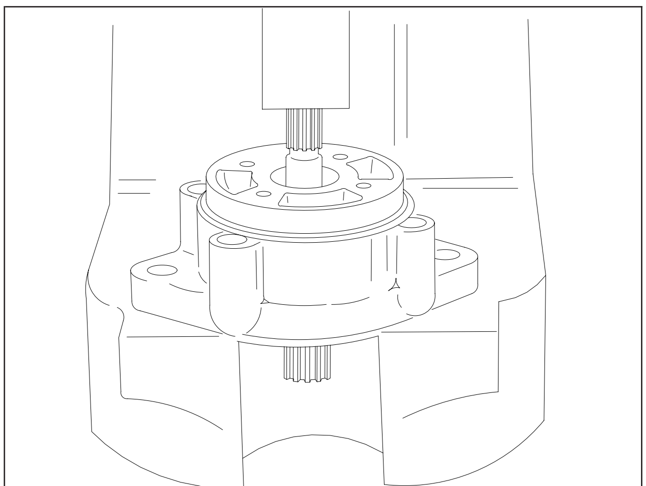


Fig. 15, Pressing out the Input Shaft and Ball Bearing Assembly

installed seal should be flush with, or just below, the sealing surface on the cover.

2. Grease the inside surface of the shaft seal using a petroleum-based chassis grease.
3. Install the spacer. See **Fig. 16**. Make sure that it lies flat.

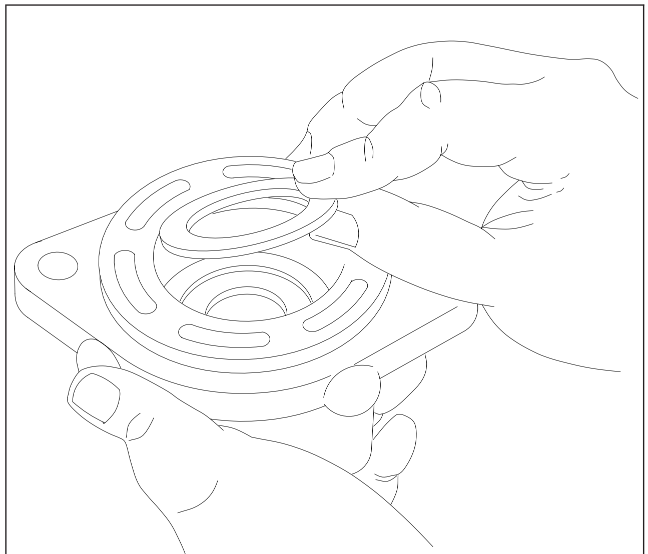


Fig. 16, Removing the Spacer

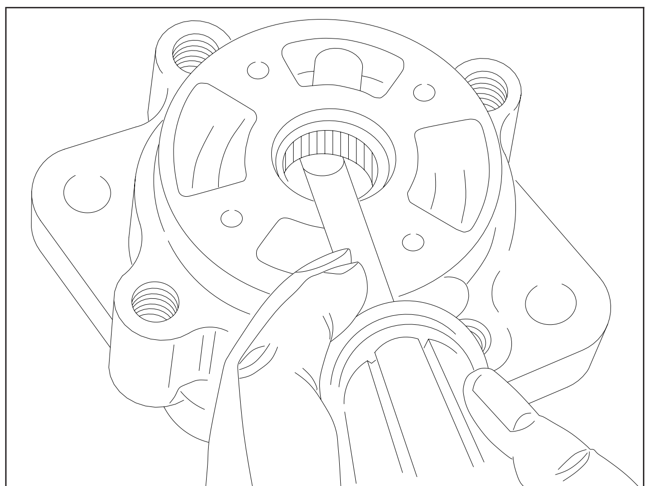


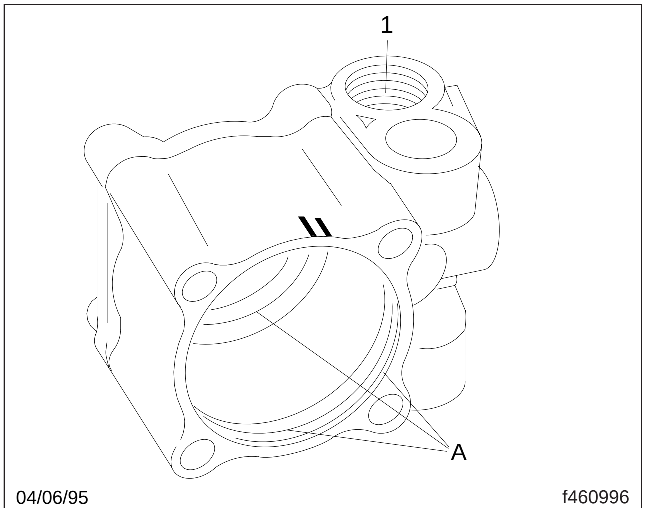
Fig. 17, Removing the Shaft Seal

CAUTION

Do not allow the splines to contact the shaft seal. The splines could damage the shaft seal.

4. Insert the input shaft (small splined end first) into the cover. Don't allow the splines to contact the shaft seal. Insert the shaft into the seal by hand until the ball bearing contacts the cover.

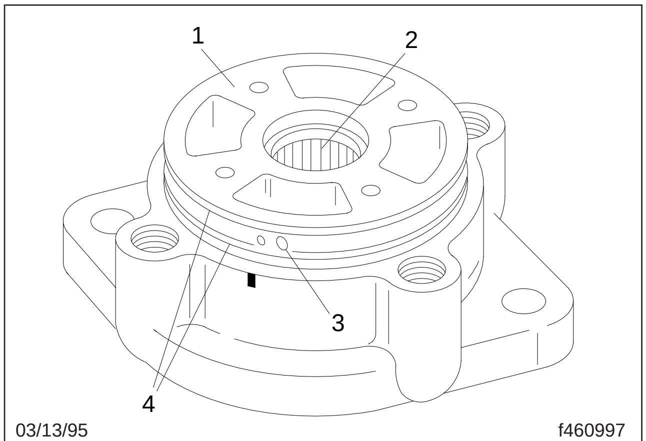
Steering Pump Disassembly, Inspection, and Assembly



A. Sealing Areas

1. Valve Bore

Fig. 18, Housing Inspection Areas



1. Bottom Plate Surface
2. Needle Bearing
3. Seal Drain Hole
4. Seal Grooves

Fig. 19, Cover Inspection Areas

Using a 7/8-inch socket, press the shaft and bearing into the cover. See **Fig. 28**.

CAUTION

When placing the cover in a padded vise, do not use excessive clamping force. This could damage the cover.

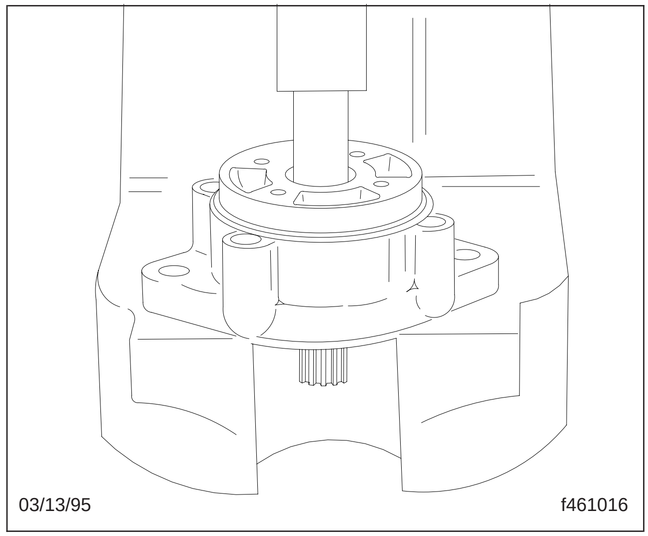


Fig. 20, Pressing the Needle Bearing out of the Cover

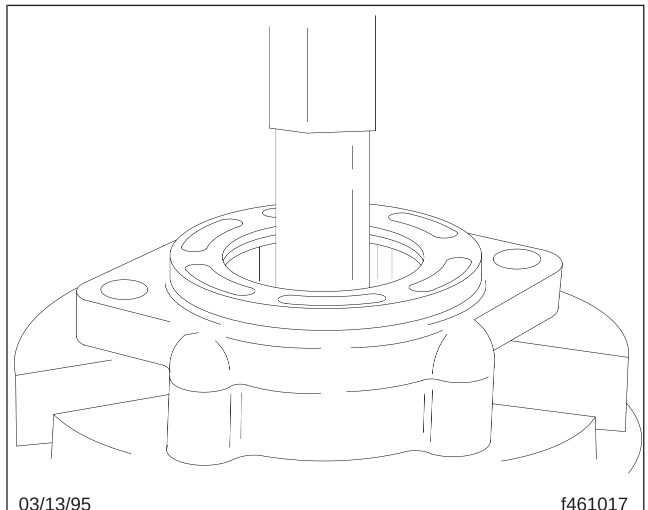


Fig. 21, Pressing a New Needle Bearing into the Cover

5. Place the cover in a padded vise and install the large retaining ring with the sheared edge out.

   Turn the cover assembly over.
6. Install the new large and small O-rings in the cover. Make sure that they are seated properly. See **Fig. 29**.
7. Using the marks made during disassembly as a guide, install the locating pins.

Steering Pump Disassembly, Inspection, and Assembly

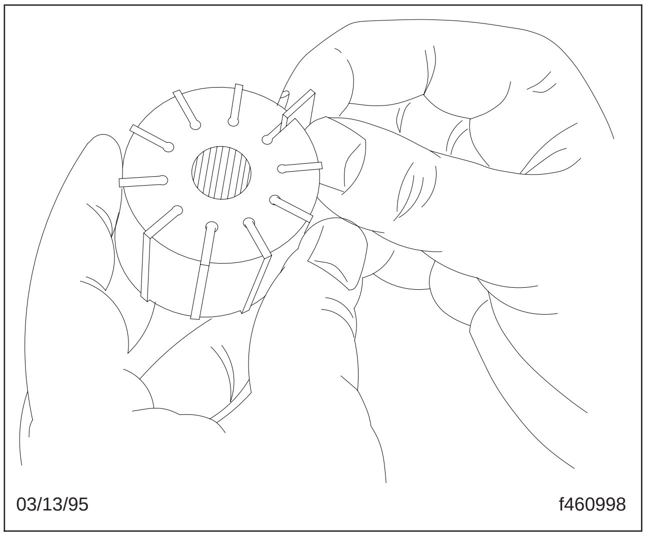
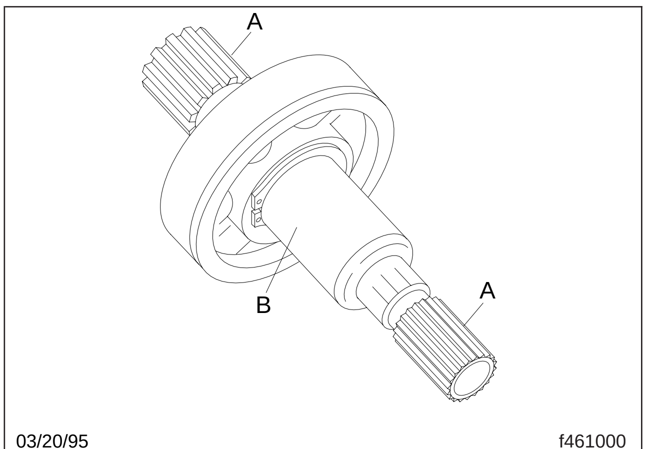


Fig. 22, Checking the Vanes



A. Splines
B. Shaft Seal Area

Fig. 23, Checking the Input Shaft

IMPORTANT: In one of the four cutouts in the cover there is a bar. When installed, the bottom plate must cover this bar.

8. Install the bottom plate with the pockets facing up. See **Fig. 30**. Make sure that the marks made during disassembly are aligned.

9. Install the cam ring with the dots facing up or down as noted during disassembly. Make sure that the cam ring is flush with the bottom plate's large outside diameter, and that the marks made during disassembly are aligned. **Fig. 31**.

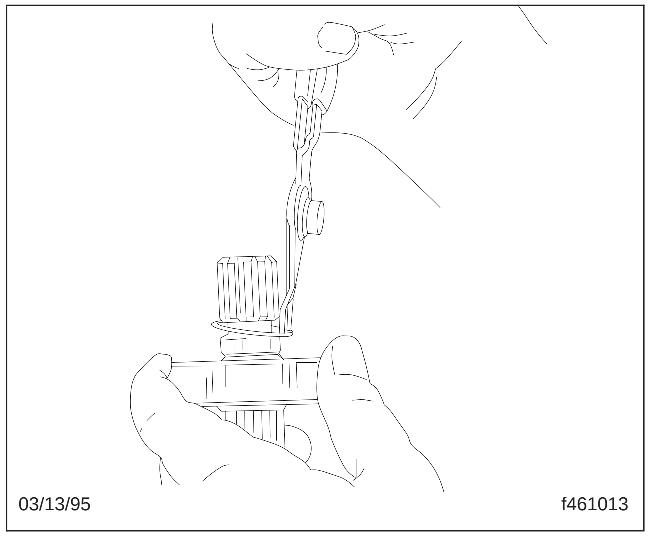


Fig. 24, Removing the Retaining Ring

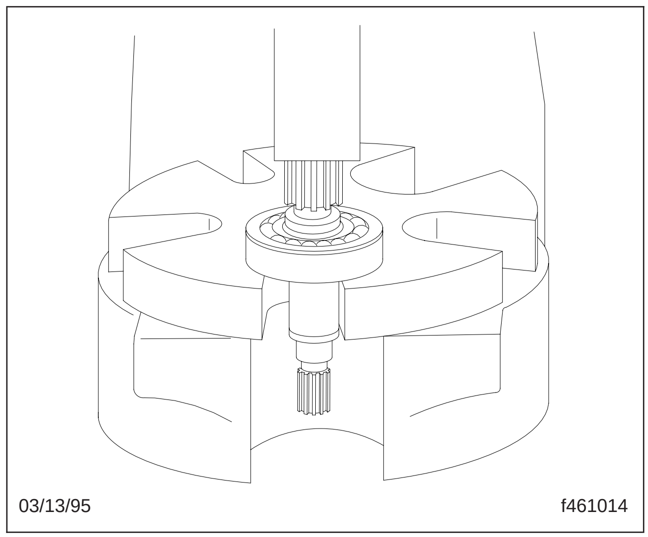


Fig. 25, Pressing the Input Shaft

10. Install the rotor and vanes. Make sure that the squared edge on each vane points toward the center of the rotor. See **Fig. 32**.

11. Install the top plate with the pin holes down. Make sure that the locating pins are engaged in the pin holes, not the pockets. See **Fig. 33.**

    Make sure that the top plate is flush with the cam, and that the marks made during disassembly are aligned.

Steering Pump Disassembly, Inspection, and Assembly

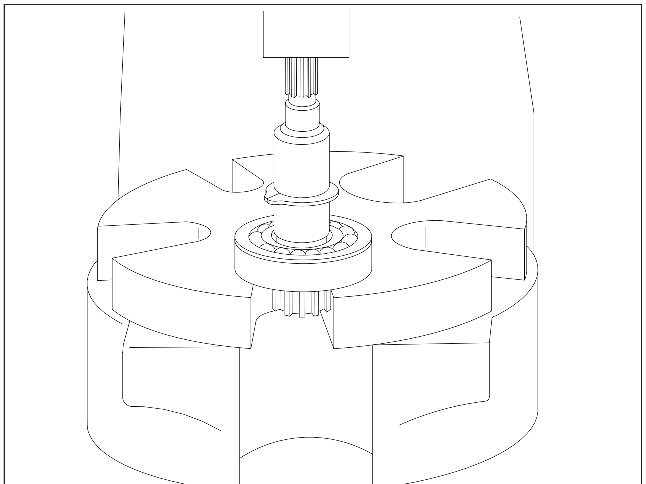

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Fig. 26, Pressing the New Input Shaft

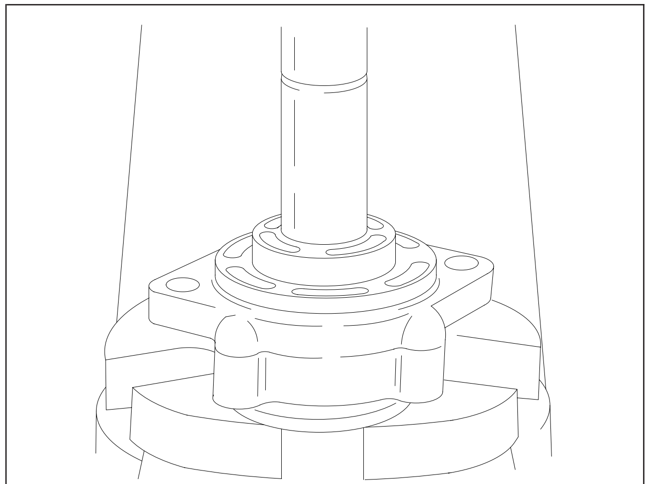
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Fig. 28, Pressing the Shaft and Bearing into the Cover

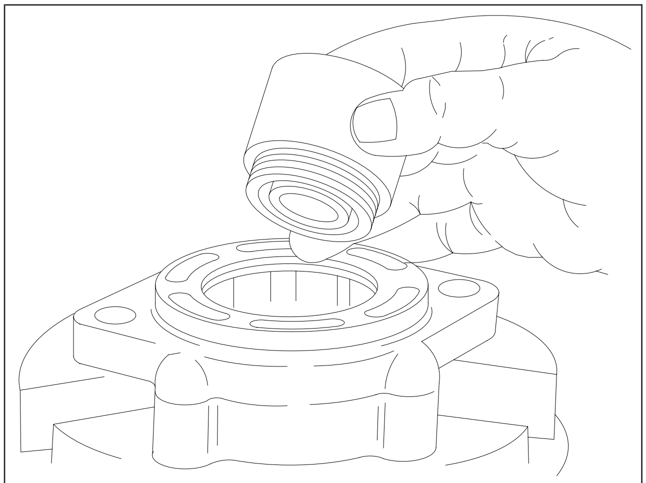
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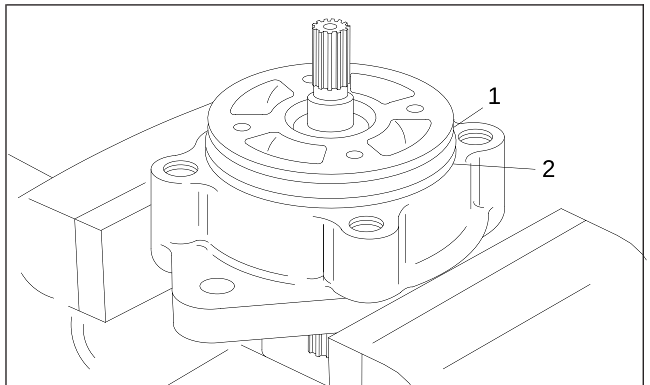
Fig. 27, Installing the Seal in the Cover



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1. Small O-Ring
2. Large O-Ring

Fig. 29, Installing the O-Rings

NOTE: The backup O-ring will fit tighter on the top plate after loosely wrapping (no twisting) it around two fingers, then allowing it to unwrap.

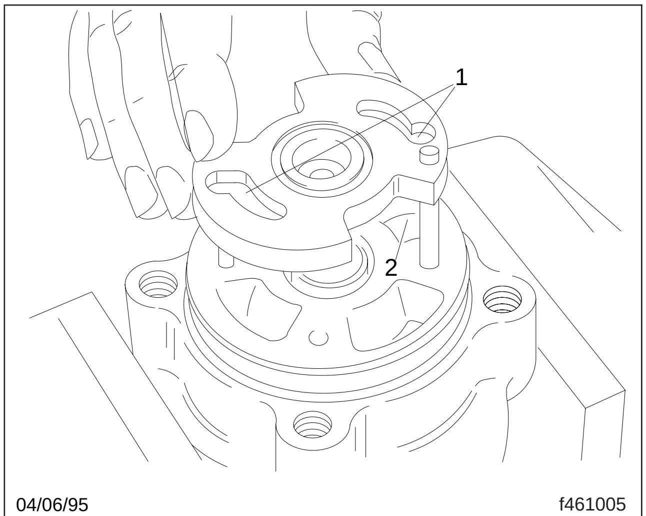
12. Install the backup O-ring on the top plate. Seat the O-ring at the bottom of the groove.
13. Install a new O-ring (without allowing it to roll) on the top plate. Seat the O-ring at the top of the groove.
14. Grease both the O-ring and the backup O-ring. See **Fig. 34**.

CAUTION

The housing may have sharp edges. Use care to not cut your finger when applying grease to the housing.

15. Grease the sealing areas of the housing. See **Fig. 35**.
16. Place the spring on the top plate.
17. Place the housing over the cover assembly. Make sure that the marks made during disassembly are aligned. See **Fig. 36**.

Steering Pump Disassembly, Inspection, and Assembly



1. Pockets
2. Bar

Fig. 30, Installing the Bottom Plate

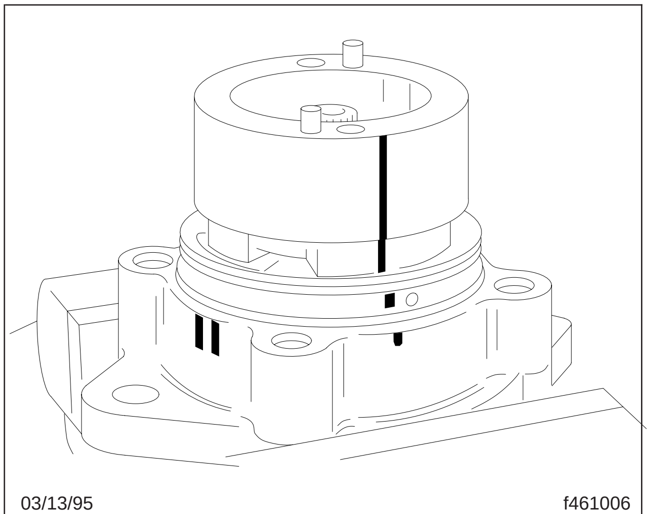
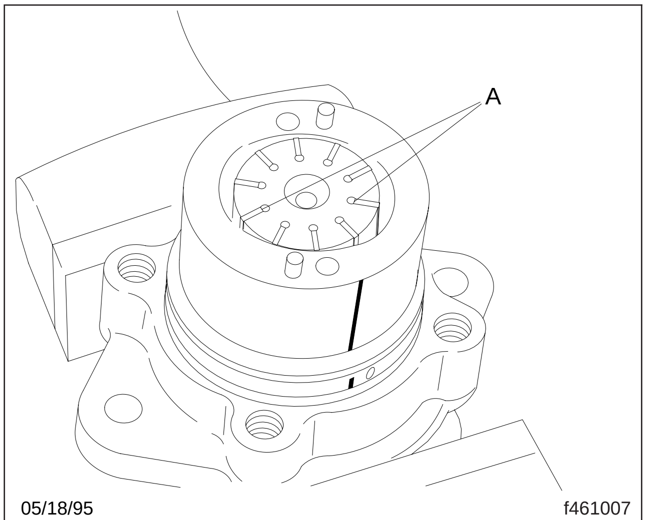


Fig. 31, Installing the Cam Ring

CAUTION

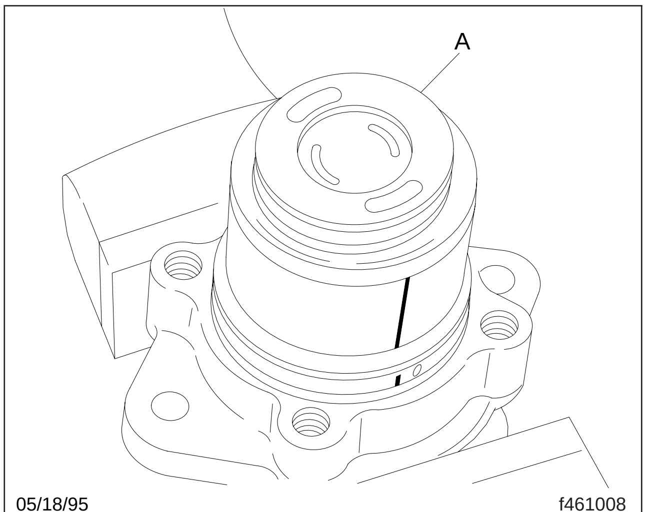
Evenly thread the mounting bolts into the cover. If not evenly threaded into the cover, damage could occur to the seals, top plate, or housing.

18. Install the mounting bolts and washers. Evenly thread all four bolts into the cover. Alternately tighten the bolts 30 lbf·ft (41 N·m).



A. Squared edge of vane pointing toward the center of the rotor.

Fig. 32, Installing the Rotor and the Vanes



A. Top plate installed with pin holes down.

Fig. 33, Installing the Top Plate

19. Screw the relief valve seat assembly into the control valve spool assembly. Tighten the assembly 87 lbf·in (982 N·cm).

NOTE: Placing the spool assembly in a collet will assist the tightening procedure.

Steering Pump Disassembly, Inspection, and Assembly

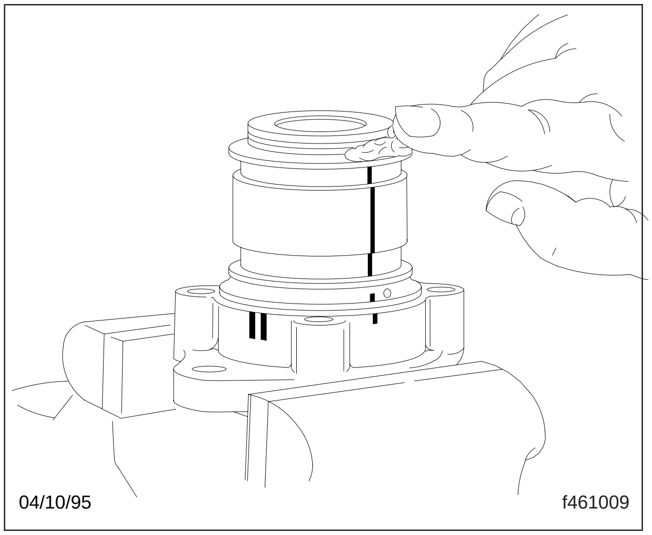


Fig. 34, Greasing the O-Rings

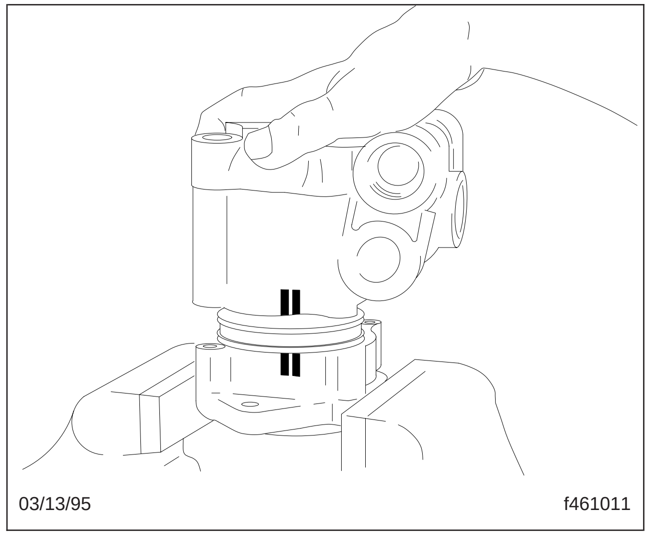


Fig. 36, Installing the Housing

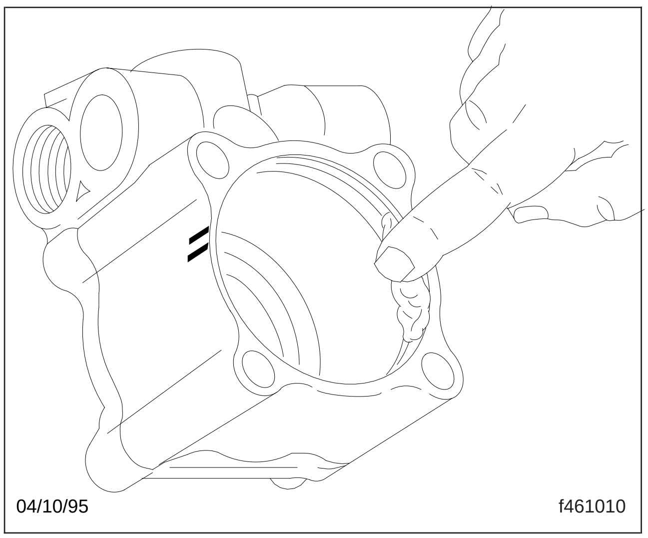


Fig. 35, Greasing the Sealing Areas

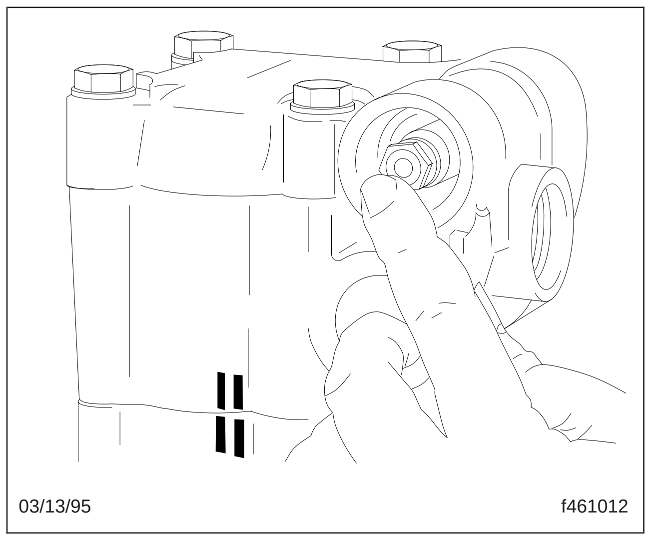


Fig. 37, Installing the Valve Spool Assembly

20. Insert the valve spool assembly (screen end last) into the housing. Make sure that the spool slides freely in the housing. See **Fig. 37**.
21. Install the spring in the housing.
22. Install a new O-ring on the end plug.
23. Lightly grease the O-ring and the end plug threads. Install the end plug and tighten 30 lbf·ft (41 N·m).
24. Install the woodruf key into the new input shaft (if removed during the input shaft replacement).
25. Turn the pump by hand and make sure that it turns freely.
26. Install the power steering pump on the engine, following the instructions in **Subject 100.**

Troubleshooting

Problem—The Power Steering Pump Doesn't Deliver Fluid

Problem—The Power Steering Pump Doesn't Deliver Fluid	
Possible Cause	**Remedy**
The pump input shaft is broken, or not engaging.	Remove the pump. Repair or replace parts as needed.
The control valve is stuck open.	Remove and disassemble the pump. Clean the control valve in a solvent. Install the control valve, then check for any binding in its bore. If the control valve binds or feels gritty when you move it, replace the pump.
One or more rotor vanes is stuck.	Remove and disassemble the pump. Check the rotor and vanes for dirt or damage. If damaged, replace the pump. If dirty, clean the rotor and vanes in a solvent, then assemble the parts and check for free vane movement. If the problem persists, replace the pump.
Incorrect steering system hydraulic fluid is used.	Check for the type of fluid used. If it's incorrect, drain, flush, and fill the system with the correct fluid.
The pump intake port is blocked.	Drain and flush the system. Fill the system with clean fluid.
The air vent in the power steering reservoir is clogged.	Remove the filter cap from the reservoir, then clean the air slot.
A power steering inlet 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 is plugged.	Drain the system. Clear the intake line if needed.
There is an air leak at the pump connections, the fittings, the reservoir connections, or the shaft seal.	Check all the connections by pouring steering system hydraulic 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.
The pump input shaft is misaligned.	Remove and disassemble the pump. Replace the shaft seal and bearing.

Specifications

Fastener Torques	
Description	**Torque: lbf·ft (N·m)**
Pump Mounting Hexbolts	35 (47)
Pump Housing-to-Cover Assembly Bolts	30 (41)
Pump End-Plug	30 (41)
Pump Inlet Connection	26 (35)

Table 1, Fastener Torques

Approved Steering System Hydraulic Fluid	
Lubricant Type	**Recommended Lubricant**
Automatic Transmission Fluid *	Dexron VI®

* Do not mix engine oil with automatic transmission fluid (ATF). Use the same lubricant for parts as is used in the power steering system.

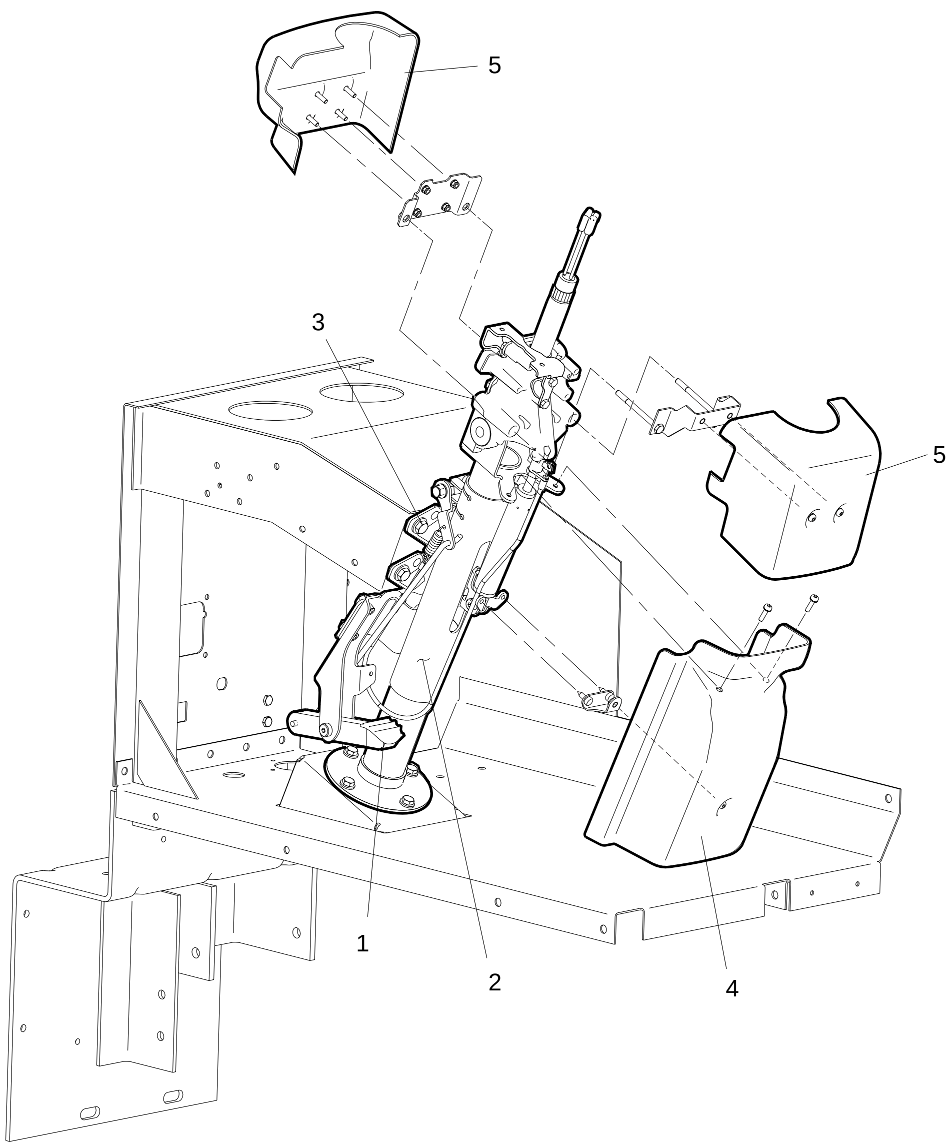
Table 2, Approved Steering System Hydraulic Fluid

General Information

NOTE: The TRW tilt/telescoping steering column was installed on vehicles built after October 7, 2002. See **Fig. 1**.

The steering wheel has four-spokes and a cushioned rim, 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.



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1. Tilt/Telescope Foot Pedal Control
2. Steering Column
3. Mounting Fasteners (Qty. 4)
4. Lower Steering Column Cover
5. Upper Steering Column Cover

Fig. 1, Tilt/Telescope Steering Column Assembly

General Information

The TRW tilt/telescoping steering column is equipped with a tilt/telescopic foot pedal control. To tilt the steering wheel, depress the foot pedal and move the wheel to the desired angle. To telescope the steering wheel, depress the foot pedal and extend or retract the steering wheel to the desired position.

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. 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.

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**.

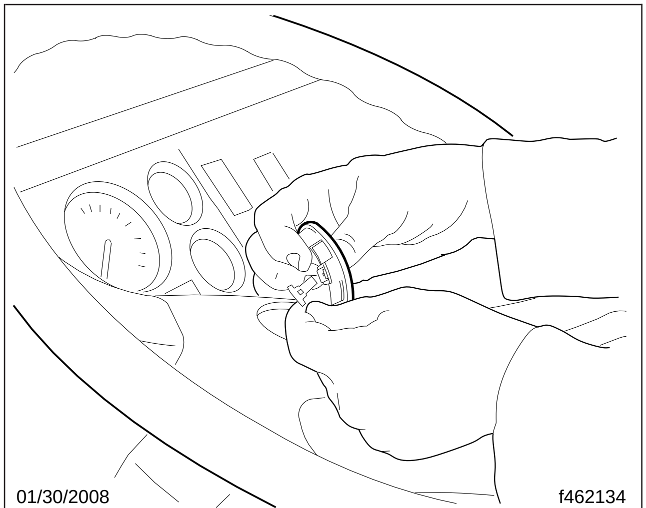

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Fig. 1, Removing the Horn Button

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.

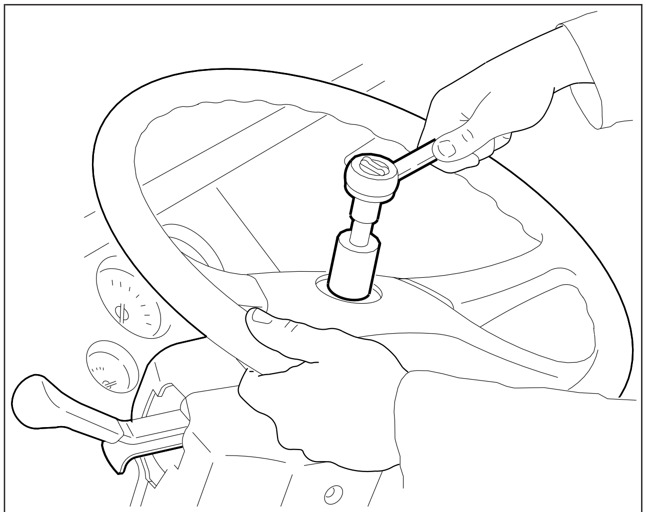

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Fig. 2, Removing the Steering Wheel Nut

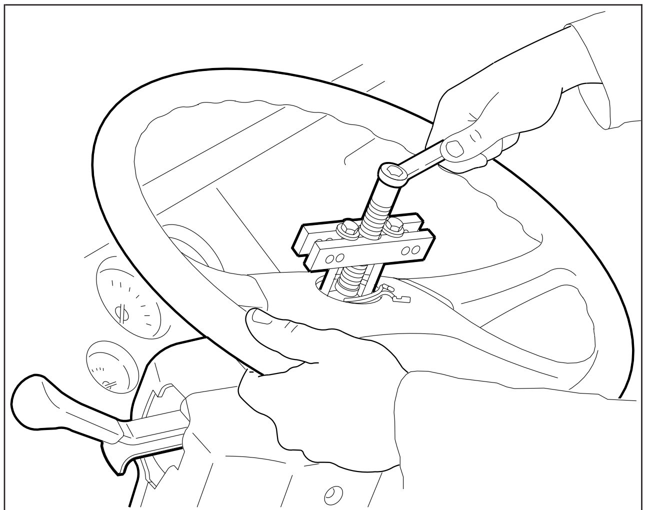

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Fig. 3, Removing the Steering Wheel from the Column

2. Put the steering wheel on the steering column so that the spokes are within 10 degrees of the 9 o'clock and 3 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.

Steering Wheel Removal and Installation

NOTE: The horn wires may be connected to either terminal.

5. Install the horn button in the steering wheel hub so the logo on it is aligned with the steering wheel spokes.
6. Connect the batteries.
7. Remove the chocks from the tires.
8. 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.

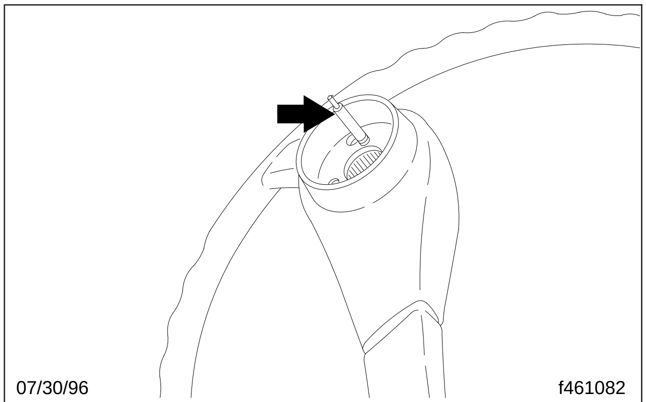

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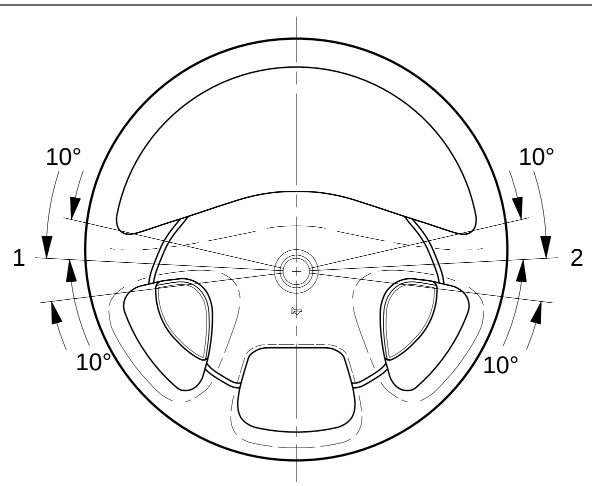
Fig. 4, Turn Signal Self-Cancelling Pin



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1. 9 o'Clock 2. 3 o'Clock

Fig. 5, Steering Wheel Centered

Steering Column Assembly Removal and Installation

Removal

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.

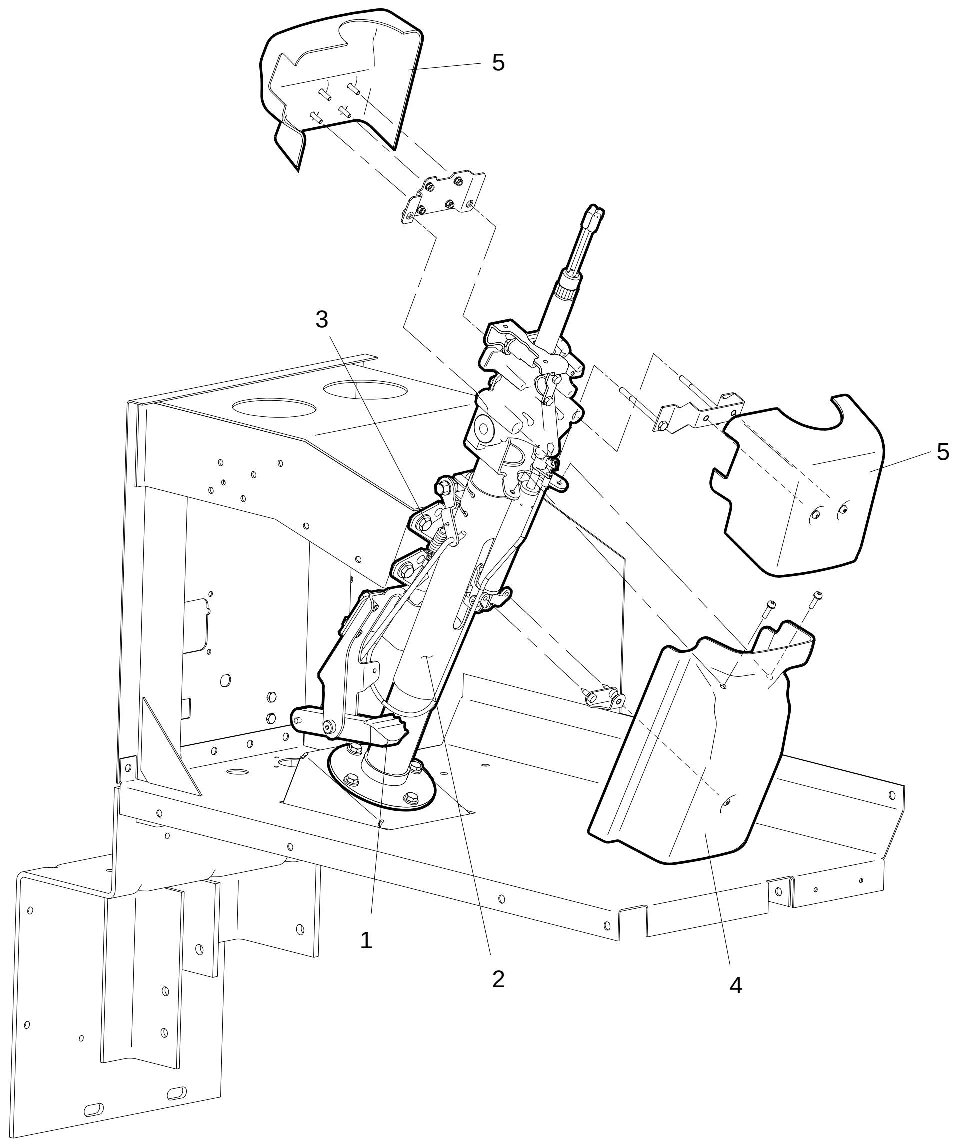
2. Disconnect the batteries at the negative terminals.
3. Remove the upper and lower steering column covers. See **Fig. 1**.
4. Remove the pinch-bolt nut and pinch bolt from the upper end yoke. Discard the nut and the bolt.
5. Remove the two screws that attach the turn signal switch mounting bracket. Remove the turn signal switch mounting assembly from the steering column. Disconnect the wiring connector from the turn signal switch.
6. Disconnect the horn wiring connector.
7. Remove the steering driveline upper end yoke from the steering column shaft.
8. Remove the capscrews that attach the steering column to the mounting bracket.
9. Remove the steering column assembly from the vehicle.

Installation

1. Position the steering column on the steering column mounting bracket. Tighten the capscrews 23 lbf·ft (31 N·m).
2. Wipe the end of the column shaft with a clean, dry cloth.
3. Slide the steering driveline 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 35 lbf·ft (48 N·m).
4. Apply torque seal OGP F900WHITE to the exposed pinch-bolt threads and to the locknut.
5. 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.
6. Connect the horn wiring connector.
7. Check the position of the steering wheel when the front tires are pointing forward. The steering wheel should be within ±10 degrees of the 9 o'clock and 3 o'clock positions, as shown in **Fig. 2**.

   If necessary, remove the steering wheel and reposition it. For instructions, see **Subject 100**.
8. Install the upper and lower steering column covers.
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.

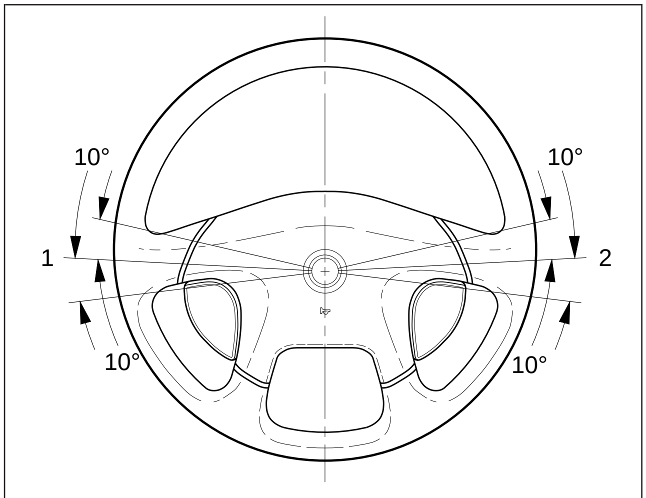
Steering Column Assembly Removal and Installation



1. Tilt/Telescope Foot Pedal Control
2. Steering Column
3. Mounting Fasteners (Qty. 4)
4. Lower Steering Column Cover
5. Upper Steering Column Cover

Fig. 1, Tilt/Telescope Steering Column Assembly

Steering Column Assembly Removal and Installation



1. 9 o'Clock
2. 3 o'Clock

Fig. 2, Steering Wheel Centered

General Description

The fuel system delivers fuel from the fuel tank(s) to the engine. It consists of the engine fuel system components, the fuel tank and tank mounting components, the fuel lines, and (if so equipped) a 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 provides a clean storage area for fuel, and is held in place by metal straps that transfer the weight load to the vehicle frame.

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 instrument panel.

Fuel Tank Removal and Installation

Removal

If there is any damage to the fuel tank, *replace* it. **Do not repair** fuel tanks.

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.

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, and drain the fuel.

   If the fuel is to be re-used, store it in a clean container, and protect it from contaminants.

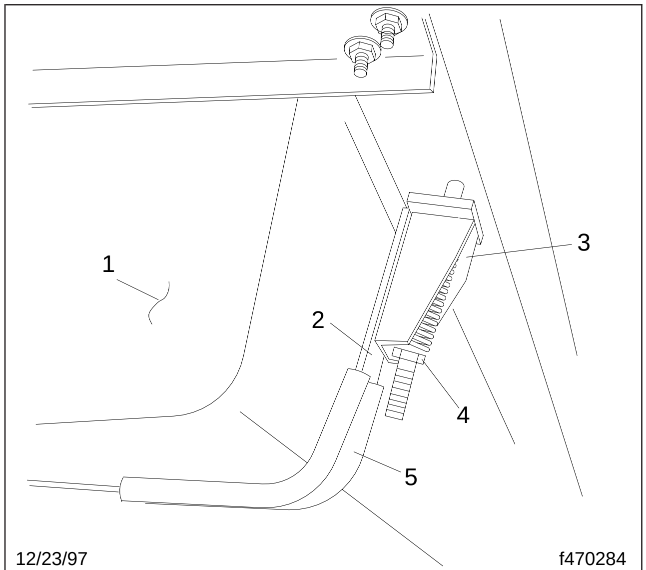
3. Disconnect the fuel fill hose and the vent hose.
4. Using a pipe wrench or similar tool, unscrew the fuel fill stem and the vent stem from the tank.
5. Disconnect and cap the fuel return and suction lines.
6. Disconnect the wires from the fuel level gauge sender.
7. Remove the fuel tank assembly.

   7.1 Support the tank with a jack (with a lifting pad).

   7.2 Remove the strap fasteners that attach the fuel tank assembly to the frame rails. See Fig. 1 .

   7.3 Using the jack, lower the fuel tank.

   7.4 Remove the tank from underneath the vehicle.



1. Fuel Tank
2. Mounting Strap
3. Strap Bracket
4. Nut
5. Isolator

Fig. 1, Fuel Tank Mounting Strap Assembly

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 chassis. Failure to do so could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.

9. If a fuel tank is being replaced, inspect the fuel tank system components for wear or damage. Replace all worn or damaged components. Undamaged components may be removed from the old fuel tank and installed on the new tank.

   9.1 Remove and clean all pipe plugs and fittings, and transfer them to the new tank. Coat all tapered (pipe plug and fitting) threads with Loctite® 592, or an equivalent.

   9.2 Inspect the vent line for wear or damage. Replace the vent line if it is worn or dam-

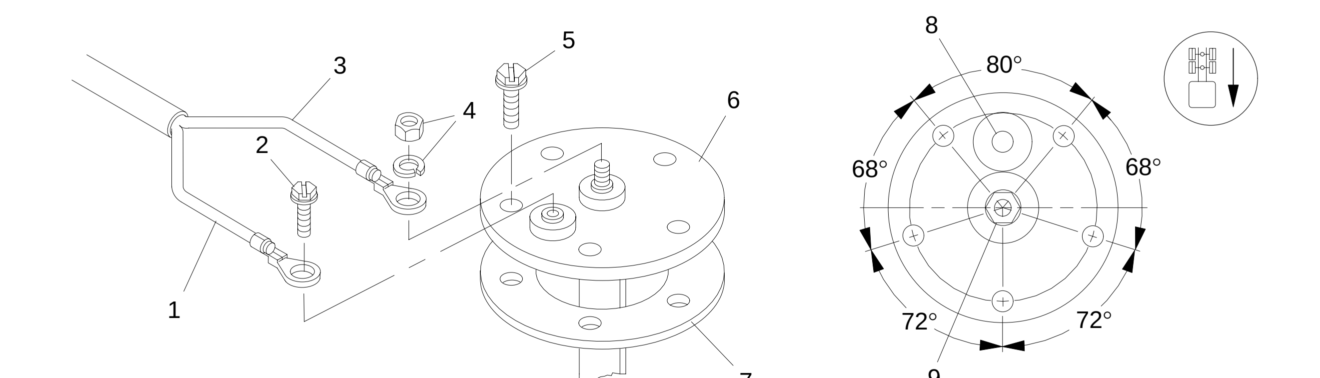
Fuel Tank Removal and Installation

aged. 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. 2**. Securely and evenly tighten the machine screws.

WARNING

Do not overtighten the fuel tank straps. Torque to the recommended specifications. Overtightening the straps could cause damage to the tank, which could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.



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. 2, Fuel Level Gauge Sender Installation

Installation

1. Using a jack with a lifting pad, position the fuel tank beneath the vehicle. Make sure the fuel filler neck hole is properly positioned, and then lift into place.
2. Before fully raising the tank, attach the wires to the fuel level gauge sender. Securely tighten the machine screw and hexnut.
3. 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.
4. Install the isolators and the tank straps on the fuel tank.
5. Install a bearing washer and one nut on each tank strap. Tighten 100 lbf·ft (136 N·m).
6. Using a pipe wrench or similar tool, install the fill stem and the vent stem.
7. Connect the fuel fill hose and vent hose.
8. Remove the jack from underneath the vehicle.
9. Add clean fuel to the fuel tank.
10. Prime the engine fuel pump; see **Subject 130**.
11. Remove the chocks.

Fuel Tank Strap Replacement

Replacement

NOTE: This procedure is for vehicles with straight-frame rail chassis.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Position a jack with a lifting pad under the tank.
3. Remove the nuts and washers from the fuel tank straps that attach the fuel tank to the frame rails. See **Fig. 1**.
4. Remove the strap to be replaced.
5. Remove the rubber isolators from the strap.
6. Inspect the isolators for wear or damage; replace if needed.

WARNING

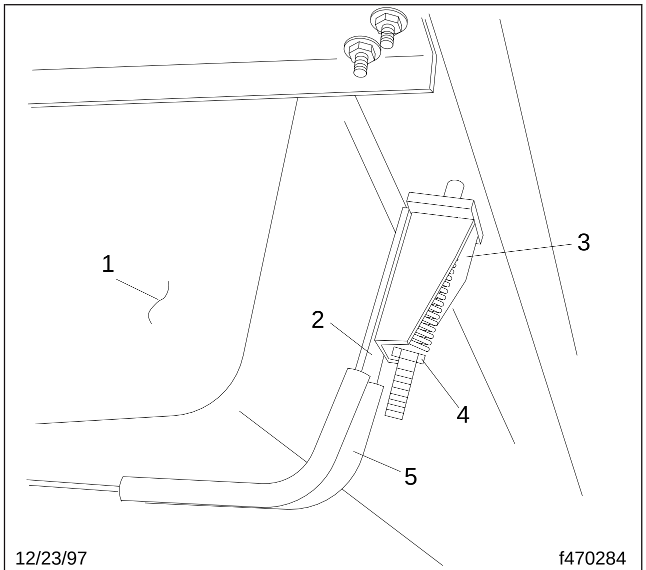
Replace worn or damaged components, such as straps or isolators, used to attach the fuel tank to the chassis. Failure to do so could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.

7. Install the rubber isolators and the new tank strap onto the fuel tank. Install each strap end evenly so that the amount of each bolt length is approximately the same.

WARNING

Do not overtighten the fuel tank straps. Torque to the recommended specifications. Overtightening the straps could cause damage to the tank, which could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.

8. Install a bearing washer and a nut on the tank strap. Tighten 100 lbf·ft (136 N·m).
9. Remove the jack from under the tank.
10. Remove the chocks from the tires.



1. Fuel Tank
2. Mounting Strap
3. Strap Bracket
4. Nut
5. Isolator

Fig. 1, Fuel Tank Mounting Strap Assembly

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 2 inches (5 cm) below the fuel tank unless they are completely enclosed in a protective housing.

Fuel lines must be secured to prevent chafing, kinking, and other causes of damage.

Fuel lines must be long enough to allow movement of the parts to which they are attached, and for fuel tank removal and installation purposes.

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 engine have an inline fuel strainer located inside the rail on the right-hand side above the rear axle, above the suspension air bag in the frame. On front-engine diesel chassis, the fuel strainer is located inside the rail on the left-hand side, behind the rear shock bracket in the frame.

1. Remove the brackets on each end of the fuel strainer.
2. Remove the P-clip.

IMPORTANT: The fuel flow arrow on the fuel strainer must be pointed toward the engine.

3. Remove the strainer, and replace it with a new strainer.
4. Install the P-clip.
5. Install the brackets on each end of the fuel strainer.

Specifications

Fuel System Fastener Specifications	
Description	**Specification**
Upper Tank Strap Nut (torque)	100 lbf·ft (136 N·m)
Lower Tank Strap Spring (height)	3-5/16 to 3-7/16 inches (84 to 87 mm)

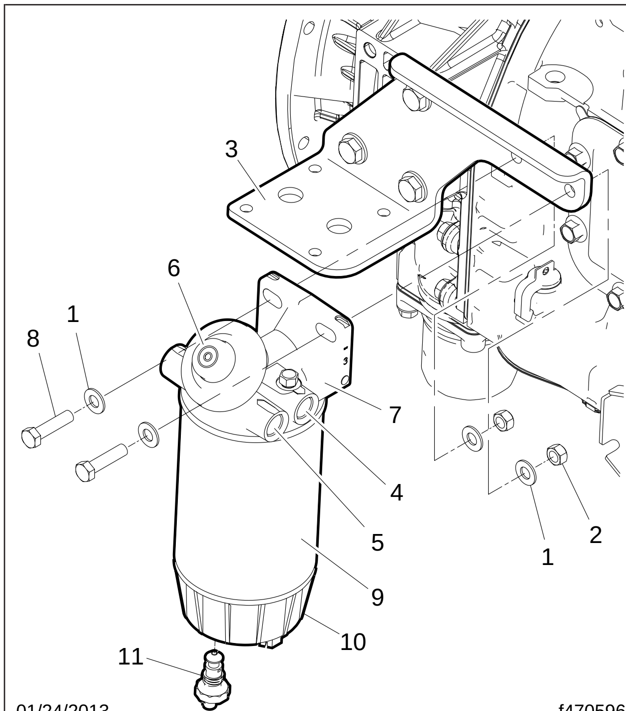
Table 1, Fuel System Fastener Specifications

General Information

General Description

The fuel/water separator is installed between the engine and the fuel tanks. It may be mounted on the side of the transmission, the backwall frame of the engine compartment, or on the right-hand outside wall of the engine compartment, depending on the vehicle design. See **Fig. 1**, **Fig. 2**, **Fig. 3** for common mounting locations. Fuel drawn to the engine travels through the fuel/water separator, which removes water and solid contaminants. The fuel/water separator includes a spin-on filter element and a sight bowl. See **Fig. 4**. The fuel/water separator may also be equipped with the following optional components:

- Ignition-controlled heater to melt ice and wax in the fuel
- Water sensor probe to alert the operator to drain the sight bowl
- Manual priming pump to easily prime the fuel/water separator



1. Washer
2. Nut
3. Mounting Bracket
4. Fuel Outlet Port
5. Fuel Inlet Port
6. Priming Pump
7. Mounting Head
8. Bolt
9. Filter Element
10. Sight Bowl
11. Drain Plug

Fig. 1, Fuel/Water Separator Assembly and Installation

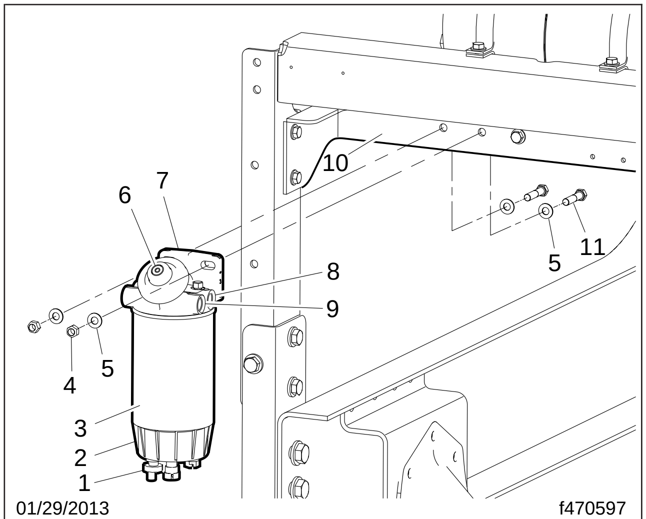
Principles of Operation

Diesel fuel enters at the top of the separator and flows down past the heater element, if equipped, to the top of the filter element. As the fuel flows down the sides of the element, the heavier contaminants fall directly to the collection bowl. The filter element itself contains a resin that repels water and forces it to bead and fall to the collection bowl.

Filtered fuel is drawn out through the top of the separator, and the water and solid contaminants remain in the collection bowl. As water collects, it completes the circuit between the two prongs of the water sensor probe, if equipped, and a warning light on the dash alerts the operator to drain the bowl.

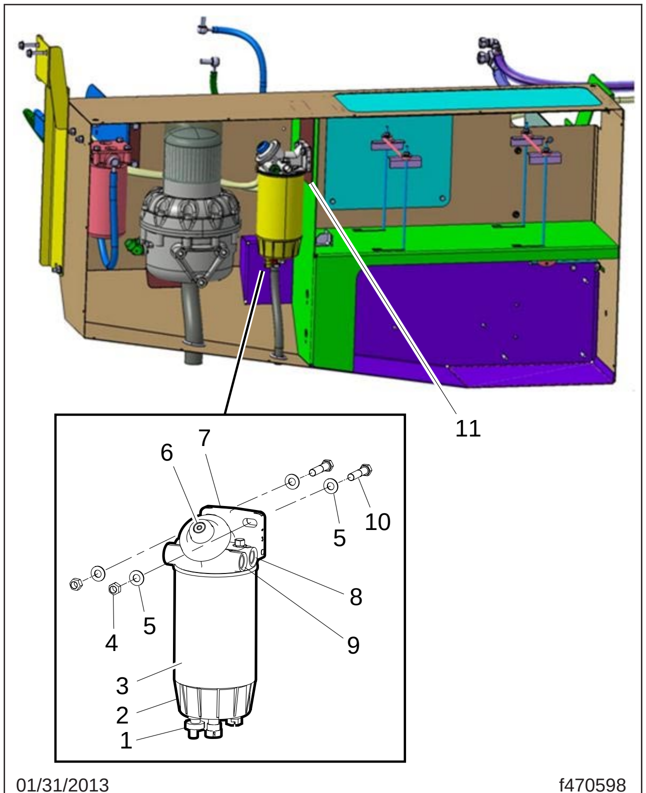
The heater is operated by turning on the ignition switch for 5 minutes before starting the engine.

General Information



1. Drain Plug
2. Sight Bowl
3. Filter Element
4. Nut
5. Washer
6. Priming Pump
7. Mounting Head
8. Fuel Inlet Port
9. Fuel Outlet Port
10. Backwall Frame
11. Bolt

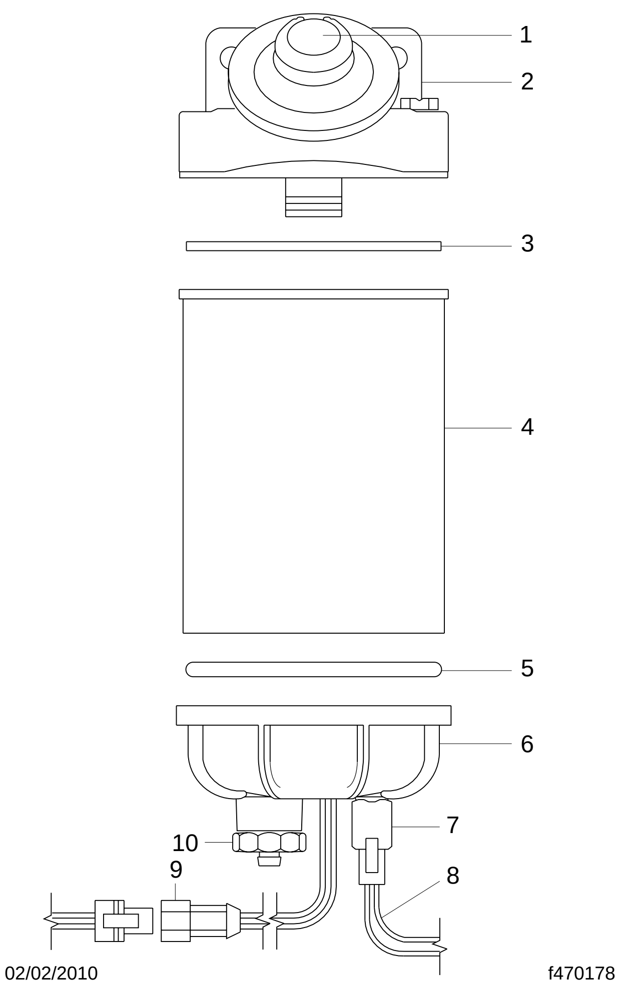
Fig. 2, Backwall Mounted Fuel/Water Separator



1. Drain Plug
2. Sight Bowl
3. Filter Element
4. Nut
5. Washer
6. Priming Pump
7. Mounting Head
8. Fuel Inlet Port
9. Fuel Outlet Port
10. Mounting Bracket
11. Bolt

Fig. 3, Sidewall Mounted Fuel/Water Separator

General Information



1. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 4, Fuel/Water Separator Assembly

Removal

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

   Open the engine access door.
2. Place a suitable container under the fuel/water separator.

WARNING

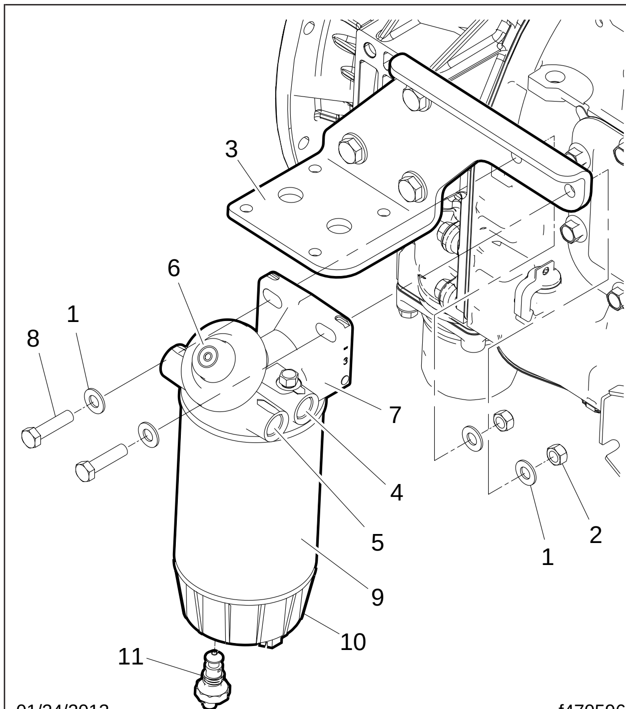
Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump. See **Fig. 1**, **Fig. 2**, **Fig. 3** for common mounting locations.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.
5. Disconnect the fuel lines from the fuel/water separator.
6. If equipped, disconnect the wiring harnesses from the water sensor probe and the heater element.
7. Remove the fuel/water separator mounting bolts, and remove the fuel/water separator from its mounting bracket.

Installation

1. Mount the fuel/water separator on the mounting bracket, and install the mounting bolts. Tighten the bolts 40 lbf·ft (55 N·m).
2. Remove the sight bowl and the filter element as a unit from the new fuel/water separator.
3. Using clean motor oil or diesel fuel, lubricate the gasket in the top of the filter element.



1. Washer
2. Nut
3. Mounting Bracket
4. Fuel Outlet Port
5. Fuel Inlet Port
6. Priming Pump
7. Mounting Head
8. Bolt
9. Filter Element
10. Sight Bowl
11. Drain Plug

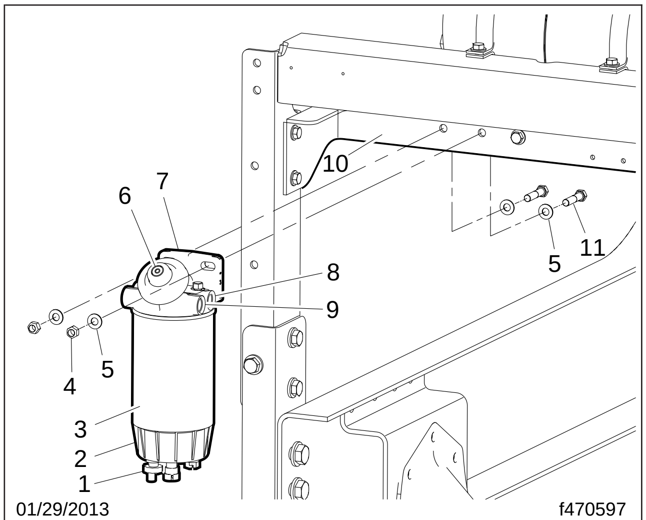
Fig. 1, Fuel/Water Separator Assembly and Installation

4. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
5. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
6. If equipped, connect the wiring harnesses to the water sensor probe and the heater.
7. Connect the fuel lines to the fuel/water separator. Tighten all fittings finger-tight plus 1/4 turn.
8. Prime the fuel/water separator.

   If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

   If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

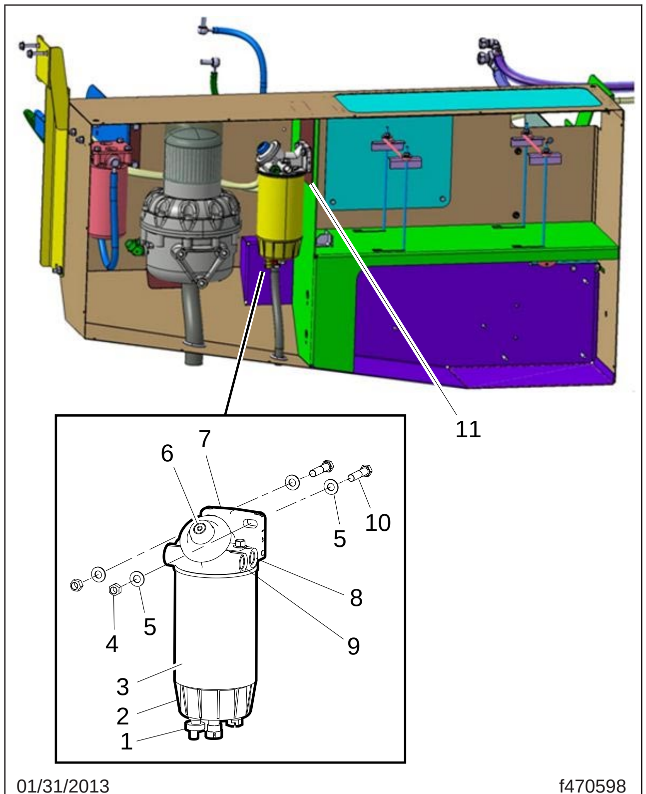
Removal and Installation



1. Drain Plug
2. Sight Bowl
3. Filter Element
4. Nut
5. Washer
6. Priming Pump
7. Mounting Head
8. Fuel Inlet Port
9. Fuel Outlet Port
10. Backwall Frame
11. Bolt

Fig. 2, Backwall Mounted Fuel/Water Separator

9. Start the engine and check for leaks.
10. Shut down the engine and repair any leaks.



1. Drain Plug
2. Sight Bowl
3. Filter Element
4. Nut
5. Washer
6. Priming Pump
7. Mounting Head
8. Fuel Inlet Port
9. Fuel Outlet Port
10. Mounting Bracket
11. Bolt

Fig. 3, Sidewall Mounted Fuel/Water Separator

Replacement

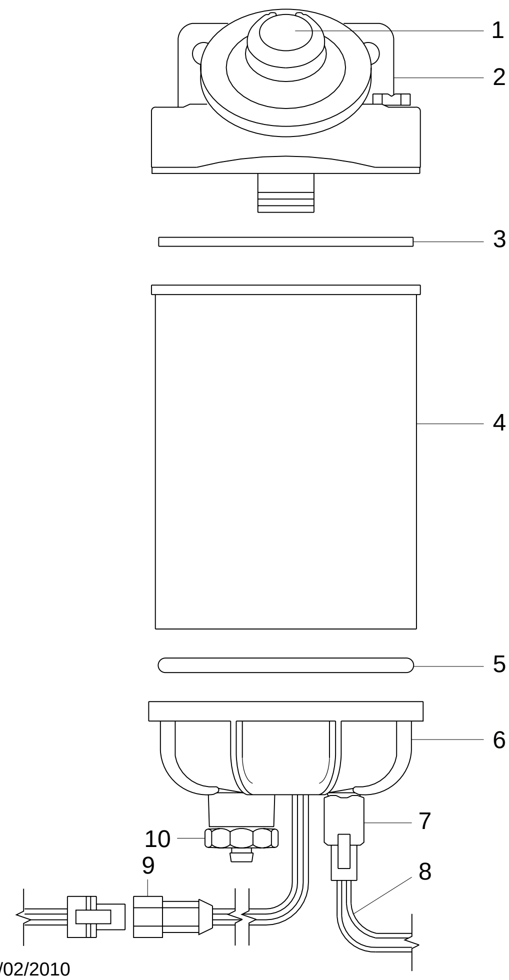
1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tires.
2. Open the engine access door.
3. Place a suitable container under the fuel/water separator.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

4. Turn the drain plug counterclockwise to open it. If equipped, operate the pump.
5. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.
6. If equipped, disconnect the wiring harnesses from the water sensor probe and the heater. See **Fig. 1**.
7. Spin the sight bowl and the filter element off as a unit. Remove the gasket from the top of the filter element.
8. Remove the sight bowl from the filter element. Clean the O-ring seating surface.
9. Apply a thin coating of clean diesel fuel or engine oil to the O-ring and the new gasket.
10. Spin the sight bowl onto the new filter element and then fill the filter element and sight bowl assembly with clean diesel fuel.
11. Spin the entire assembly onto the mounting head and tighten by hand until snug.
12. Connect the heater and water sensor wiring harnesses, if equipped.
13. Prime the fuel/water separator.



1. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

14. Start the engine and check for leaks.
15. Shut down the engine and repair any leaks.

The heater is an integral part of the sight bowl. If the heater fails, replace the sight bowl.

Replacement

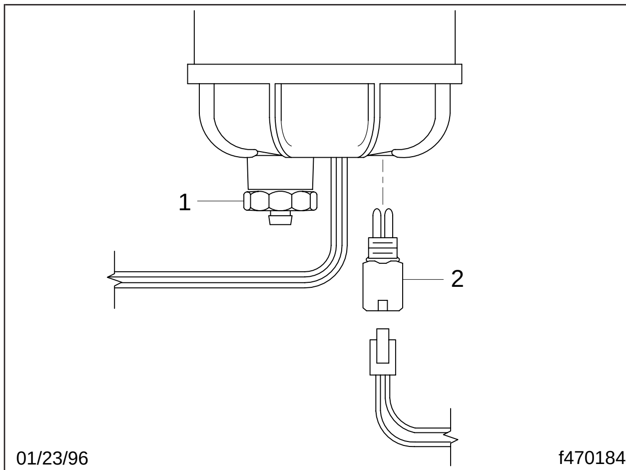
1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tires.
2. Open the engine access door.
3. Place a suitable container under the fuel/water separator.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

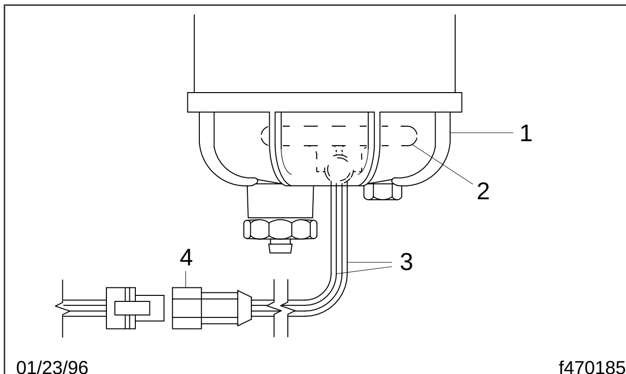
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

4. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
5. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.
6. If equipped, disconnect the wiring harness from the water sensor probe. See **Fig. 1**.
7. Disconnect the heater wiring harness. See **Fig. 2**.
8. Spin the sight bowl and the filter element off as a unit.
9. Remove the sight bowl from the filter element.
10. Remove the O-ring from the lip of the new sight bowl. Lubricate the O-ring with a thin film of clean engine oil or diesel fuel and put it back in the sight bowl.
11. Install the sight bowl on the bottom of the filter element and hand-tighten until it is snug.
12. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.



1. Drain Plug
2. Water Sensor Probe

Fig. 1, Water Sensor Probe



1. Sight Bowl
2. Heating Element
3. Heater Wires
4. Heater Wiring Harness

Fig. 2, In-Bowl Heater

13. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
14. Connect the heater wiring harness.

    If equipped, connect the water sensor wiring harness to the water sensor probe.
15. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

Heater Replacement

If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

16. Start the engine and check for leaks.
17. Shut down the engine and repair any leaks.

Replacement

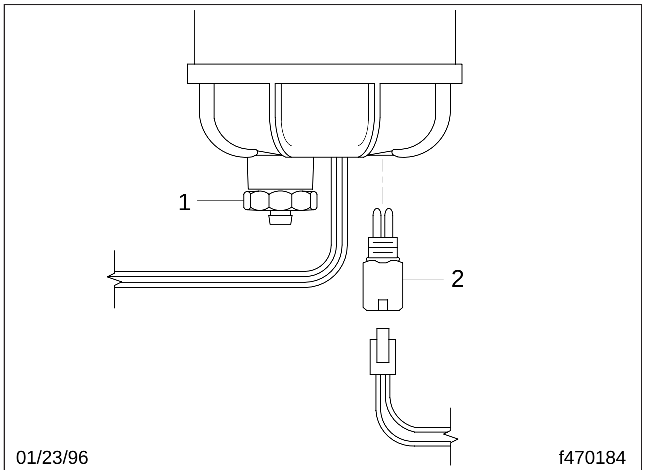
1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tires.
2. Open the engine access door.
3. Place a suitable container under the fuel/water separator.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

4. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
5. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.
6. Disconnect the water sensor wiring harness from the water sensor probe. See **Fig. 1**.



1. Drain Plug
2. Water Sensor Probe

Fig. 1, Water Sensor Probe

7. Spin the sight bowl and filter element off as a unit.
8. Unscrew the water sensor probe from the base of the sight bowl.
9. Install a new water sensor probe in the base of the sight bowl.
10. Make sure the drain plug in the base of the sight bowl is closed snugly.
11. Fill the filter element and sight bowl assembly with clean diesel fuel.
12. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
13. Connect the water sensor wiring harness to the water sensor probe.
14. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.
15. Start the engine and check for leaks.
16. Shut down the engine and repair any leaks.

Troubleshooting

Problem—Air Leaking into the Fuel System

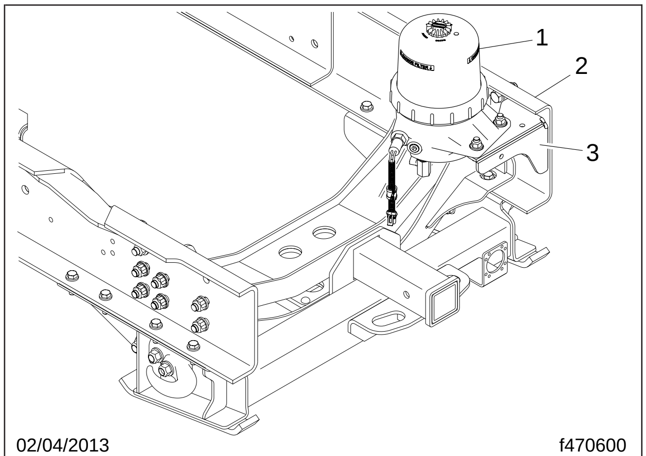
Problem—Air Leaking into the Fuel System	
Possible Cause	**Remedy**
The drain is not closed.	Tighten the drain valve.
The sight bowl or filter element is loose.	Hand-tighten the sight bowl or filter element until snug.
There are loose, broken, or clogged fuel fittings, valves, or filters.	Tighten, clean, or repair the fuel fittings, valves, or filters as needed.

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY	
Possible Cause	**Remedy**
Wiring connections are loose.	Tighten connections as needed.
Fuel/water separator is not grounded.	Check that power is on, and the fuel/water separator is grounded.
Wiring is damaged.	Check for damaged wiring and replace as needed. See EZWiring™ for a diagram of the sensor circuit.
Water sensor probe is damaged.	Replace the water sensor probe. See **Subject 130** for instructions.

General Description

Fuel/water separators are mounted between the fuel tank and the fuel pump, usually on the right frame rail in the engine comaprtment. See **Fig. 1** for the typical location. Fuel drawn to the engine travels through the fuel/water separator, which removes water and impurities. See **Fig. 2**, **Fig. 3**, or **Fig. 4** for DAVCO fuel/water separator configurations.



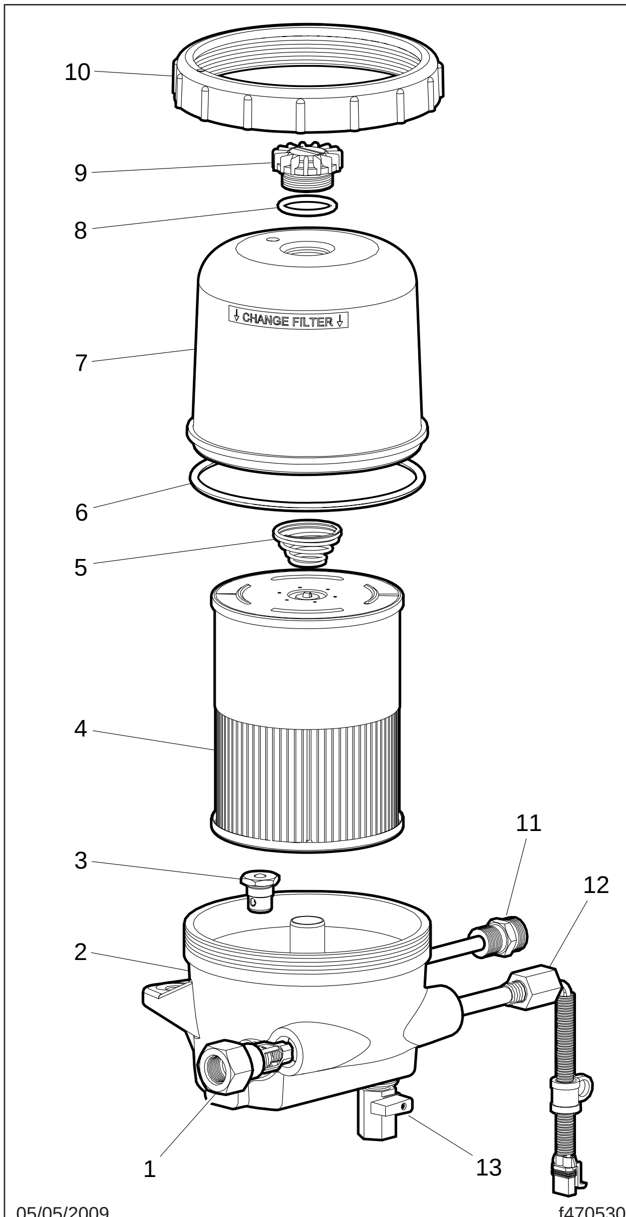
1. lFuel/Water Separator
2. Frame Rail
3. Mounting Bracket

Fig. 1, Davco Fuel/Water Separator Location

Heavier contaminants and water separate from the fuel in the lower housing of the fuel/water separator, and collect in the bottom to be drained out when the drain valve is opened. From the lower housing, the fuel level rises into the clear cover, which contains the replaceable filter element. The fuel passes through the filter element into the center of the filter, and on to the outlet port.

When the filter is new, the fuel is able to pass through the lower part of the filter element. As the element's lower portion clogs, the fuel level rises in order to pass through the filter. This process continues until the filter element is clogged all the way to the top.

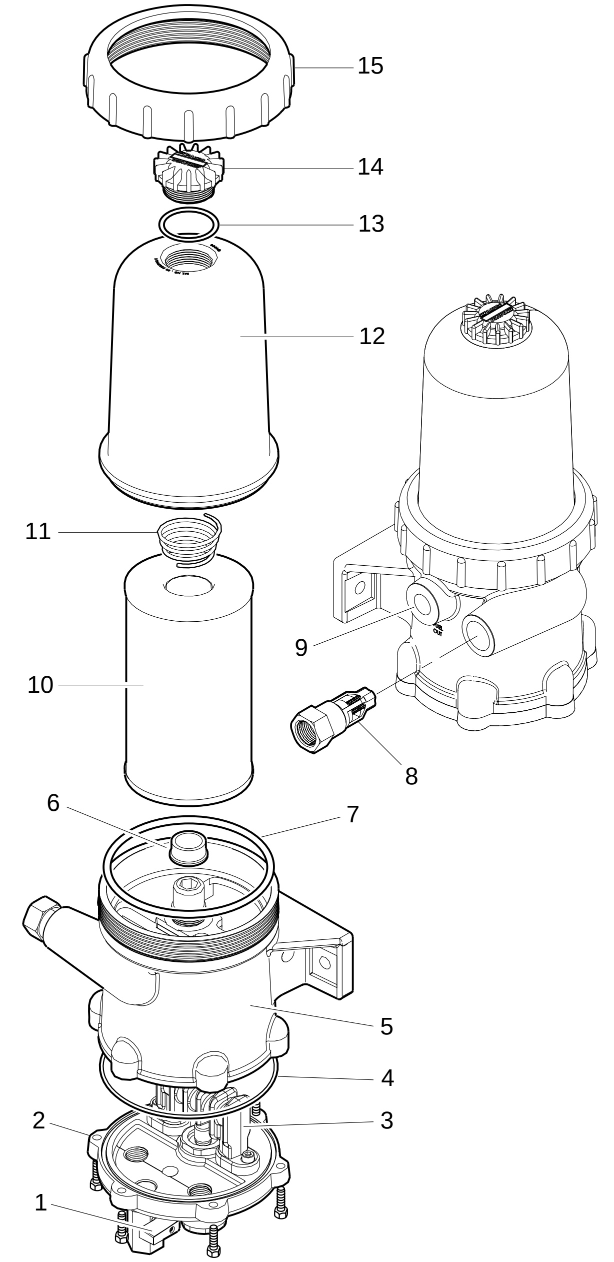
For efficiency, the filter should be changed only when the fuel level has reached the top of the filter element. There is no significant restriction to fuel flow until the element is completely clogged.



1. Inlet Port/Check Valve
2. Lower Housing
3. Bypass Valve
4. Filter Element
5. Spring
6. Cover O-Ring
7. Clear Cover
8. Vent Cap O-Ring
9. Vent Cap
10. Collar
11. 120VAC Pre-Heater
12. 12VDC Pre-Heater
13. Drain Valve

Fig. 2, DAVCO Fuel Pro 482

General Information



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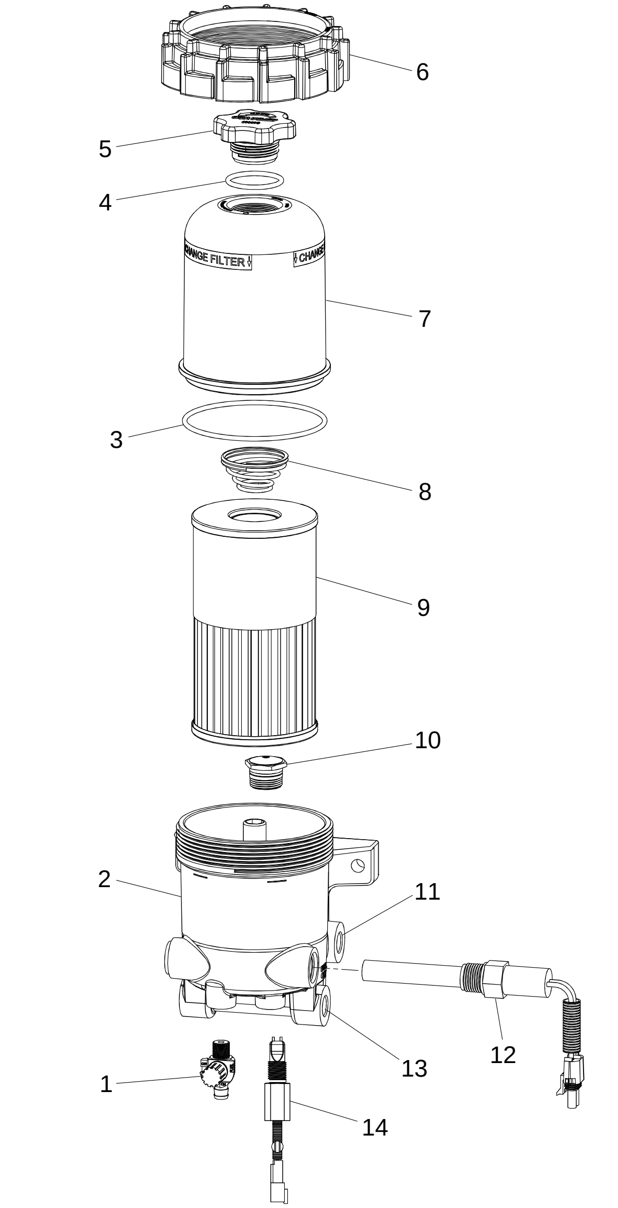
1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 3, DAVCO Fuel Pro 382



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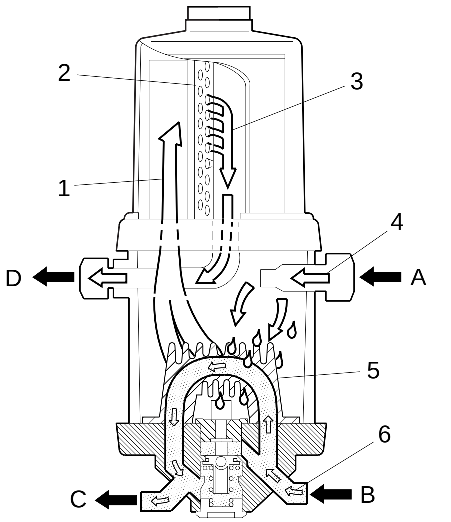
1. Drain Valve
2. Lower Housing
3. Cover O-Ring
4. Vent Cap O-Ring
5. Vent Cap
6. Collar
7. Clear Cover
8. Spring
9. Filter Element
10. Check Valve Assembly
11. Fuel Inlet Port
12. Pre-Heater
13. Fuel Outlet Port
14. Water-In-Fuel Sensor

Fig. 4, DAVCO Diesel Pro 243

DAVCO fuel/water separators come in a number of different configurations. There may be an electric heating element installed in the lower housing (**Fig. 2**, items 11 and 12) or there may be a fluid heat exchanger in the lower housing (**Fig. 3**, item 3). If there is fluid heat, the warming fluid may be fuel returning from the engine or engine coolant. **Fig. 5** shows the patterns that fuel and heating fluids follow in fluid-heated units.



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A. Fuel Inlet Flow
B. Heating Fluid Inlet Flow
C. Heating Fluid Outlet Flow
D. Fuel Outlet Flow

1. Unfiltered, Heated Fuel
2. Filter Element
3. Filtered Fuel
4. Fuel From Fuel Tank
5. Heat Exchanger
6. Heating Fluid From Engine

Fig. 5, DAVCO Fluid Circulation, Fluid-Heated Units

NOTE: The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.

Removal

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

Most service procedures are done with the fuel/water separator in place, but some procedures, such as pressure testing, require that the fuel/water separator be removed from the vehicle.

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

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

4. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
5. Unplug the electric heating element, if equipped, or disconnect the heating fluid lines.
6. Disconnect the fuel outlet line.
7. Disconnect the fuel inlet line. If the inlet line is difficult to reach, loosen the connection, then fully disconnect it after the fuel/water separator is removed from the frame rail.
8. Remove the fuel/water separator mounting fasteners and remove the fuel/water separator from the frame rail. If the fuel inlet line was not completely disconnected in the previous step, disconnect it.

Installation

IMPORTANT: All fittings, including the locking collars, must be very clean as they are installed. A piece of grit or a damaged surface on a sealing face or in threads can cause air leaks.

Use paste sealer to ensure that the tapered thread fuel line fittings will not leak. Do not use sealer on compression fittings and do not seal the fittings with tape, which will eventually leak.

1. If the inlet fuel line is inaccessible when the fuel/water separator is mounted on the vehicle, loosely connect the inlet fuel line before mounting the fuel/water separator on the frame rail.

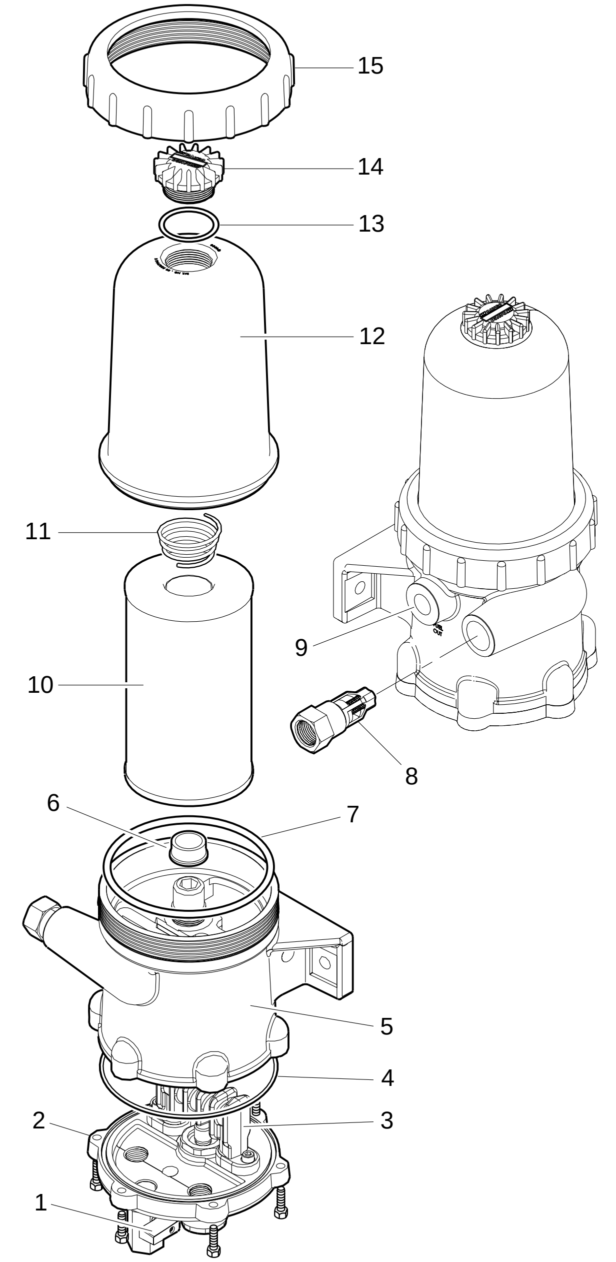
   To minimize restrictions, keep fuel line routing as smooth as possible, with no low-hanging loops that could trap water. If the fuel line is being made to length on the job, be sure that the inner liner of the hose is not cut by the fitting. Be certain the interior of all fuel lines is clean and free of debris before connecting them, and confirm that all fittings are clean.
2. Mount the fuel/water separator on the frame rail and install the mounting fasteners.

NOTICE

The lower housings on DAVCO fuel/water separators are made of aluminum. To avoid damaging threads, be careful not to overtighten fasteners or fittings on the fuel/water separator.

3. If the fuel inlet line was loosely connected previously, tighten it. If it was not connected, connect and tighten it.
4. Connect the fuel outlet line. Tighten the fitting 25 to 40 lbf·ft (34 to 54 N·m).
5. Install the electric heating element, if equipped, and connect the wiring harness, or connect the fluid heater lines. It does not matter which direction the heating fluid flows through the housing; the lines can be reversed.

Removal and Installation



1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 1, Fuel/Water Separator (Fuel Pro 382 shown)

6. Prime the system

   6.1 Ensure that the drain valve is closed.

   6.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

   6.3 Install and hand-tighten the vent cap.

   6.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

   6.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

   6.6 Check for leaks and shut down the engine.

Filter Element Replacement

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

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

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO Collar Wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO Collar Wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter, cover O-ring, and vent cap O-ring. Dispose of them in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
7. Install the grommet on the bottom of the new filter.
8. Install the new filter and grommet assembly and cover O-ring on the housing.
9. Install the clear cover and the collar. Hand-tighten the collar.
10. Prime the system.
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap O-ring and vent cap.
    - 10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
    - 10.6 Check for leaks and shut down the engine.

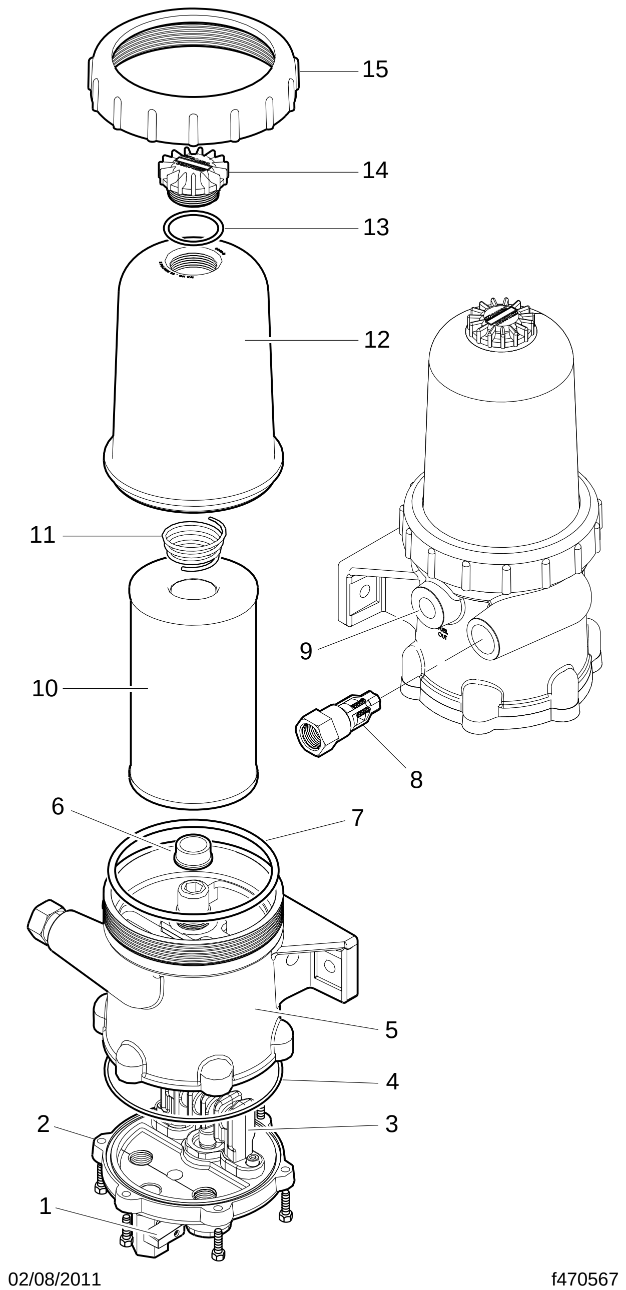
Emergency Temporary Filter Replacement

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense

Filter and Check Valve Replacement



1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 1, Fuel/Water Separator (Fuel Pro 382 shown)

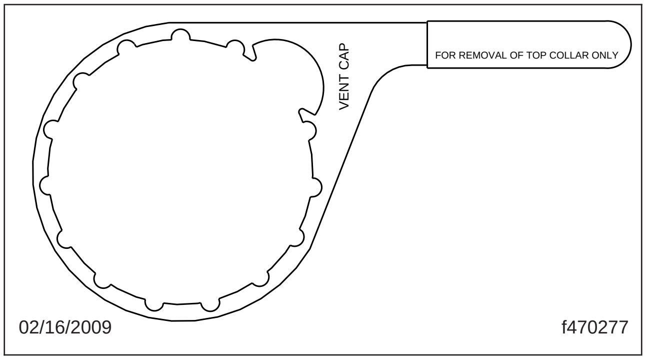


Fig. 2, DAVCO Collar Wrench

heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

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

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO Collar Wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO Collar Wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and dispose of it in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent

the fuel/water separator from sealing, and an air leak will result.

7. Ensure that the drain valve is closed.
8. Remove the filter grommet from the filter stud, if equipped.
9. Fill the housing to the top with clean diesel fuel.
10. Install a standard engine spin-on filter (part number FF105 or equivalent) on the filter stud.
11. Install the cover O-ring, clear cover, and the collar. Hand-tighten the collar.
12. Install and hand-tighten the vent cap O-ring and vent cap.
13. Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
14. Check for leaks and shut down the engine.

Check Valve Replacement, Fuel Pro 382/482 and Diesel Pro 233 Configurations

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

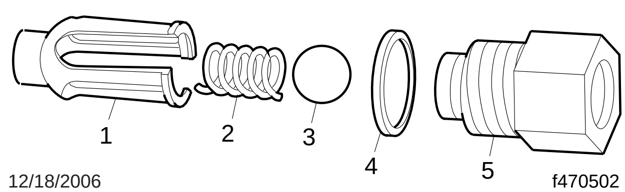
1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tire.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing.
6. Remove and discard the check ball, spring, and plastic retainer. See **Fig. 3**.



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 3, Check Valve Assembly

7. Carefully clean the threads on the check valve body. Install the new check ball, spring, and plastic retainer on the check valve body.
8. Clean the threads on the fuel inlet fitting and fuel/water separator housing. Apply a soft-set pipe thread sealant to the check valve body threads.
9. Install the check valve body in the fuel/water separator housing and tighten per the specifications in **Table 1**. Do not use tape to seal the fuel fittings; it will eventually leak.

Check Valve Assembly Torque Values	
Fuel/Water Separator	**Torque Value: lbf·ft (N·m)**
Fuel Pro 382	44–60 (60–81)

Filter and Check Valve Replacement

Check Valve Assembly Torque Values	
Fuel/Water Separator	Torque Value: lbf·ft (N·m)
Fuel Pro 482	45 (61)
Diesel Pro 233	25–40 (34–54)

Table 1, Check Valve Assembly Torque Values

10. Prime the system
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap.
    - 10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
    - 10.6 Check for leaks and shut down the engine.

Check Valve Replacement, Diesel Pro 243

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

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

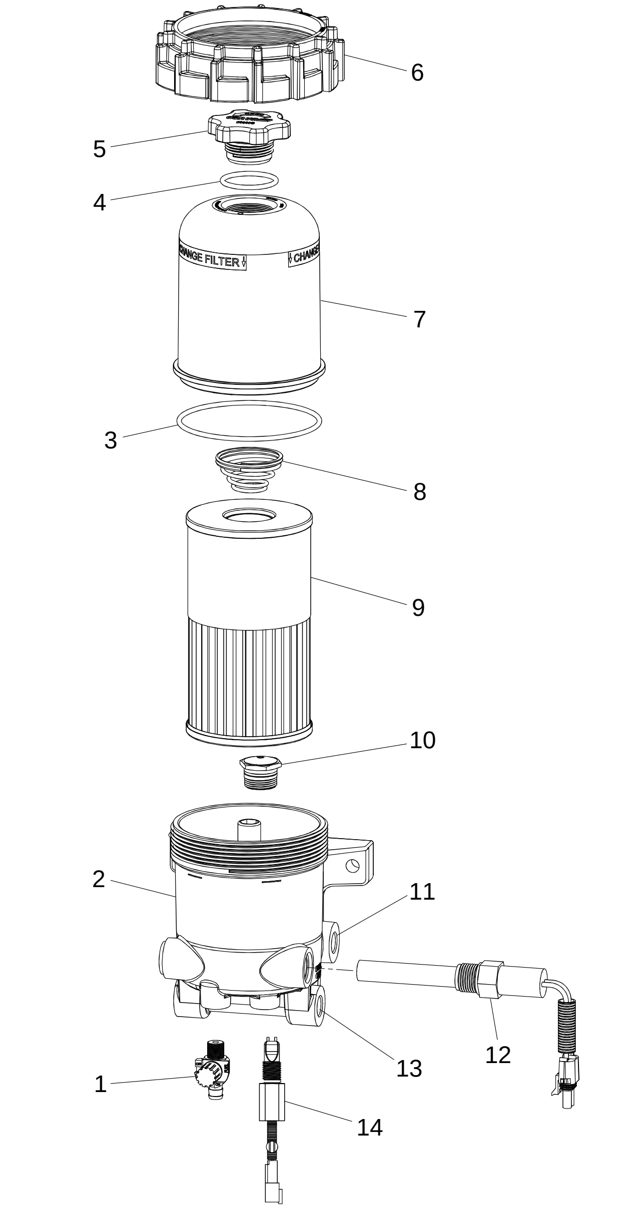
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.
3. Remove the vent cap (**Fig. 4**, Item 5) and open the drain valve (**Fig. 4**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO collar wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO collar wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and O-rings. Dispose of the filter and O-rings in an environmentally acceptable manner.
6. Remove the check valve from the lower housing.
7. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
8. Install the new check valve body in the lower housing. Tighten the check valve 12 to 14 lbf·ft (16 to 19N·m).
9. Install the new filter and cover O-ring on the housing.
10. Install the clear cover and the collar. Hand-tighten the collar.
11. Prime the system
    - 11.1 Ensure that the drain valve is closed.
    - 11.2 Fill the housing to the top with clean diesel fuel.
    - 11.3 Install and hand-tighten the vent cap O-ring and vent cap.

Filter and Check Valve Replacement



1. Drain Valve
2. Lower Housing
3. Cover O-Ring
4. Vent Cap O-Ring
5. Vent Cap
6. Collar
7. Clear Cover
8. Spring
9. Filter Element
10. Check Valve
11. Fuel Inlet Port
12. Pre-Heater
13. Fuel Outlet Port
14. Water-In-Fuel Sensor

Fig. 4, DAVCO Diesel Pro 243

11.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

11.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

11.6 Check for leaks and shut down the engine.

Electric Heater, Thermoswitch, and Fluid Heater Tests

Any one of several types of heaters and thermoswitches may be fitted to DAVCO fuel/water separators. They include 12 VDC heaters, 120 VAC heaters, combination heater thermoswitches, and fluid heaters. The voltage and wattage ratings are stamped on the hex or the sheath of each component.

Test procedures under these headings apply to the following heater types, as specified:

- Electric Heater
- 12 VDC Thermoswitch
- Combination Heater Thermoswitch
- Fluid Heat

The following equipment is recommended to test DAVCO heaters and thermoswitches:

- A precision low-resistance ohmmeter capable of measuring 0.1 ohm or less
- A clamp-on DC current-flow meter
- A means of chilling a thermoswitch, such as ice, dry ice, or compressed carbon dioxide
- A flameless source of heat, such as an infrared heat lamp
- A vortex tube to heat and cool a thermoswitch

Electric Heater

1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tire.
2. Disconnect the heater from the wiring harness.
3. Connect the ohmmeter leads to the pins of the heater (for heaters with one pin, connect to the pin and the bushing).
4. Read the resistance and use **Table 1** to determine whether the heater is within the acceptable resistance range.
5. Connect the heater wiring harness.

Electric Heater Test Paramaters		
Electric Heater	Watts	Resistance Range: Ohms
12 VDC (two pin)	250	0.6–0.8
12 VDC (single pin)	250	0.4–0.5
12 VDC (single pin)	150	0.8–1.1
120 VAC	75	173–203
120 VAC	37	369–411

Table 1, Electric Heater Test Parameters

12 VDC Thermoswitch

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

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the thermoswitch wiring harness, see **Fig. 1**. Remove the thermoswitch from the fuel/water separator.

Electric Heater, Thermoswitch, and Fluid Heater Tests

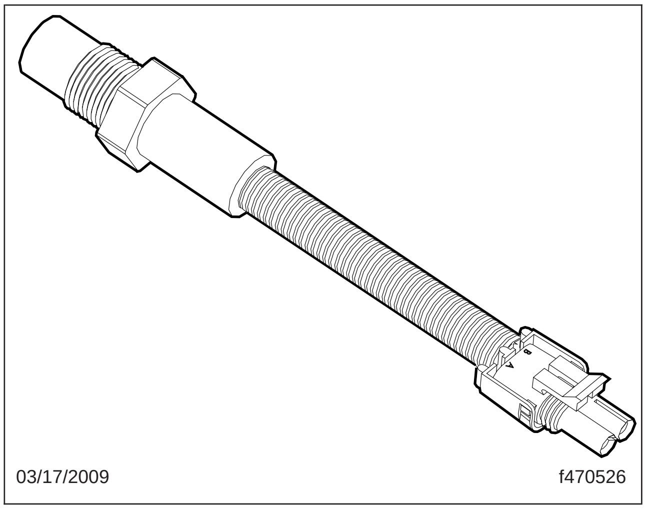


Fig. 1, 12 VDC Thermoswitch

5. Connect the ohmmeter leads to the pins of the thermoswitch.
6. Lower the thermoswitch temperature to below 40°F (4.4°C). The resistance shown on the ohmmeter should be less than 0.1 ohm.
7. Raise the thermoswitch temperature to above 60°F (15.5°C). The resistance should be more than 10 megohms.
8. Install the thermoswitch in the fuel/water separator. Connect the thermoswitch wiring harness.
9. Prime the system.
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Shut down the engine; check for leaks.

Combination Heater Thermoswitch

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

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heater/thermoswitch unit from the wiring harness, see Fig. 2.
5. Connect the ohmmeter leads to the heater/thermoswitch pins.
6. Lower the heater/thermoswitch unit temperature to below 40°F (4.4°C).

   The resistance shown on the ohmmeter should be:

   - 0.8 to 1.1 ohms for a 12 VDC 150 W unit
   - 0.2 to 2.5 ohms for a 24 VDC 250 W unit

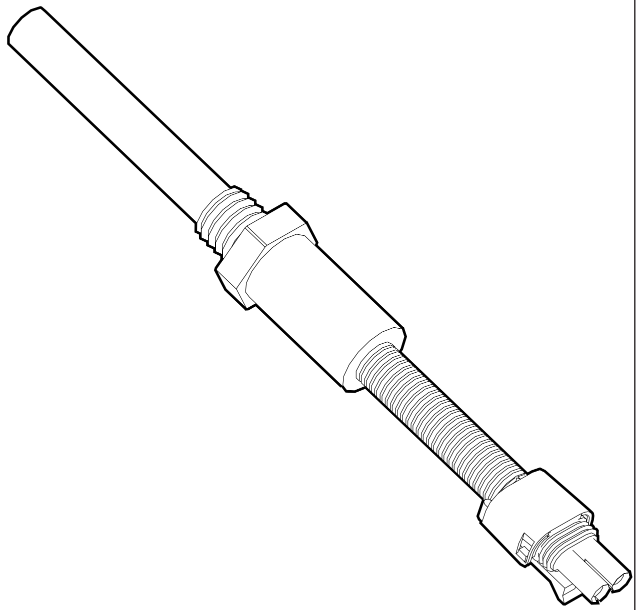


Fig. 2, Combination Heater Thermoswitch

7. Raise the heater/thermoswitch unit temperature to above 70°F (21°C). The heater/thermoswitch unit should show an open circuit.
8. Install the heater/thermoswitch in the fuel/water separator. Connect the heater/thermoswitch wiring harness.
9. Prime the system.
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Shut down the engine; check for leaks.

Fluid Heat Exchanger

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

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

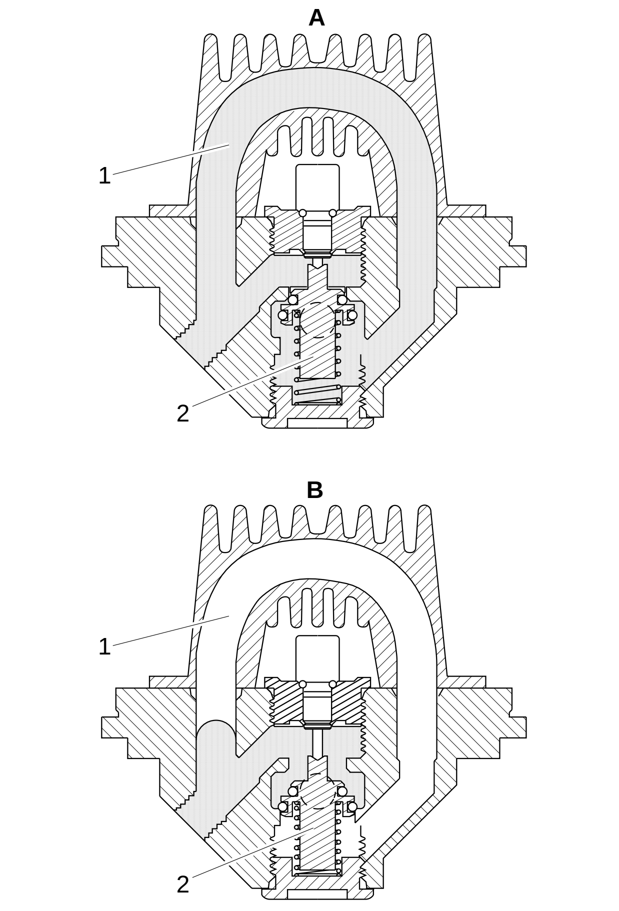
NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heating fluid lines from the bottom plate. These will be either engine coolant lines or return fuel lines. Plug engine coolant lines after removing them from the bottom plate of the housing.
5. Remove the bottom plate and lower housing O-ring.
6. When the fuel entering the fuel/water separator is cold, the thermovalve moves up, allowing warming fluid to enter the heater loop in the heat exchanger. When the fuel is warm, the thermovalve moves down, causing the warming fluid to bypass the heater loop and return directly to the tank. See **Fig. 3**.

Electric Heater, Thermoswitch, and Fluid Heater Tests

While looking into the fluid port of the bottom plate (**Fig. 4**), flow cold water over the thermovalve for 30 seconds, then run hot water over the thermovalve to determine whether the thermovalve spool is opening and closing.

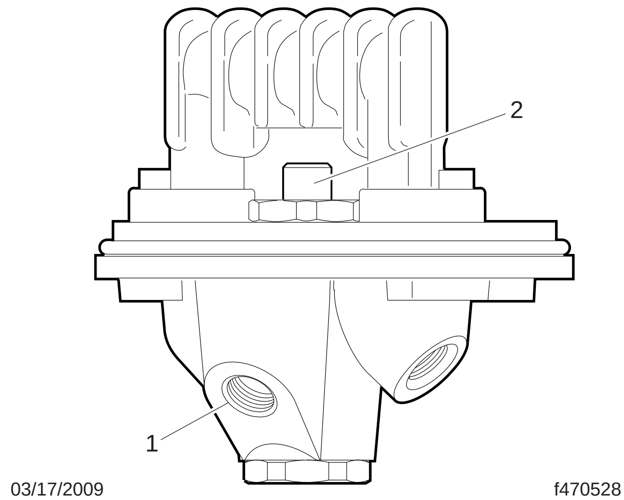
7. Replace the lower housing O-ring, and install the bottom plate on the fuel/water separator. There are two types of bottom plates: locking-collar-assembled and screw-assembled.



A. Fuel is Cold, Thermovalve Is Up
B. Fuel is Warm, Thermovalve is Down

1. Heater Loop 2. Thermovalve

Fig. 3, Heat Exchanger Fluid Flow



1. Fluid Port
2. Top of Thermovalve Spool

Fig. 4, Fluid Heater Thermovalve Test

- Locking-collar-assembled: Apply 2 to 3 drops of Loctite 406 to the bottom collar threads, then tighten 50 to 60 lbf·ft (68 to 81 N·m).
- Screw-assembled: Install the screws on the bottom plate and tighten them 8 to 10 lbf·ft (11 to 14 N·m).

8. Connect the heating fluid lines.
9. Prime the system.
   9.1 Ensure that the drain valve is closed.
   9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   9.3 Install and hand-tighten the vent cap.
   9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

Electric Heater, Thermoswitch, and Fluid Heater Tests

9.6 Shut down the engine and check for leaks.

The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.

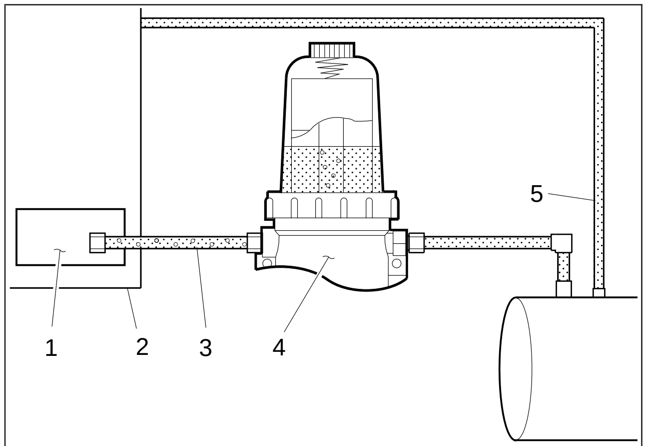
Identifying Bubble Types

Vapor Bubbles

Vapor bubbles are harmless and are present in all diesel fuel systems. Vapor bubbles are often mistaken for air bubbles, but *do not affect engine performance.*

Vapor bubbles (see **Fig. 1**) may be visible in a diagnostic sight tube installed between the fuel/water separator and the fuel pump. They consist of harmless fuel vapor and trapped air, may vary from champagne-size to 1/4-inch (6-mm) diameter, and may increase in volume or size as the engine rpm increases. The lower pressure inside a fuel/water separator filter, caused by the suction of the fuel pump pulling fuel through the fuel/water separator, creates vapor bubbles. These vapor bubbles are normal and harmless to engine operation. In the fuel pump, the fuel is pressurized and the vapor bubbles dissolve. Vapor bubbles do not appear on the fuel return side of the system.

There is no troubleshooting or repair procedure required for vapor bubbles. Vapor bubbles do not cause performance issues and will not be present downstream of the fuel pump.



1. Fuel Pump
2. Engine
3. Fuel Outlet Line, Vapor Bubbles Visible
4. Fuel/Water Separator, Vapor Bubbles Visible *Inside* Filter, *No* Bubbles Visible in Clear Cover
5. Fuel Return Line (no bubbles)

Fig. 1, Harmless Vapor Bubbles

Air and Gas Bubbles

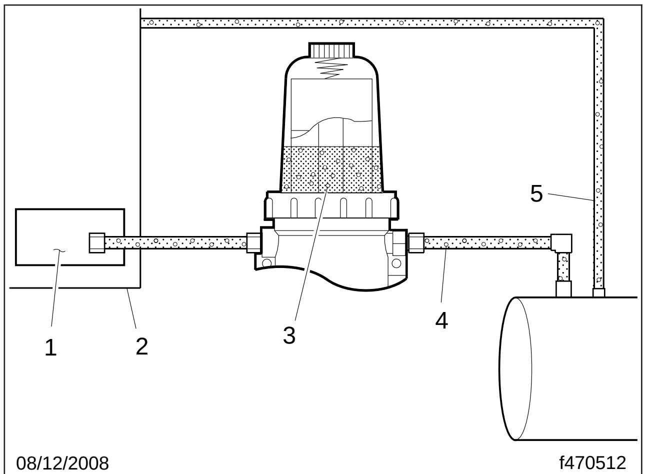
Air or gas bubbles indicate harmful leaks, and can cause hard starting and impaired engine performance. All diesel fuel holds some trapped air, caused by the natural splashing that occurs in the fuel tank. But excessive air bubbles, severe enough to degrade engine performance, indicate an air leak on the suction side of the fuel system, from the fuel tank into the fuel pump.

Air bubbles visible in the clear cover of a DAVCO fuel/water separator may indicate an air leak in the fuel system upstream of the bubbles, or in the fuel/water separator; see **Fig. 2**. If there are no bubbles visible in the clear cover but the engine runs rough, there may be an air leak at or between the fuel/water separator outlet port and the fuel pump inlet. These bubbles will be visible in a diagnostic sight tube installed between the fuel pump and the fuel/water separator, and in a diagnostic sight tube installed in the fuel return hose.

Exhaust gas bubbles may also be visible in the clear filter cover. They are the result of leaking fuel injector seals, which can allow combustion gases to enter the fuel system, pass through the fuel return line into the fuel tank, and be drawn into the fuel/water separator. They may be visible in a diagnostic sight tube installed in the fuel return line. To test for combustion gas in the fuel, disconnect the return line at the tank, submerge the end in a bucket of fuel, run the engine, and watch for bubbles. As they pop, these bubbles may smell like exhaust fumes.

In extreme cases, these combustion gas bubbles cause enough aeration in the fuel tank to create visible bubbles in the clear cover of the fuel/water separator and impair engine performance. See the engine manufacturer's documentation for diagnosis and repair of injector seal leakage.

Use the following procedures to determine which bubbles are present in the fuel system, and whether repair is necessary.



1. Fuel Pump
2. Engine
3. Fuel/Water Separator, Bubbles Visible in Clear Cover
4. Fuel Inlet Line, Bubbles Visible
5. Fuel Return Line, Bubbles Visible

Fig. 2, Air Bubbles Indicating a Leak

Initial Diagnostic Procedure

1. Apply the parking brake, chock the tires, and turn on the engine.
2. Check for air bubbles in the fuel/water separator clear cover.
3. If no bubbles are visible in the clear cover, but the engine continues to run rough, lopes, or has loss of power, there may be an air leak between the fuel/water separator outlet and the fuel pump inlet.

   If so, bubbles should be visible in a diagnostic sight tube installed at the fuel pump inlet. Air bubbles may also be visible in a diagnostic sight tube installed in the fuel return line to the fuel tank.
4. Replace fuel lines and tighten fittings as needed.

Testing Procedures

Air Leak in the Fuel System

Air leaks are sometimes caused by:

- loose fittings;
- a faulty inlet check valve;
- faulty O-rings;
- leakage elsewhere in the fuel system;
- or dirt on threads and sealing surfaces.

Air leaks originating between the fuel tank and the fuel/water separator cause air bubbles visible in the clear cover, as shown in **Fig. 2**.

If there are symptoms of sucking air and there are no bubbles in the clear cover, look for the air leak at:

- the outlet fitting;
- the fuel pump inlet connection;
- the fuel hose connections;
- or at the vent cap O-ring.

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Remove the fuel hose from the fuel pump inlet port.
3. Install a jumper hose from the inlet port into the fuel tank through the fill cap, or into a container of fuel.
4. Start the engine and look for bubbles in the clear filter cover. If the air bubbles are eliminated, the air source (and the leak) is at either the fuel tank fittings, or the hose connections.

   If air bubbles persist after the tank fittings and hose connections are secured, the leak may be in the fuel/water separator.
5. If the leak is suspected to be in the fuel/water separator, disconnect all fuel connections, coat

the threads with liquid or paste sealer, and reconnect the fuel connections and tighten them securely.

Air Pressure Testing

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Remove the fuel/water separator from the chassis. For instructions, see **Subject 100**.

WARNING

Wear goggles and skin protection when pressure-testing a fuel/water separator, and be careful not to perform this test near a source of possible ignition, such as an open flame. Never exceed the maximum pressure stipulated for the test, and do not perform this test if the clear cover appears to be damaged.

5. Plug the fuel outlet port. Do not remove the filter, filter cover, collar, vent cap, drain valve, or check valve. Do not remove the electric heating element (if equipped), and do not plug the fluid heat ports (if equipped).
6. Apply 15 psi (207 kPa) air pressure at the fuel inlet. Immerse the unit in a tank of water and look for air bubbles.
7. If no bubbles appear, the air leak is not in the fuel/water separator.
8. Install the fuel/water separator onto the chassis frame rail. For instructions, see **Subject 100**.
9. Prime the system.

   9.1 Ensure that the drain valve is closed.

   9.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

   9.3 Install and hand-tighten the vent cap.

   9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

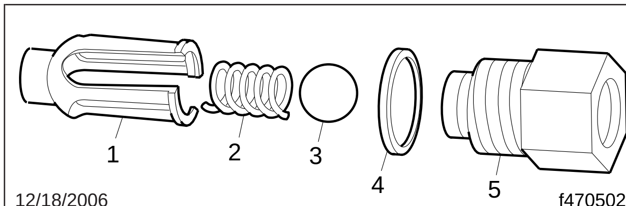
   9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

Filter Element Restriction Check

A DAVCO fuel/water separator, properly assembled with the rubber grommet in the bottom of the fuel filter, does not restrict fuel flow until the fuel level has risen to the top of the filter. If the fuel level has risen to the top of the filter, replace the filter.

Check Valve Operation Test, Fuel Pro 382/482 and Diesel Pro 243 Configurations

When air is introduced into the fuel system, (e.g. when draining fluid or when replacing the fuel filter), the check valve (**Fig. 3**) works to keep the fuel system primed from the fuel tank to the fuel/water separator.



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 3, Check Valve Assembly

To test for proper check valve operation, remove the fuel inlet line, then open the vent cap. Fuel should not flow out of the check valve, although a slight seepage of fuel is normal. If fuel drains back out of the check valve, complete the following procedure.

1. Shut down the engine, apply the parking brake, and chock the tires.

Troubleshooting

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing, see **Fig. 3**.
6. Clean and inspect the check valve body. If the valve body is damaged, or if the ball seat is not smooth, replace the valve. For instructions, see **Subject 110**.
7. If the valve body and ball seat are not damaged, clean the threads on the check valve body, fuel inlet fitting, and the water separator housing.
8. Apply a soft-set pipe thread sealant to the check valve body threads. Install the check valve body in the fuel/water separator housing. Do not use tape to seal the fuel fittings; it will eventually leak.

   Tighten the check valve body 44 to 60 lbf·ft (60 to 81 N·m) on a Fuel Pro 382, or 25 to 40 lbf·ft (34 to 54 N·m) on a Diesel Pro 232/233.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap O-ring and vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Check for leaks and shut down the engine.

Other Conditions Visible Inside the Cover

The clear filter covers fitted to DAVCO fuel/water separators provide the opportunity to monitor several aspects of fuel condition and engine status, as described in **Table 1**.

Troubleshooting

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
Amber-colored fuel below the top of the filter element	Nothing, the filter is doing its job	Do not change the filter.
Amber-colored fuel with dark patches in places on the filter element	Dark patches indicate bacteria or algae may be present. Use Fleetguard Monitor Kit CC2650 to test for microbiological activity.	It may be necessary to use a microbicide, and suggest vehicle operator carry extra filters.
Extremely dark or cloudy fuel with thick black film or sludge collecting on the filter element	Black film or sludge on the filter media indicates the presence of asphaltenes. It may be necessary to use an asphaltene conditioner.	Do not assume this is oil from the engine. Monitor the vehicle for oil consumption. Refer to engine manufacturer's service literature for more information.
Bubbles inside the clear cover	Check for air leaks anywhere in the fuel system. Any leak in any fitting will cause bubbles to appear in the clear cover.	This problem will lead to power complaints; it must be remedied.
No bubbles in the cover, but the engine is running rough	Check for air leaks between the fuel/water separtor outlet port and the fuel pump inlet. Check and tighten all fuel fittings in the area of the leak.	Do not replace the fuel/water separator.
Coolant in the fluid drained from the fuel/water separator	Check for leaks in the engine, where fuel and coolant are near each other. The most common problem place is the injector cup.	Do not allow the equipment to be operated until the problem is found and repaired.
Anything not listed here	Call DAVCO at 1-800-328-2611, or email: customerservice@DavcoTec.com	—

Table 1, Conditions Visible Inside DAVCO Clear Filter Covers

Specifications

Component	Fuel Pro 482	Fuel Pro 382		Diesel Pro 243		Diesel Pro 233	
	lbf·ft (N·m)	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)
Inlet Port/Check Valve	45 (61)	44–60 (60–81)	—	12–14 (16–19)*	—	25–40 (34–54)	—
Water in Fuel Sensor	—	—	20–24 (226–271)	—	20–24 (226–271)	—	20–24 (226–271)
Electric Heating Element	15–30 (20–41)	15–30 (20–41)	—	25–40 (34–54)	—	15 (20)	—

* Check valve assembly not connected to inlet port on Diesel Pro 243 configurations.

Table 1, Torque Values

General Information

The exhaust system routes hot exhaust gas away from the vehicle, and reduces engine exhaust noise. System components include various configurations and lengths of piping and clamps, a catalytic converter muffler and mounting components, and an exhaust brake. For information on the exhaust brake, see **Group 01** of this manual. See **Fig. 1** for the exhaust routing.

Catalytic Converter Muffler

Vehicles with a Cummins B Series engine or a Caterpillar 3126 EPA ’02 engine use a catalytic converter muffler.

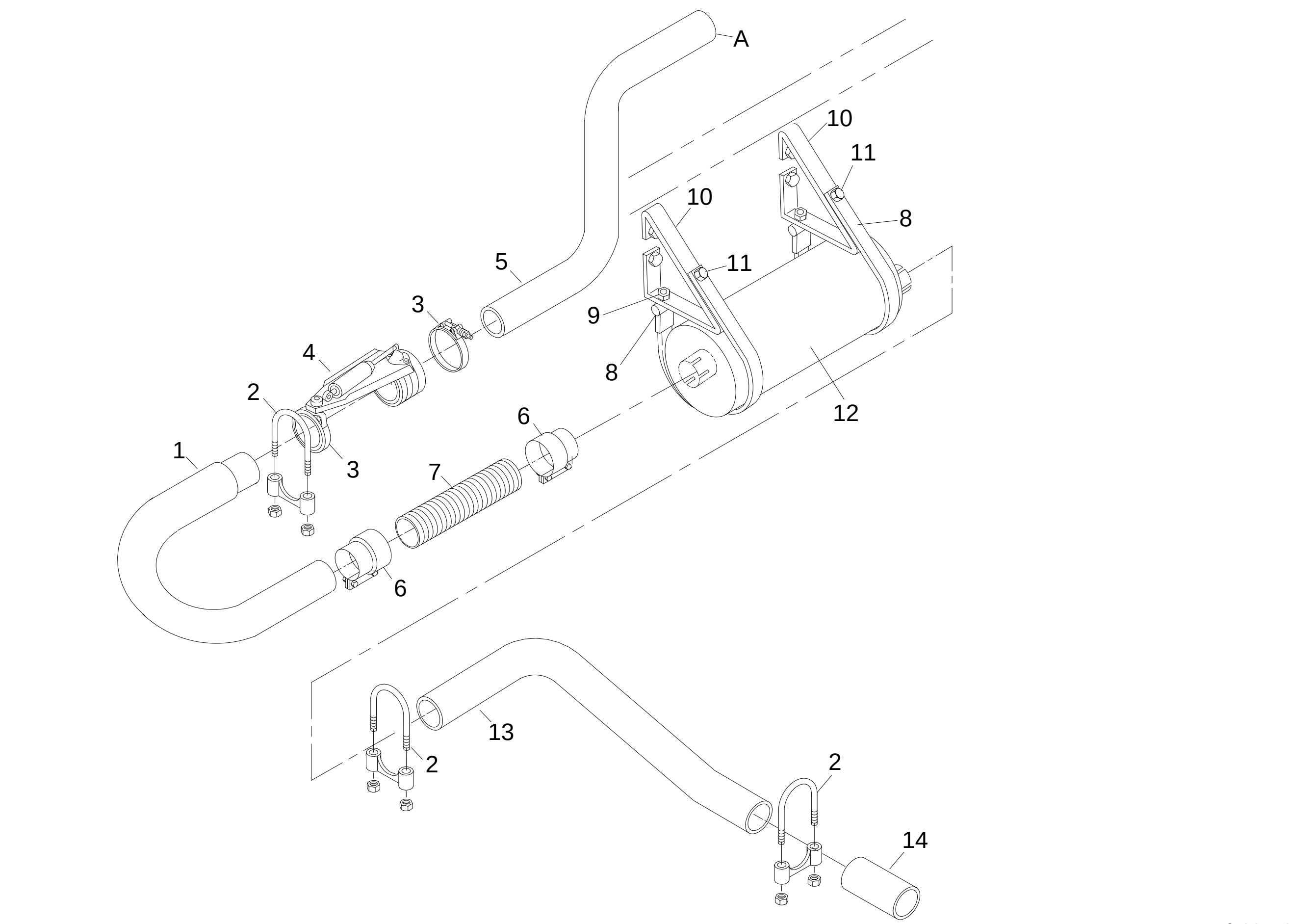
The converter muffler consists of three sections: a muffler section, the catalytic converter, and another muffler section. See **Fig. 2**.

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.

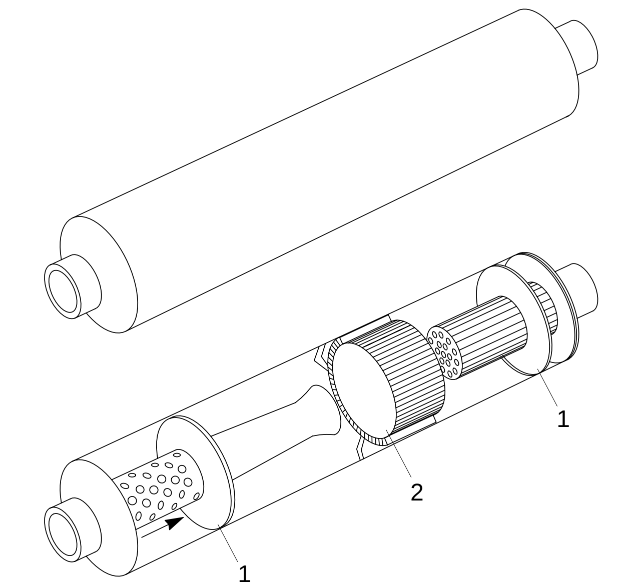
Use parts specified by PartsPro® when replacing any of the exhaust system components.

General Information



A. Connects to the Turbocharger
1. Exhaust Brake Outlet Pipe
2. Saddle Clamp Assembly
3. Constant-Torque Clamp
4. Exhaust Brake Assembly
5. Exhaust Brake Inlet Pipe
6. Wide-Band Clamp
7. Flex Pipe
8. Muffler Mounting Band
9. Nut
10. Muffler Bracket
11. Hexbolt
12. Catalytic Converter Muffler
13. Tail Pipe
14. Tail Pipe Extension

Fig. 1, Exhaust System Routing (rear-mounted engine, typical)



1. Baffle
2. Substrate

Fig. 2, Typical Catalytic Converter Muffler

Exhaust System Components Removal and Installation

Removal

NOTE: It is not necessary to remove the muffler from the vehicle when removing only the exhaust pipe, the flex pipe, or the tail pipe.

1. Remove the catalytic converter muffler, exhaust and tail pipe assembly clamp, and U-bolt assemblies, and the exhaust brake as required to remove worn or damaged components. See **Fig. 1**.
   - 1.1 Remove the tail pipe and tail pipe extension by removing the U-clamps connecting them to the muffler and each other.
   - 1.2 Remove the exhaust brake outlet pipe by removing the wide-band clamp holding it to the flex pipe; then remove the U-clamp holding the pipe to the exhaust brake.
   - 1.3 If it is necessary to remove the exhaust brake, see **Group 01** for instructions.
   - 1.4 Remove the exhaust brake inlet pipe by disconnecting it from the turbocharger and the engine brake.
2. Remove the muffler.

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.

NOTICE

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.

   - 2.1 Disconnect the flex pipe from the muffler inlet. Discard the wide-band exhaust clamp.
   - 2.2 Remove the muffler straps from the muffler bracket; then remove the muffler.

Installation

1. Install any exhaust system components that were removed. See **Fig. 1**.
   - 1.1 Position the exhaust brake inlet pipe to the turbocharger outlet. Install the clamp and tighten it 60 to 108 lbf·in (678 to 1220 N·cm).
   - 1.2 If the exhaust brake was removed, install it following the instructions in **Group 01** of this manual.
   - 1.3 Attach the exhaust brake inlet pipe to the exhaust brake. Install the constant-torque clamp. Tighten the clamp firmly.
   - 1.4 Attach the exhaust brake outlet pipe to the exhaust brake. Install the constant torque clamp and tighten it firmly. Install the saddle clamp. Tighten the saddle clamp U-bolt nuts 35 to 45 lbf·ft (49 to 61 N·m).
   - 1.5 Using a new wide-band clamp, attach the flex pipe to the exhaust brake outlet pipe. Tighten the fasteners for the clamp (starting at the larger end) alternately and in three increments to 55 lbf·ft (75 N·m).

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.

NOTICE

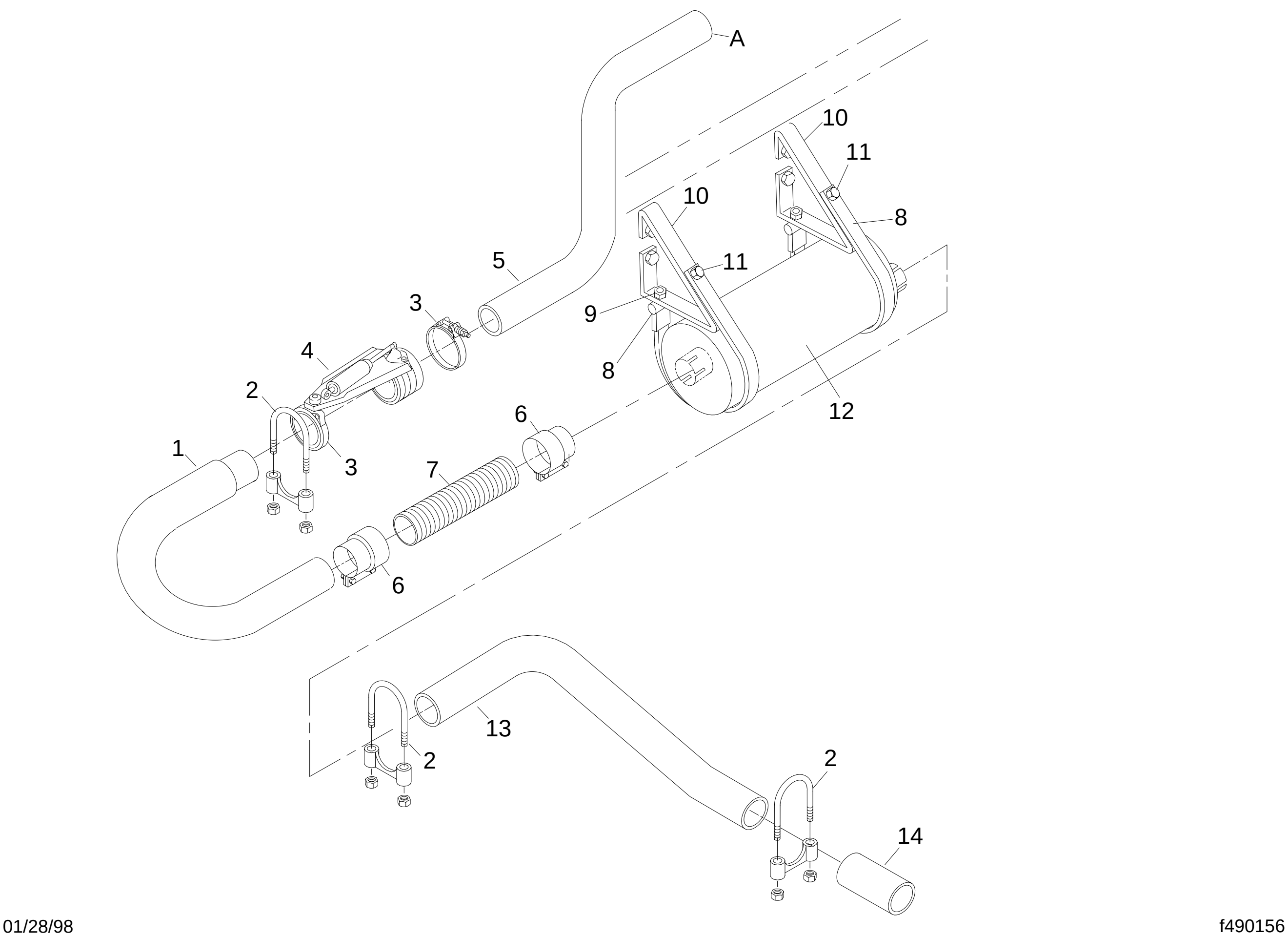
A catalytic converter muffler contains a fragile ceramic core. To prevent damage to the muffler, do not drop or strike any part of the muffler assembly.

   - 1.6 Install the muffler onto its brackets, using the muffler mounting bands. Install the mounting band fasteners, but do not tighten them.

     Slide the muffler rearward or forward as needed, then attach the flex pipe to the muffler inlet tube, using a new wide-band exhaust clamp. Tighten the fasteners for the clamp (starting at the larger end) alternately and in three increments to 55 lbf·ft (75 N·m).

     Tighten the muffler mounting band fasteners 10 lbf·ft (14 N·m).

Exhaust System Components Removal and Installation



A. Connects to the Turbocharger

1. Exhaust Brake Outlet Pipe
2. Saddle Clamp Assembly
3. Constant-Torque Clamp
4. Exhaust Brake Assembly
5. Exhaust Brake Inlet Pipe
6. Wide-Band Clamp
7. Flex Pipe
8. Muffler Mounting Band
9. Nut
10. Muffler Bracket
11. Hexbolt
12. Catalytic Converter Muffler
13. Tail Pipe
14. Tail Pipe Extension

Fig. 1, Exhaust System Routing (rear-mounted engine, typical)

1.7 Attach the tail pipe to the muffler outlet tube. Tighten the saddle clamp U-bolt nuts 35 to 45 lbf·ft (49 to 61 N·m).

1.8 Attach the tail pipe extension to the tail pipe. Tighten the saddle clamp U-bolt nuts 35 to 45 lbf·ft (49 to 61 N·m).

2. Start the engine and check for leaks in the exhaust system. Tighten any connections as needed. If the wide-band exhaust clamps leak, replace them.

Alignment

Perform the following procedure to align the complete exhaust system.

1. Loosen the pipe connection clamps and the pipe support bracket clamps. Loosen the inlet pipe-to-exhaust manifold attaching nuts.
2. Work from the front and progressively align the exhaust system components and hangers to eliminate any interferences.
3. Working from the rear forward, retighten the clamps. Tighten the exhaust manifold to inlet pipe attaching nuts alternately and equally so that the pressure on the ball flange will be uniform.

Exhaust System Adjustments

Adjustments

Inspect inlet pipes, outlet pipes and mufflers for cracked joints, broken welds and corrosion damage that would result in a leaking exhaust system. Inspect the clamps, brackets and insulators for cracks and stripped or badly corroded threads. When pipe clamps are loosened and/or removed to replace a pipe or muffler, replace the clamps if there is a reasonable doubt that its service life is limited.

NOTE: Care should be taken during inspection for leaks since staining or moisture around the muffler seam can be interpreted as a sign of a leaky muffler. Because mufflers are designed without drain holes, it is normal for a certain amount of moisture and staining to be present around the muffler seams. The presence of soot, surface rust, or moisture does not indicate a faulty muffler and should not constitute a basis for replacement.

Muffler clamps can be broken due to over tightening during servicing of exhaust leaks. When attempting to eliminate exhaust leaks at joints, the muffler clamp should be tightened to specification limits only. If this does not eliminate the leak, the clamp should be loosened, rotated approximately one-quarter turn, and then retightened to the specification.

General Information

Exhaust system performance complaints such as excessive back pressure or a malfunctioning exhaust control valve are usually noticeable by their effect on engine performance.

However, other malfunctioning components may have similar effects on engine performance and be characterized by the same symptoms or complaints. It is therefore necessary to refer to the engine diagnosis and service procedures in the engine manufacturer's manual when attempting to diagnose this type of problem.

For general complaints, refer to the diagnosis guide in this subject.

Noisy or Leaking Exhaust Diagnosis Guide

1. Check for broken or loose clamps and/or brackets.

   If the clamps or brackets are okay, go to the next step.

   If the clamps and/or brackets are not okay, repair or replace them as necessary. Then start the engine. If the noise still exists, go to the next step.

2. Check the inlet pipe and the muffler for punctures, split seams, or improper welds.

   If the pipe and the muffler are okay, go to the next step.

   If the pipe and the muffler are damaged, replace the inlet pipe and/or the muffler as necessary. If the noise still exists, go to the next step.

3. Inspect the exhaust manifold for loose fasteners or cracks.

   If the manifold is okay, refer to the engine manufacturers service manual.

   If the manifold is not okay, tighten the fasteners to the specification or replace the exhaust manifold.

Specifications

Fastener Torques		
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)

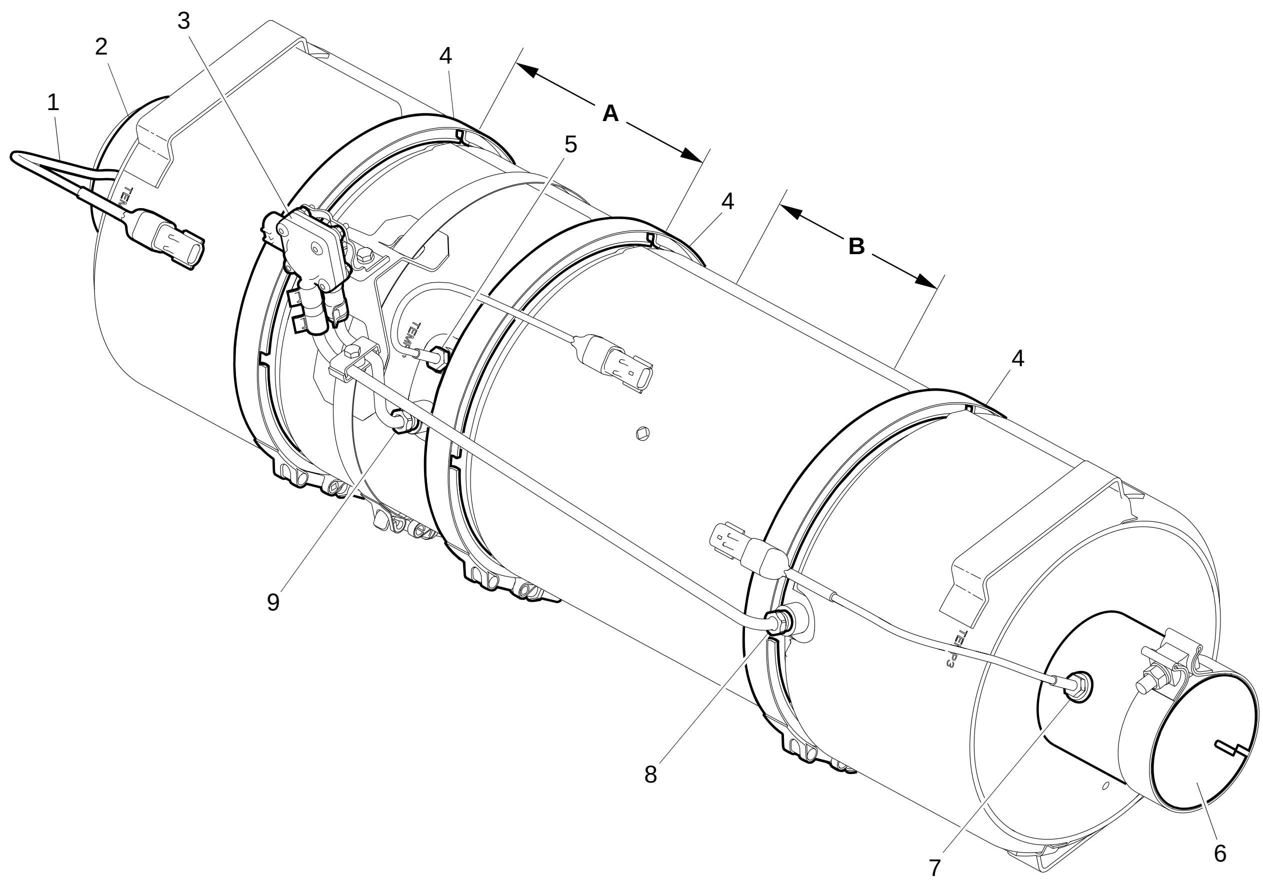
Table 1, Fastener Torques

General Information

The aftertreatment system (ATS) includes all the piping and equipment between the engine turbocharger outlet and the tip of the exhaust pipe. It corresponds to the exhaust system on pre-EPA07 vehicles, but includes an aftertreatment device (ATD) instead of a muffler, and other equipment. See **Fig. 1**Operation of the ATS is controlled by an electronic control module (ECM).

Engine manufacturers use different methods and equipment to reduce emissions from their engines, but an ATD is used on all of them. The ATD is available only in chassis-mounted configuration, and can be mounted either vertically or horizontally. ATS exhaust piping is stainless steel.

Inside the ATD, the exhaust emissions pass first through the diesel oxydation catalyst where they are chemically treated, then through the diesel particulate filter (DPF), where solid particles are trapped. The



A. DOC Area
1. Inlet Temperature Sensor
2. Marmon Fitting at Inlet from Turbocharger
3. Sensor Housing
4. DPF V-Band Mounting Clamps
5. Inlet Temperature Sensor

B. DPF Area
6. Exhaust Outlet to Diffuser
7. Outlet Temperature Sensor
8. DPF Outlet Pressure Sensor
9. DPF Intake Pressure Sensor

Fig. 1, Aftertreatment Components (typical)

General Information

remaining particulates are almost completely vaporized in the DPF, in a process called regeneration (regen).

Soot from additives in the engine oil cannot be vaporized, but it is burned to ash and held in the DPF. When the ash buildup is heavy enough to begin clogging the DPF, the DPF must be removed from the vehicle and physically cleaned in special processes specified by the engine manufacturers.

Using low-ash oil extends the time required for DPF cleaning, and **only low-ash oil should be used in EPA07 engines**.

EPA07 emissions regulations limit NOx to just over 1 gram per brake horsepower hour (g/bhp-hr) and particulate matter cannot exceed 0.01 g/bhp-hr. **EPA07 engines require ultralow-sulphur diesel (ULSD) fuel, for low emissions and long life of the ATD**.

EPA07 engines will run on higher sulfur fuel, but that reduces the efficiency of the ATS. Using non-ULSD fuel in an EPA07 engine will cause expensive damage to the ATD after a few tankfuls.

NOTE: FCCC documentation deals only with removal and installation of the ATD and other parts of the ATS. Refer to the engine manufacturers' service literature for all testing, disassembly, cleaning, and repair of the ATD and other components.

IMPORTANT: The ATS is part of an interrelated engine and emissions management system, controlled by the ECM. Follow the engine manufacturer's procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

In Cummins and Mercedes-Benz engines, there is a diesel oxidation catalyst (DOC) inside the intake side of the ATD. The DOC chemically treats the exhaust, to reduce gas emissions before the exhaust reaches the DPF.

The DPF honeycomb tubes are closed at alternate ends, forcing the exhaust to move through its walls where it traps the soot.

There are two types of regen, passive and active.

Passive regen is ongoing, whenever vehicle operation creates an ATD temperature of 572°F (300°C) or higher. There is no indication to the driver that the process is happening, and exhaust gas temperature is no higher than normal. Under load and at highway speeds, passive regen may be all that is necessary to keep the DPF clear. But operating under light loads or at low speeds does not generate enough heat in the ATD for passive regen, and particulate matter builds up in the DPF.

As particulate matter builds up in the DPF, it blocks exhaust gas from passing through the honeycomb tube walls. Pressure sensors on the intake and exhaust sides of the DPF sense the increase in back pressure, and signal the ECM. The ECM also keeps track of engine hours and mileage, and other measurements, to calculate when active regen is necessary.

During active regen, the inside of the ATD is raised to very high temperatures. Exhaust gas temperature reaches over 1112°F (600°C), to reduce the trapped soot to ash. There are two types of active regen, at-speed and parked.

- At-speed regen is automatically initiated by the ECM. Exact conditions for its initiation vary, according to the engine manufacturer's design. Generally, it happens when the vehicle is travelling at least 7.5 mph (12 km/h), and stops when the vehicle slows to 5 mph (8 km/h) or below.
- Parked regen is initiated by the driver when the vehicle is safely parked, a specific sequence of procedures is followed, and the driver pushes the regen button on the dashboard. The parked regen sequence varies with vehicle configuration. Follow the exact sequence prescribed for a given vehicle, according to engine manufacturer's literature.

IMPORTANT: The ATS is an integrated system, and every component must be operating, in order for the ATS to work correctly.

Aftertreatment Device (ATD) Removal and Installation

Removal

It may be necessary to raise the vehicle or remove body panels to service the ATD, depending on vehicle configuration.

NOTICE

The ATD assembly weighs from 125 to 150 pounds (57 to 68 kg) and must be protected from impact or sharp jolts. Dropping the ATD, or subjecting it to jarring impact can crack the diesel particulate filter (DPF) inside, which is built on a ceramic substrate. If that happens, the DPF is ruined and must be replaced.

A secure support is necessary to remove and install the ATD safely. The ATD must be held securely to protect it from falling, or hitting hard against something else.

The horizontal ATD lifting device (TLZ00785) is designed for the job on a horizontal ATD.

The ATD is designed so that its exterior operating temperature is comparable to that of a standard muffler, but its interior and the outlet become extremely hot during regeneration events.

DANGER

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

1. Set the parking brake, and chock the tires.

NOTE: Never attempt to start the vehicle with the ATD removed or with the ATD sensors disconnected, unless proper diagnostic tools are connected. See the engine manufacturer's literature for proper equipment and procedures.

2. Disconnect the connections at the sensor box and the diesel oxidation catalyst (DOC) inlet temperature sensor. See **Fig. 1**.
3. Using a suitable marker, mark the inlet and outlet joints and mounting bracket locations on the ATD, so that the ATD can be installed exactly as it was removed.

NOTE: There are positioning pins to guide placement of the ATD during vehicle manufacture, but they are designed to break off if they are highly stressed, to avoid damaging to the ATD. If the positioning pins are gone, the locating marks serve the same purpose.

4. Move the ATD handling device into place against the ATD, so that it is in position to support the ATD securely and the ATD can not roll, tip, or fall.
5. The exhaust piping may require support, such as a rope sling, to support it when the ATD is removed. If such support is required, install it now.

NOTICE

Be careful not to stress or twist the bellows as the ATD is manipulated. The bellows are not designed to support weight or withstand undue stress and can easily be damaged, requiring expensive replacement.

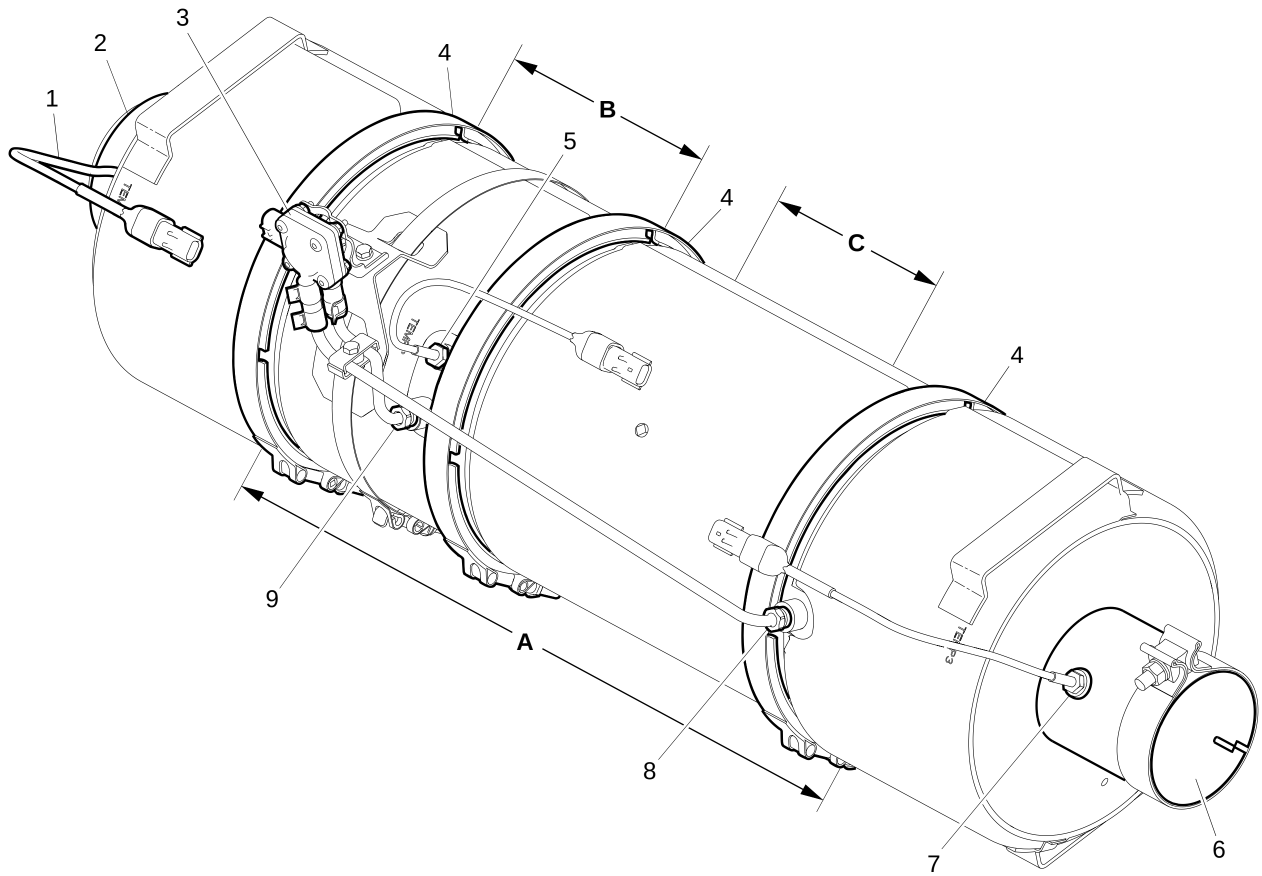
6. Remove the clamps from the Marmon fittings at the inlet and outlet of the ATD.
7. Remove the two mounting bands that hold the ATD to its mounting brackets, so that the ATD is held by the ATD handling device.
8. Move the ATD slightly, so that the ATD positioning pin clears its hole in the front mounting bracket; see **Fig. 2**. Carefully remove the ATD from the vehicle.

NOTE: ATD component service procedures, such as cleaning the diesel particulate filter or servicing the sensors, are documented in the engine manufacturer's service literature.

Installation

1. Using the ATD handling device, move the ATD into position so the inlet and exhaust align with the inlet and exhaust piping. Be sure the ATD

Aftertreatment Device (ATD) Removal and Installation



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A. Inspect this area of the canister for dents.
B. DOC Area
C. DPF Area

1. Inlet Temperature Sensor
2. Marmon Fitting at Inlet from Turbocharger
3. Sensor Housing
4. DPF V-Band Mounting Clamps
5. Inlet Temperature Sensor
6. Exhaust Outlet to Diffuser
7. Outlet Temperature Sensor
8. DPF Outlet Pressure Sensor
9. DPF Intake Pressure Sensor

Fig. 1, Aftertreatment Device (typical)

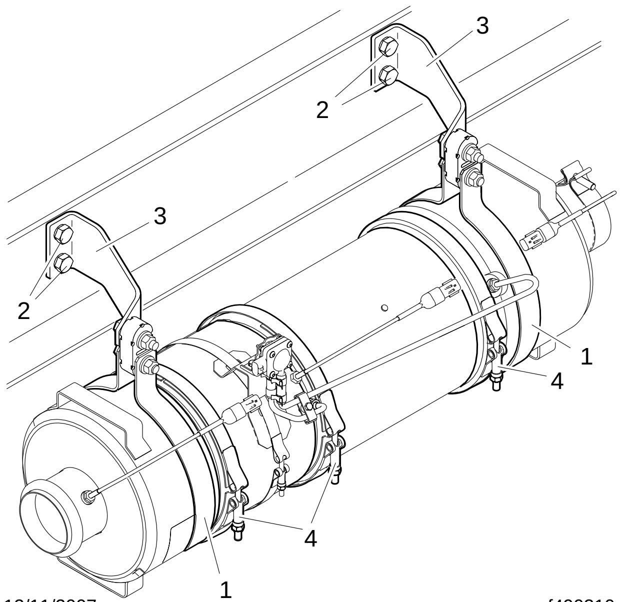
positioning pin engages its hole in the ATD mounting bracket.

2. Install the ATD mounting bands, but do not tighten them yet.

IMPORTANT: The exhaust flex bellows are easily damaged by improper handling or applying incorrect torque to the clamps.

3. Position the V-band clamps on the Marmon fittings and tighten them to the value shown in **Table 1**.
4. Tighten the ATD mounting bands to the value shown in **Table 1**. Do not overtighten, or the ATD could be deformed and the DPF may be ruined.
5. Connect the harness to the sensor housing and the front temperature sensor.

Aftertreatment Device (ATD) Removal and Installation



1. Mounting Bands
2. Mounting Bracket Fasteners
3. Mounting Brackets
4. V-Band Clamp Fasteners

Fig. 2, Aftertreatment Device Mounting

Aftertreatment Device Torque Values	
Fitting	**Torque: lbf·ft (N·m)**
Mounting Bands	Initial: 15 (20) Final: 30 (41)
Temperature Sensor Nuts	26–29 (35–39)
Pressure Line Tube Nuts	11–13 (15–18)
Pressure Sensor Jam Nuts	15–18 (20–24)
Marmon V-Band Clamps	12–13 (16–18)
Compression Fittings	15–18 (20–24)
Bellows Torco Clamps	Target: 41 (56) Range: 35–48 (47–65)

Table 1, Aftertreatment Device Torque Values

6. Remove the ATD handling device.
7. If a support was fastened around the exhaust pipe, remove it.
8. Remove the chocks from the tires.
9. Run an operational check on the vehicle and check for leaks.

General Information

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx), and 0.01 g/bhp-hr of particulate matter (PM).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream. DEF is colorless, non-toxic, and biodegradable.

The EPA10 aftertreatment system (ATS) includes all the piping and equipment between the turbocharger outlet and the tip of the exhaust pipe. It includes an aftertreatment device (ATD) a SCR catalyst, and other equipment. See **Fig. 1** for system components and function. Monitoring and operation of the ATS is controlled by an electronic control module (ACM).

EPA10 engines require ultralow sulphur diesel (ULSD) fuel, for low emissions and long life of the diesel particulate filter (DPF), a honeycomb soot filter inside the ATD.

The ATS is always chassis-mounted, but there are several different installation options available to fit any needed vehicle configuration. ATS exhaust piping is stainless steel.

Inside the ATD, the exhaust first passes through the diesel oxidation catalyst (DOC) where combustion gases are chemically broken down to water and carbon dioxide, then through the (DPF), where solid particles are trapped. The soot is reduced to ash during regeneration, and the ash is collected in the DPF until the DPF is full, at which time the DPF must be removed and cleaned.

The trapped particles are almost completely vaporized in the DPF during regeneration (regen). The soot from engine oil additives which cannot be vaporized is burned to ash and held in the DPF until it eventually builds up, and the DPF must be removed and physically cleaned. After the exhaust gases pass through the ATD, they are treated with precisely-controlled quantities of DEF, and then pass into the SCR catalyst. In the presence of heat from the exhaust gas, DEF is converted to ammonia gas. The ammonia gas reacts with NOx in the SCR catalyst to yield nitrogen and water vapor, which exits out the tailpipe.

IMPORTANT: To minimize soot buildup on the DPF, low-ash oil is necessary for maximum service between physical cleanings. Only low-ash oil should be used in EPA10 engines. Refer to the engine manufacturer’s service literature for specific information.

NOTE: Freightliner documentation deals only with removal and installation of the components of the ATS. Refer to the engine manufacturer’s service literature for all testing, disassembly, cleaning, and repair of the ATS components.

IMPORTANT: The ATS is part of an integrated engine and emissions management system, controlled by the ACM. Follow the engine manufacturer’s procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

Regeneration

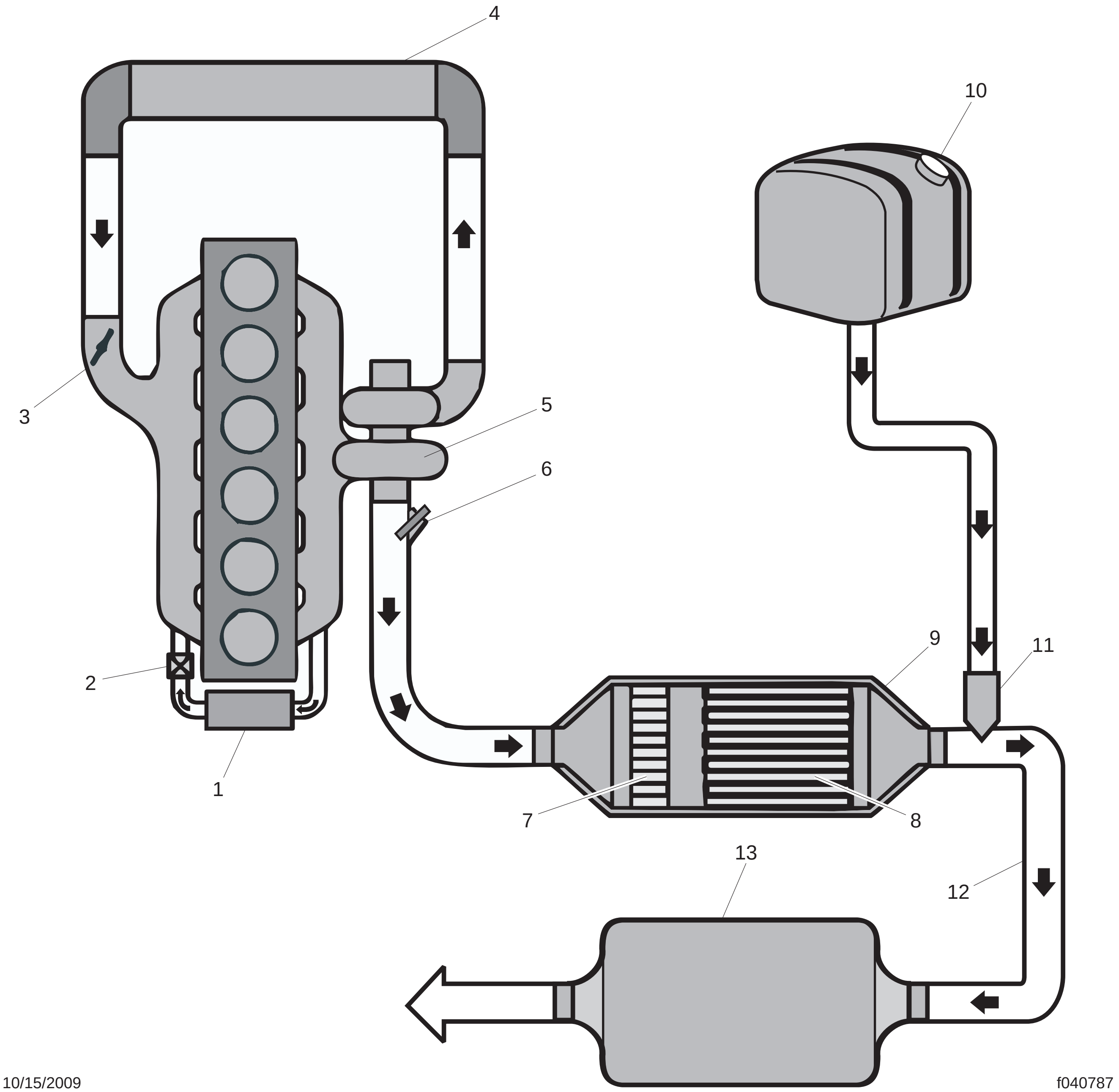
There are two types of regeneration; passive and active. Refer to the vehicle driver’s manual and the engine operator’s and maintenance manual for detailed regen information.

Passive regeneration happens whenever the ATD internal temperature is 572°F (300°C) or higher. This happens during normal loaded vehicle operation, and exhaust gas temperature is no higher than normal. Under load and at highway speeds, passive regeneration may be all that is necessary to keep the DPF clear. But running light loads, or at low speeds, does not generate enough heat in the ATD for passive regeneration, and soot builds up in the DPF.

The ACM monitors conditions in the ATS. As soot builds up in the DPF, and passive regeneration is not sufficient to burn off accumulated soot, the ACM will initiate active regeneration and monitor its operation.

During active regeneration, engine rpm rises to fast-idle speed and extra fuel is injected into the ATD to raise its interior temperature very high, over 1112°F (600°C), and turn the trapped soot to harmless ash. There are two types of active regeneration; at-speed and parked.

General Information



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

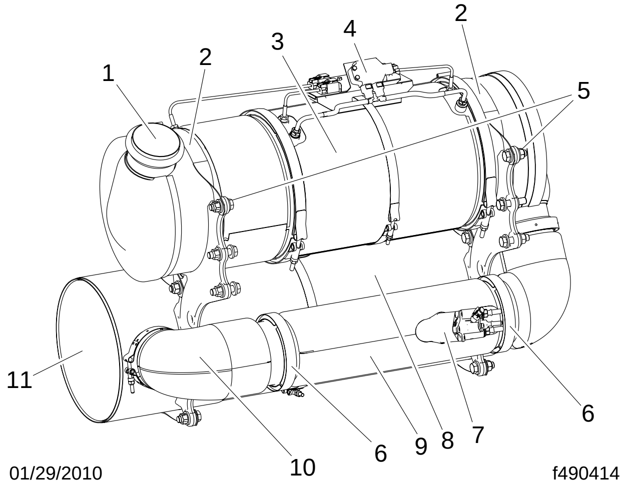
Fig. 1, Aftertreatment System (typical)

- When conditions permit, the ACM automatically initiates at-speed regeneration. The exact conditions for regeneration vary, according to the engine manufacturer's design. Generally, it can happen only when the vehicle speed is above 7.5 mph (12 km/h), and active regeneration stops when the vehicle slows to 5 mph (8 km/h) or below.
- Parked regeneration is initiated by a driver or technician when the vehicle is safely parked with the exhaust outlet well away from any flammable substance, a specific sequence of procedures is followed, and the driver pushes the regeneration button on the dashboard. The parked regeneration sequence varies according to engine and vehicle configuration, but it must be exactly followed or regeneration cannot happen. Follow the exact sequence prescribed for the vehicle, according to the engine manufacturer's literature.

Cummins Switchback ATD Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the Aftertreatment System (ATS) components.



1. DPF Inlet
2. Mounting Strap
3. Aftertreatment Device (ATD)
4. NOx Sensor Module
5. Mounting-Strap Bolt and Nut
6. Spherical Clamp
7. Doser
8. SCR Catalyst
9. Mixer Tube (Decomposition Pipe)
10. SCR Inlet
11. SCR Catalyst Chamber

Fig. 1, Cummins Switchback ATD Installation

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before working on it.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

3. Make alignment marks on all of the components to be removed.
4. Disconnect the wire harness to the control module on the ATD.
5. Remove the spherical clamp and gasket that connects the ATD inlet pipe to the ATD. Discard the clamp and gasket.
6. Remove the spherical clamp and gasket that connects the ATD to the mixer tube. Discard the clamp and gasket.
7. Position the ATD jack and cradle under the assembly and secure it with straps.
8. Remove the bolts and nuts from the four mounting straps.
9. Lower the unit.
10. Remove and discard the mounting straps and hardware.

Installation

NOTICE

Be careful not to bump the probe on the back side of the ATD when positioning the ATD on the frame rail. The probe could be damaged.

1. Position the assembly in the ATD jack cradle and secure it with straps.
2. Slide the unit under the vehicle and raise it into position.
3. Install the new mounting straps.

Cummins Switchback ATD Removal and Installation

4. Position the assembly in the mounting straps, then install the clamp bolts and nuts. Do not tighten at this time.

NOTICE

Make sure that all exhaust outlet piping is installed or the DEF tank will be damaged.

IMPORTANT: Always use new gaskets when installing exhaust system components.

5. Connect the ATD to the ATD inlet pipe and install the new spherical clamp and gasket. Do not tighten at this time.
6. Connect the ATD outlet to the mixer tube and install the new spherical clamp and gasket. Do not tighten at this time.
7. Recheck the alignment of all components. Make adjustments to the mounting straps (and brackets) as needed then incrementally tighten the bolts 15 lbf·ft (20 N·m) then 30 lbf·ft (41 N·m).
8. Tighten the spherical clamps at the connections to the ATD inlet pipe and the mixer tube 126 to 138 lbf·in (1424 to 1560 N·cm).
9. Connect the wiring harnesses to the control module on the ATD.
10. Remove the jack and cradle.
11. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

Cummins Switchback SCR Catalyst Removal and Installation

Removal

Refer to Fig. 1 for removal and installation of the SCR catalyst.

1. Shut down the engine and chock the tires.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

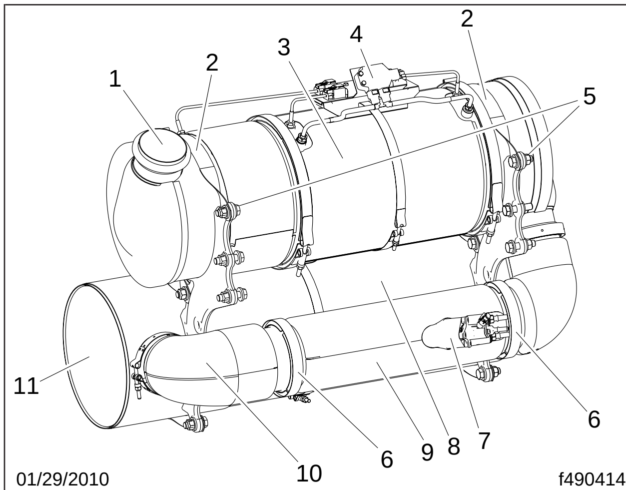
- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the Aftertreatment System (ATS) to completely cool before working on it.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

3. Make alignment marks on all components to be removed.
4. Disconnect the chassis wire harness from the NOx sensor.
5. Remove the NOx sensor module from the frame rail bracket and secure it to the SCR catalyst.
6. Disconnect the wire harness to the control module on the SCR catalyst.
7. Remove the spherical clamp that connects the SCR catalyst to the mixer tube. Discard the clamp.



1. DPF Inlet
2. Mounting Strap
3. Aftertreatment Device (ATD)
4. NOx Sensor Module
5. Mounting-Strap Bolt and Nut
6. Spherical Clamp
7. Doser
8. SCR Catalyst
9. Mixer Tube (Decomposition Pipe)
10. SCR Inlet
11. SCR Catalyst Chamber

Fig. 1, Cummins SCR Catalyst Installation

8. Remove the wide-band clamp that connects the SCR catalyst to the exhaust pipe. Discard the clamp.
9. Position the jack and cradle under the SCR catalyst and secure it with straps.
10. Remove the bolts and nuts from the SCR mounting straps.
11. Remove and discard the mounting straps and hardware.
12. Carefully lower the unit. If replacing the SCR, transfer the control box to the new SCR.

Installation

NOTICE

Make sure that all exhaust outlet piping is installed or the DEF tank will be damaged.

1. Position the assembly in the jack cradle and secure it with straps.
2. Install the new clamp straps, but do not tighten at this time.

Cummins Switchback SCR Catalyst Removal and Installation

3. Slide the unit under the vehicle and raise it into position.
4. Position the assembly in the mounting straps, and install the clamp bolts and nuts. Do not tighten at this time.

IMPORTANT: Always use new gaskets when installing exhaust system components.

5. Connect the SCR catalyst to the mixer tube and install the new spherical clamp and gasket. Do not tighten at this time.
6. Connect the SCR catalyst to the exhaust outlet pipe and install the new wide-band clamp. Do not tighten at this time.
7. Recheck the alignment of all components. Make adjustments to the mounting straps (and brackets) as needed then tighten the bolts 15 lbf·ft (20 N·m) then 30 lbf·ft (41 N·m).
8. Tighten the spherical clamp at the connection of the SCR catalyst and the mixer tube 126 to 138 lbf·in (1425 to 1560 N·cm).
9. Install the NOx sensor module on the bracket on the frame rail, then connect it to the chassis harness.
10. Connect the wiring harness to the control box on the SCR catalyst.
11. Remove the jack and cradle.
12. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

Replacement

NOTE: Always use new exhaust pipe clamps and gaskets when installing exhaust system components.

1. Shut down the engine and chock the tires.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

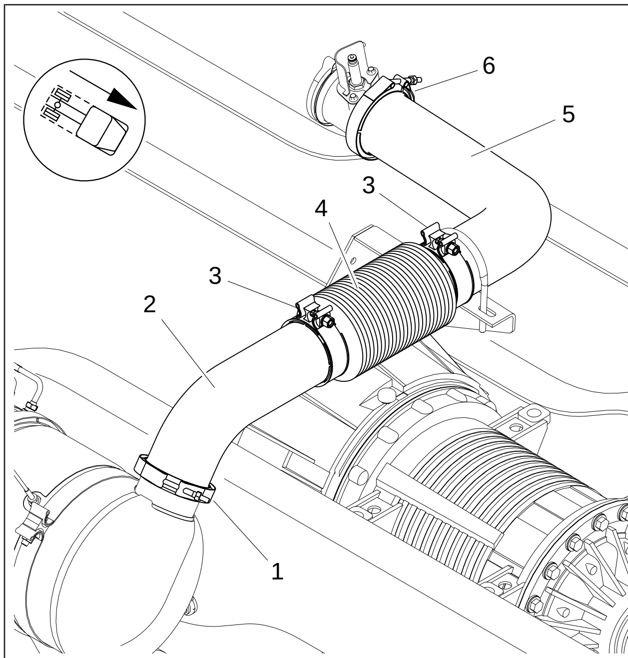
- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the exhaust system to cool before working on it.
3. Make alignment marks on all of the components to be removed.
4. Remove the V-band clamp at the bellows outlet pipe. See **Fig. 1**. Discard the clamp.
5. Remove the V-band clamp at the turbocharger. Discard the clamp.
6. Remove the fasteners from the exhaust piping support bracket. Save the fasteners for reuse.
7. Remove the bellows and ATD exhaust piping as an assembly.
8. On a workbench, remove the exhaust bellows.
9. Slide the new exhaust bellows onto the exhaust piping, but do not tighten at this time.

NOTICE

Make sure that all exhaust outlet piping is installed or the DEF tank will be damaged.

10. Position the bellows and exhaust piping on the chassis, and loosely install the support bracket fasteners.



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1. V-Band Clamp
2. ATD Inlet Piping
3. Bellows Seal Clamps
4. Bellows
5. Turbocharger Outlet Piping
6. V-Band Clamp

Fig. 1, Exhaust Piping, Engine to ATD

11. Install a new V-band clamp on the exhaust bellows outlet. Do not tighten at this time.
12. Install a new V-band clamp at the bellows to the turbocharger outlet-pipe connection. Do not tighten at this time.
13. Using a straight edge, align the bellows, the ATD inlet pipe, and the turbocharger outlet pipe. Check from at least two positions about 90 degrees apart. All three components should form a straight line through the connections.
14. At each end of the bellows, tighten the seal clamp nuts 41±6 lbf·ft (56±8 N·m).
15. Tighten the V-band clamp at the turbocharger outlet pipe connection 108 lbf·in (1220 N·cm).
16. Tighten the V-band clamp at the ATD inlet connection 60 lbf·in (678 N·cm).
17. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

General Description

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

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). See **Fig. 1**.

The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream. DEF is colorless, non-toxic, and biodegradable. In the ATS, the exhaust gases pass through the ATD, then are treated with precisely-controlled quantities of DEF, and then pass into the SCR catalyst. DEF consumption is dependent on vehicle operation.

DEF is drawn from the tank by the DEF pump. The DEF is then filtered and, from the pump, transported through the DEF lines to the metering unit. The metering unit measures the correct amount of DEF, which is then injected into the hot exhaust flow after exhaust gases have passed through the ATD. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the selective catalyst chamber to yield harmless nitrogen and water vapor, which exit out the tailpipe.

DEF causes mild discoloration to aluminum, but will not affect its strength or structure. White crystals may be noticeable around components that come into contact with DEF. The crystals can be easily removed using water.

DEF freezes to a slush consistency at 12°F (-11°C). Because DEF can freeze, the DEF lines and metering unit are designed to purge whenever the engine is shut down to prevent damage. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

DEF in the tank is allowed to freeze while the vehicle is non-operational. The DEF temperature sensor detects when the temperature of the DEF in the tank is approaching its freezing point. After the engine has been started and the engine coolant reaches a certain temperature, the coolant valve opens, allowing the coolant to flow through the coolant lines inside the DEF tank. The lines transfer heat, causing any frozen DEF in the tank to thaw and preventing liquid DEF from freezing during operation in cold weather. After flowing through the tank, the coolant is redirected back to the engine.

DEF will degrade over an extended period of time; shelf life is between twelve and eighteen months in standard operating conditions and temperatures. As DEF begins to degrade, it is usable but may be consumed at a slightly higher rate than normal.

A minor engine derate (approximately 25%) will occur when the DEF level registers below 5% on vehicles with Detroit Diesel engines, or 2.5% on vehicles with Cummins engines. If the DEF tank is empty, a major engine derate (vehicle speed is limited to 5 mph) will occur after an engine shut down and restart if the diesel tank has been refueled and the DEF tank is not refilled.

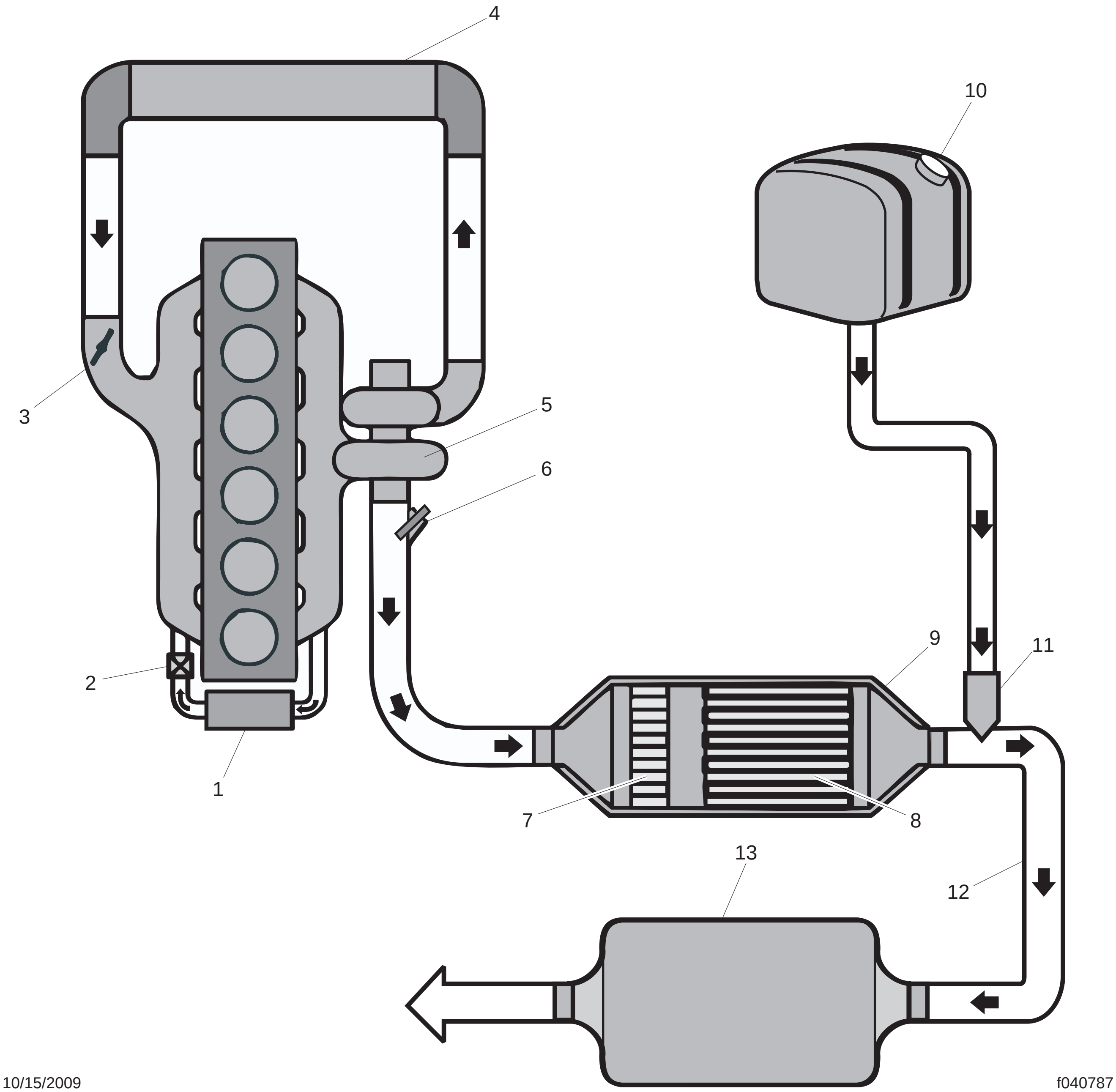
There are also safety controls that derate the engine if a contaminant has been introduced into the DEF tank. When a contaminant is detected, a minor engine derate will occur. When the vehicle has operated for 20 hours or 1000 miles with a contaminated tank, the vehicle will experience a major engine derate once the system determines that the vehicle is in a safe situation. Once the DEF tank has been filled with clean DEF, engine performance will return to normal.

DTNA-covered components of the DEF system include the DEF tank, tank header unit, pump, and coolant, DEF, and air lines between these components. See the engine manufacturer's service literature for information regarding other DEF system components such as the metering unit and injector, and DEF system maintenance instructions and intervals.

For additional operating information, see the *Recreational Vehicle Operator's Manual*.

For additional information on the ATS, see **Section 49.02**, Aftertreatment System, EPA10.

General Information



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

Fig. 1, EPA10 Aftertreatment System (typical)

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

13-Gallon Tank

Removal

IMPORTANT: Discard contaminated DEF and coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the coolant from the cooling system. For instructions, see **Group 20**.
3. Place a clean drain pan underneath the tank to catch draining DEF. Uncontaminated DEF may be reused.

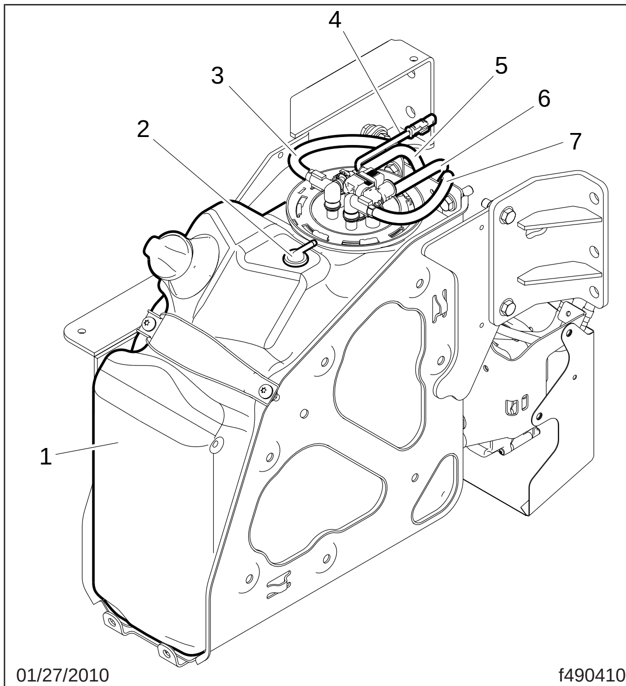
IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

4. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank. See **Fig. 1**.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF port.

5. Disconnect the DEF lines from the supply and return ports, and let the DEF drain into the drain pan.
6. Disconnect the wiring harness from the tank header unit.
7. Disconnect the coolant lines from the supply and return ports.



1. Tank
2. Vent
3. DEF Supply
4. DEF Level and Temperature Sensor Wiring Harness
5. Coolant Return
6. Coolant Supply
7. DEF Return

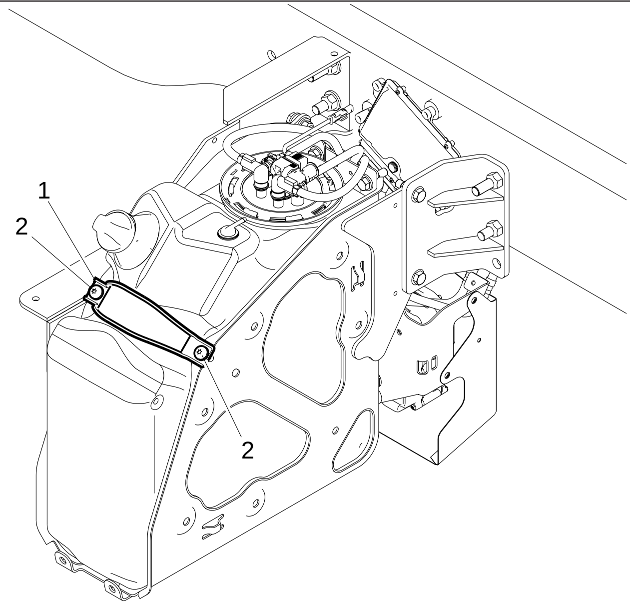
Fig. 1, 13-Gallon Tank Ports

8. Remove the fasteners and bolts that secure the tank in the mounting bracket assembly. See **Fig. 2**.
9. Remove the tank from the mounting bracket assembly.

IMPORTANT: The tank must be removed from the mounting tray before the header unit can be removed.

10. Rotate the header lockring counterclockwise to loosen it, then remove the lockring.
11. Remove the header unit from the tank by pulling the assembly straight up, then tilting it to pull the horizontal end clear of the tank.

Tank Removal and Installation



1. Mounting Strap
2. Mounting Bolts

Fig. 2, 13-Gallon Tank Mounting

Installation

1. Install the header in the new tank by tilting it to insert the horizontal end into the tank. When correctly installed in the tank, the header locating pin will sit on a nipple at the bottom of the tank, and the header will not move. Once the horizontal segment is inside the tank, tilt the header unit back to vertical to settle the bracket on top of the tank.
2. Turn the header lockring clockwise to secure it to the tank.
3. Slide the tank onto the mounting bracket assembly.
4. Install the fasteners and bolts to secure the tank to the mounting bracket assembly.
5. Connect the coolant supply and return lines to the coolant ports on the top and back of the tank.
6. Remove any white DEF crystals from the DEF ports on the tank and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

7. Connect the DEF supply and return lines to the DEF ports on the back of the tank.
8. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
9. Connect the wiring harness to the tank header unit.
10. Fill the DEF tank.
11. Fill the cooling system. For instructions, see **Group 20**.

Tank Header Unit Replacement

The DEF header unit on vehicles with a 13- gallon DEF tank is secured to the top of the tank, and contains the engine coolant lines that run through the tank, the coolant valve, the DEF level sensor, and the DEF temperature sensor.

The DEF temperature sensor detects when the temperature of the DEF in the tank is approaching its freezing point. As soon as the engine coolant reaches a temperature of 149°F (65°C), the coolant valve opens, allowing the coolant to flow through the coolant lines inside the DEF tank. The lines transfer heat, causing any frozen DEF in the tank to thaw and preventing liquid DEF from freezing during operation in cold weather. The coolant then flows to the DEF pump, and is finally redirected back to the engine.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

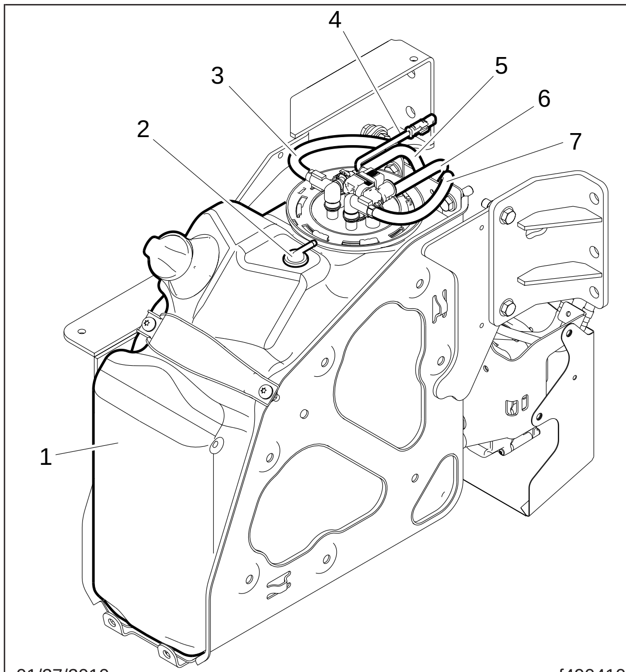
Replacement

IMPORTANT: Discard contaminated DEF and coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the coolant from the cooling system. For instructions, see **Group 20**.
3. Place a drain pan underneath the DEF tank to catch any draining DEF or remaining coolant.
4. Disconnect the coolant valve and DEF level and temperature sensor wiring harnesses from the tank header unit. See **Fig. 1**.
5. Disconnect the coolant lines from the tank header unit.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

6. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank.



1. Tank
2. Vent
3. DEF Supply
4. DEF Level and Temperature Sensor Wiring Harness
5. Coolant Return
6. Coolant Supply
7. DEF Return

Fig. 1, DEF Tank and Header Unit Connections

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF port.

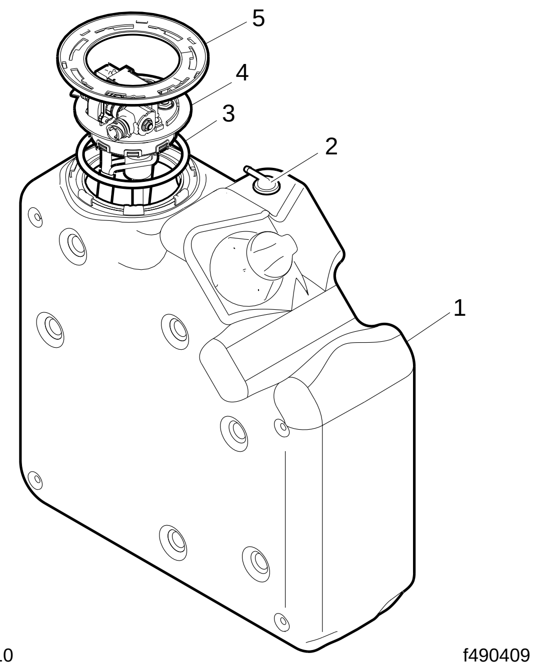
7. Disconnect the DEF lines from the tank header unit.

IMPORTANT: The tank must be removed from the mounting tray before the header unit can be removed.

8. Rotate the header lockring counterclockwise to loosen it, then remove the lockring.

Tank Header Unit Replacement

9. Remove the header unit from the tank by pulling the assembly straight up, then tilting it to pull the horizontal end clear of the tank; see **Fig. 2**.



1. Tank Assembly
2. Vent
3. Header O-Ring
4. Tank Header
5. Lockring

Fig. 2, Header Unit Assembly

10. Install a new header in the tank by tilting it to insert the horizontal end into the tank. When correctly installed in the tank, the header locating pin will sit on a nipple at the bottom of the tank, and the header will not move. Once the horizontal segment is inside the tank, tilt the header unit back to vertical to settle the bracket on top of the tank.
11. Install the header lockring and rotate it clockwise to secure it to the tank.
12. Remove any white DEF crystals from the DEF ports on the header unit and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

13. Connect the DEF supply and return lines to the DEF ports on the tank header unit.
14. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
15. Connect the coolant lines to the tank header unit.
16. Connect the coolant valve and DEF level and temperature sensor wiring harnesses to the tank header unit.
17. Fill the DEF tank.
18. Fill the cooling system. For instructions, see **Group 20**.

If a contaminant has been introduced into the system and the engine has been started, the following diesel exhaust fluid (DEF) components must be replaced:

- Tank
- Pump
- Header unit
- Metering unit
- Injector

See the other subjects in this section for tank and header unit replacement.

See the engine manufacturer's service literature for other component replacement instructions.

Flushing

If a contaminant has been introduced to the DEF tank, but the engine has not been started, complete the following steps.

1. Apply the parking brake and chock the tires.
2. Place a suitable container underneath the DEF tank to catch draining DEF.

IMPORTANT: Discard contaminated DEF and coolant in accordance with EPA regulations.

3. Remove the DEF and contaminant from the tank.

   Disconnect the DEF lines from the supply and return ports and let the DEF drain into the drain pan.
4. Remove the DEF tank. See **Subject 100** for instructions.
5. Thoroughly flush the tank with water until the tank is free of all contaminants.
6. Install the DEF tank. See **Subject 100** for instructions.

General Information

The on-highway environment places severe demands on a vehicles electrical system. The following material describes the methods for repairing and sealing electrical connections that will provide the durability necessary for the automotive environment.

There are four distinct components for making a wire repair that will withstand:

- the mechanical demands of vibration, strain, and thermal cycling
- the electrical requirement of oxidation free conductivity
- the insulating properties to resist shorting to adjacent objects
- the ability to seal for corrosion protection

When troubleshooting electrical systems, consider cab 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.

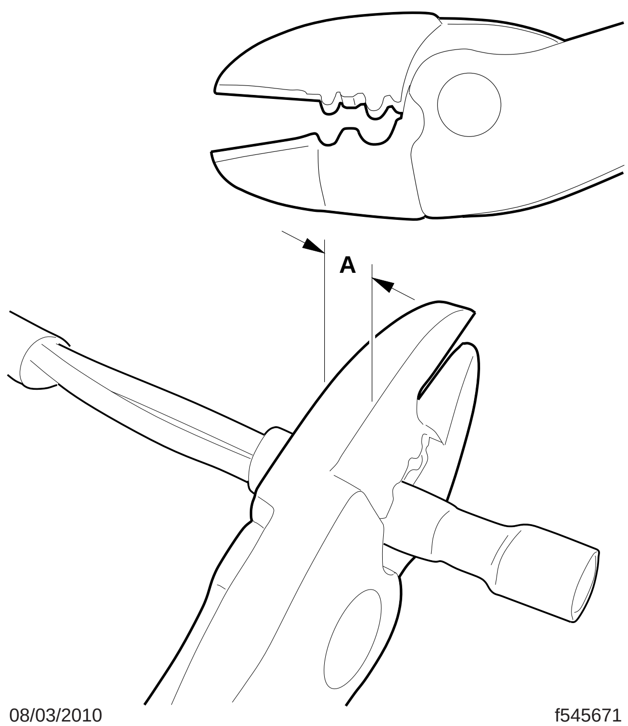
Wiring Repair Using Phillips STA-DRY® Solderless Connectors

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).



A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a 3-inch section of adhesive coated shrink tubing onto one of the wires.
2. Crimp the splice connector onto the wires. Use the type of crimp tool that makes a dimple in the connector. The dimple must be at least 3/16 inch wide or there will be too much space inside the connector and the solder will not flow into the wire. This crimp provides the mechanical retention needed. See **Fig. 2**.

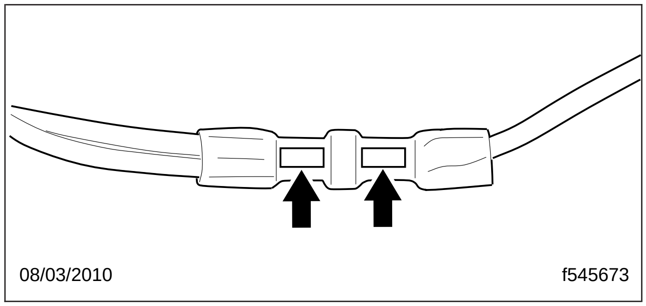


Fig. 2, Properly Crimped Splice

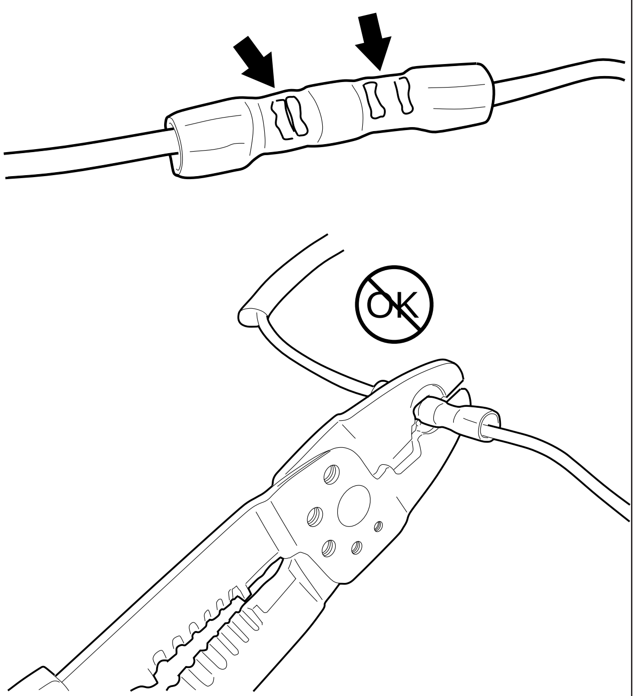
3. Pull test the wires by hand to ensure the crimp is mechanically solid.
4. A crimp tool that is too narrow will leave excessive air gaps in the crimp. The connection will not have the required amount of mechanical strength and the solder will not bond the wire to the connector. **Figure 3** shows an example of a bad crimp when the wrong tool is used.
5. Heat the properly crimped splice connector with the heat gun while slowly rotating the wire. The solder will take longer to flow than it will for the shrinkable insulation to contract. Heat until the solder band has completely melted into the connector. If the shrinkable insulation ruptures and a small amount of solder bubbles out, gently shake the splice to remove the solder. See **Fig. 4**.
6. When the connector has cooled, center the shrinkable tubing over the splice and heat the tubing until it has completely sealed the splice and a small fillet of adhesive is visible at the ends of the shrink tube. See **Fig. 4**.
7. A three-wire tap splice can be made following the same procedure. Use a connector that is large enough to fit all the strands of the wires. See **Fig. 5** for an example of the completed splice.

Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Solderless Connector Parts		
Wire Size: gauge (mm)	**Connector Part Number***	**Shrinkable Tubing (Daimler Part Number)**
20 to 18 (0.5 to 0.8)	PHM 1 1863	1/4 inch with internal adhesive coating (48-02461-025)
16 10 14 (1 to 2)	PHM 1 1862	1/4 inch with internal adhesive coating (48-02461-025)
12 to 10 (3 to 5)	PHM 1 1861	3/8 inch with internal adhesive coating–4 foot length (48-02461-038)
8 or larger (5 or larger)	Replace the terminal or the entire cable	Use adhesive lined red for positive cables and black for negative cables.

* Twenty-five connectors per pack.

Table 1, Solderless Connector Parts



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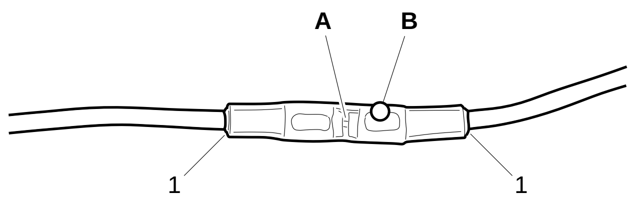
NOTE: Even with two crimps, there is too much air gap; the solder will not bond.

Fig. 3, Wrong Tool Being Used and a Crimp That Will Fail



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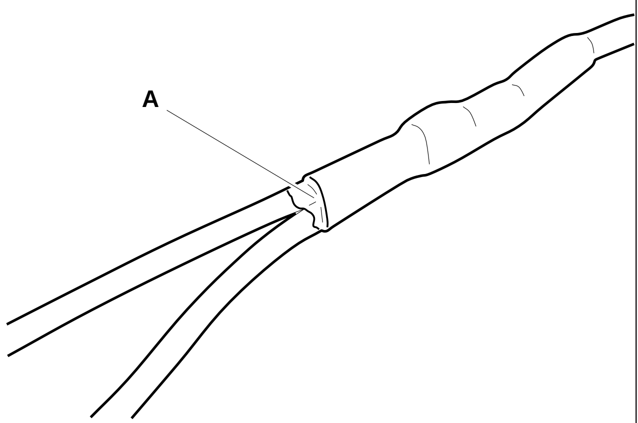
A. The solder band is completely melted.
B. Insulation rupture; gently shake off the solder bead.

1. Adhesive Fillet

Fig. 4, Solder Bead Rupture



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A. The fillet of adhesive at the ends of the shrink tube indicate a complete seal.

Fig. 5, Completed Three-Wire Tap Splice

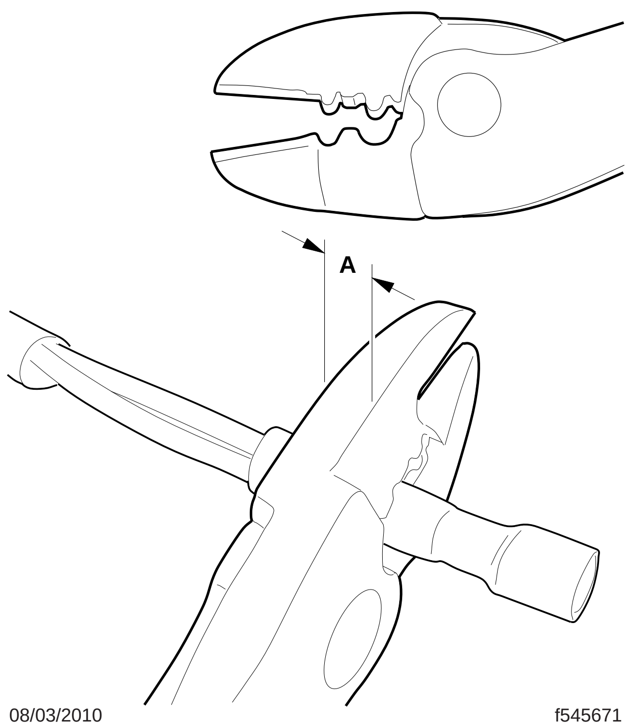
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404

Parts and Tools

Parts are available through the Parts Distribution Centers (PDCs) in kits with material for 50 splices. This kit may be used on 16 to 14 gauge (1 to 2 mm) wire.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 250°F (121°C).



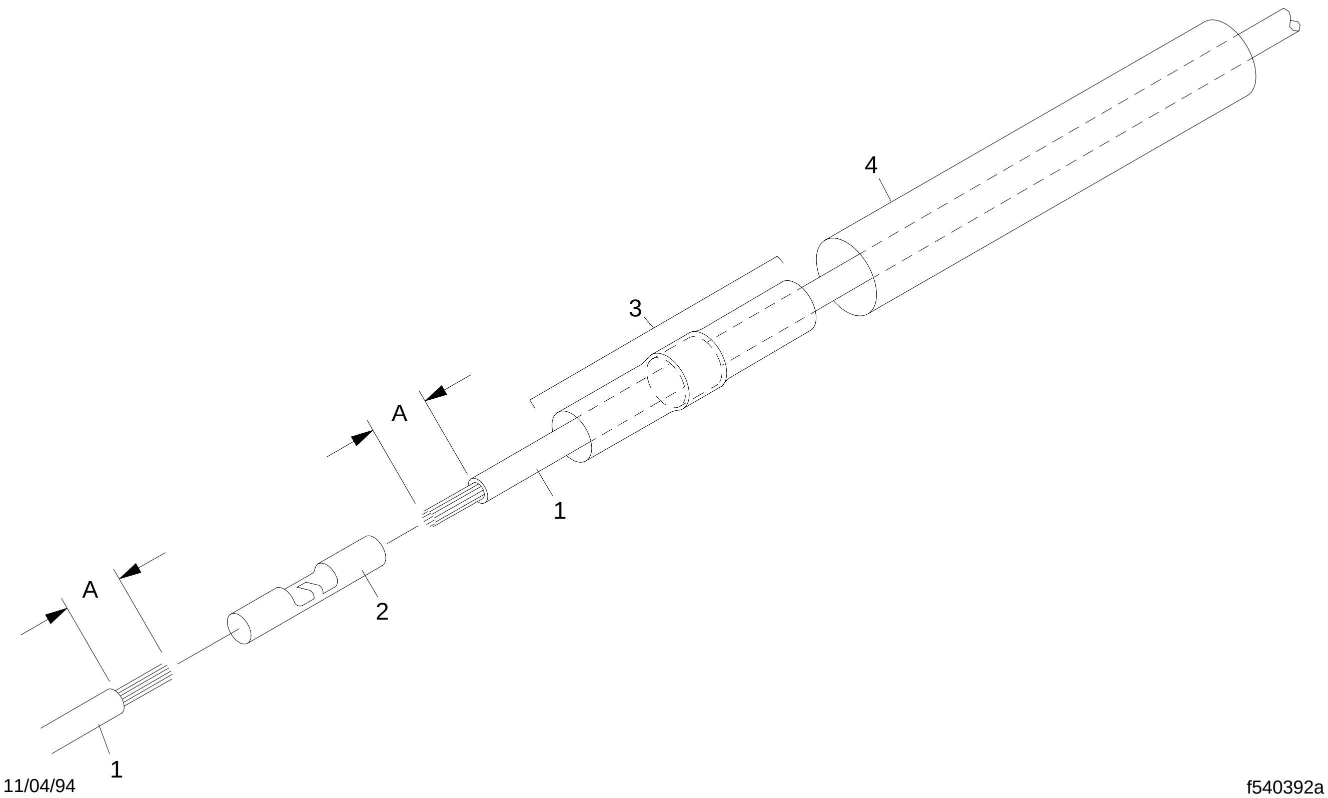
A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a piece of the shrink tubing from the kit onto one of the wires.
2. Slide a shrinkable solder sleeve from the kit onto one of the wires.
3. Place the wires that will be spliced into each end of the barrel connector. See **Fig. 2** for an example of the splice.
4. Crimp each end of the barrel using a dimple-type crimp tool to secure the wires. See **Fig. 1** for an example of a proper crimp tool.
5. Pull test the wires by hand to ensure the crimp is mechanically solid.
6. Slide the shrinkable solder sleeve onto the barrel connector so the solder band is at the center of the barrel connector.
7. Heat the splice using a heat gun rated at 250°F (121°C) until the sleeve has completely shrunk against the wire and the solder flows into the barrel connector. A small fillet of adhesive may be visible at the ends of the connector. See **Fig. 3**.
8. Slide the shrinkable tubing over the splice and apply heat with a heat gun rated at 250°F (121°C) until it has completely shrunk against the wire insulation. A small fillet of adhesive should be visible at the ends of the shrinkable tubing.

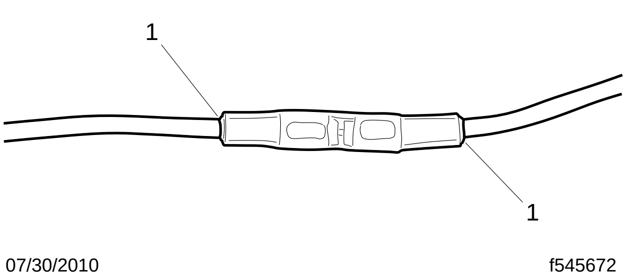
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404



A. 1/4 inch (6.4 mm)

1. Wire End
2. Barrel Connector
3. Solder Sleeve
4. Shrink Tube

Fig. 2, Splice Prepared with Parts in Kit ESY ES66 404



1. Adhesive Fillet

Fig. 3, Heated Solder Sleeve with Solder Band Melted into the Splice

Parts

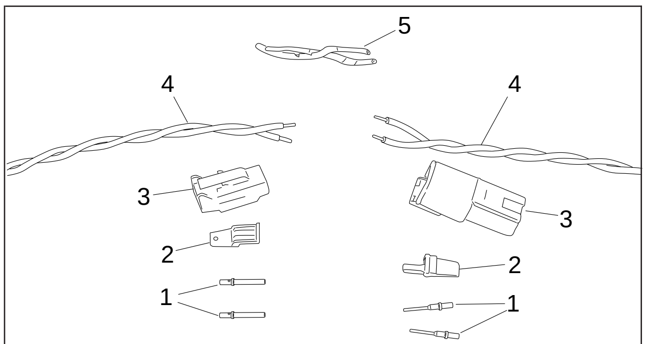
Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

Datalink Connector Parts		
Description	**Part Number**	**Quantity**
Connector Body Plug	23-13148-204	1
Terminal Lock	23-13303-015	1
Terminals	23-13210-020	2
Connector Body Receptacle	23-13148-206	1
Terminal Lock	23-13303-013	1
Terminals	23-13210-030	2

Table 1, Datalink Connector Parts

Procedure

1. Cut out any damaged section of datalink wire, keeping the lengths of the two wires equal. See **Fig. 1** for an example of a damaged section of datalink wire that has been removed and the datalink prepared for repair.



1. Terminals
2. Terminal Lock
3. Connector
4. Twisted-Pair Datalink Wires
5. Damaged Section of DatalinkWires

Fig. 1, Datalink Splice Parts

2. Crimp the terminals onto the wires using the proper crimp tool.
3. Pull test the terminals by hand to ensure the crimp is mechanically solid.
4. Insert the terminated wires into the connector body and install the terminal lock. The protocol for J1939 is for the yellow wire to be in cavity 1 and the green wire to be in cavity 2. Note that the lock is installed while holding the wires in position. Test the installation. If the wires slipped back during the lock installation, they will pull out of the connector.
5. Make certain the wires are twisted as close to the entry point of the connector as possible. Plug the two connector halves together. See **Fig. 2**.

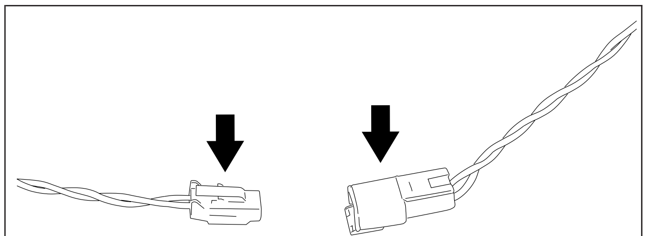


Fig. 2, Datalink Connectors

Electrical Connection Protection

Use the dielectric protectants and procedures provided here to protect electrical connections from corrosion. A list of approved dielectric protectants is shown in **Table 1**.

The components listed in **Table 2** have electrical connections that need to be protected.

When disconnecting any of these circuits, clean the connection and remove the old dielectric material. Completely cover the exposed area after assembly using the product and procedure in this bulletin. Always follow the product manufacturers recommendations for work area ventilation.

Approved Dielectric Protectants			
Material	**Type**	**Manufacturer**	**Product**
Dielectric Red Enamel	Spray On	3M®	1602 IVI
		Glyptal	1201A
	Brush On	Glyptal	1201E 2100
Dielectric Grease	Lithium Base	Fiske Brothers Lubriplate® (FLP)	DS-ES
	Synthetic	Nye	Nyogel 760G

Table 1, Approved Dielectric Protectants

Electrical Component Protection and Procedure		
Protection	**Component**	**Procedure**
Dielectric Red Enamel	Starter - All Exposed Connections	Protect connections and cable terminals.
	Magnetic Switch	Protect connections and cable terminals.
	Alternator	Protect all connections. Do not allow dielectric material to enter the alternator.
	Bolt and Stud Ground Connections (outside cab)	Cover all terminals, studs, and nuts with dielectric enamel.
	Battery Cut-Off Switch Connections	Protect connections and cable terminals.
	Exposed Battery Cable Connections (located outside of the battery box)	Protect connections and cable terminals.
	Power Distribution Modules	Protect battery power studs on chassis mounted PDMs.
	Mega Fuses (when located outside of the battery box)	Place tape across the part of the fuse with the labeling, then apply the dielectric material. Remove the tape.

Electrical Connection Protection

<table>
<tr><th colspan="3">Electrical Component Protection and Procedure</th></tr>
<tr><th>Protection</th><th>Component</th><th>Procedure</th></tr>
<tr><td rowspan="6">Dielectric Grease, Lithium Base</td><td>Tail Lamp Bulb Sockets (non LED)</td><td>Remove the bulb, apply grease to the inside of socket. Replace the bulb.</td></tr>
<tr><td>Battery Terminals</td><td>Apply grease to battery terminals before connecting interconnect cables.</td></tr>
<tr><td>Battery Interconnect Cable Connections</td><td>Apply grease to connection studs and pads before connecting battery cables.</td></tr>
<tr><td>Parked HVAC Power Connections</td><td>Disconnect the two power and one ground cable where they enter the basket on the underside of the cab. Apply grease, then connect.</td></tr>
<tr><td>Inverter Power Connections</td><td>Disconnect the power and ground feeds at the cab pass through. Apply grease, then connect.</td></tr>
<tr><td>Mega Fuses (if located in the battery box)</td><td>Apply grease to protect exposed terminals and connections.</td></tr>
<tr><td>Dielectric Grease, Synthetic</td><td>Connections with serial data circuits or with very low voltage signals.</td><td>Apply synthetic grease to the terminals inside the connector.</td></tr>
</table>

Table 2, Electrical Component Protection and Procedure

Specifications

Standard Wiring Color Coding		
Color	**Abbr**	**Typical Usage**
Black	BK	Ground, General
Black-White	BK-W	Ground, Clean or Isolated
Blue DK	DKBL	Backup/Wiper/Trailer Auxiliary
Blue LT	LTBL	HVAC/Circulation Fans/1922+
Blue LT-White	LTBL-W	Water, Oil Gauge, and Indicator (engine and transmission)
Brown	BR	Marker, Tail, and Panel Lamps
Gray	GY	Electronic Engine (or TXL Insulation)
Green DK	DKG	Turn Signal, Right-side/Driver’s Display/Data Record/1587+/1939–
Green DK-White	DKG-W	Starting Aids/Fuel Heaters/Material Control/Winch/Tailgate
Green LT	LTG	Headlamp/Roadlamp/DRL
Green LT-White	LTG-W	Axle Controls and Indicators/Suspension/Fifth Wheel
Orange	O	ABS/EBS/1587–
Pink	PK	Start Control/Ignition/Charging/Volt and Ammeter/1922–
Pink-White	PK-W	Fuel Control and Indicators/Shutdown/Speed Limiter
Purple	PRP	Engine Fan/PTO/Auto Lube and Oil
Purple-White	PRP-W	Utility/Spot/Ad/Interior/Emergency Lighting
Red	R	Power Distribution, Constant
Red-White	R-W	Brake/Pneumatic/Hydraulic/Retarder/Stop
Tan	T	mph, rpm Signals/Horn/Flasher/Pyro/Turbo
Tan-White	T-W	Audio/Video/Security/Window/Computer/Seat/Mirror/Cab-Tilt
White	W	Transmission (or SXL insulation)
Yellow	Y	Turn Signal, left/1939+ (or GXL insulation)
Yellow-White	Y-W	Air Bag and SPACE

Table 1, Standard Wiring Color Coding

Circuit Numbers		
Circuit Number	**Description**	**Modules**
1	Battery Cable, Ground	156 286 291
6	Battery Cable, Positive	224 281 291 292 293 295
14	Cab Power, Main	156 224 277 281 285 286 291 292 293 295 306 320 321
15	Starter, Crank Circuit	146 155 156 157 158 286 291 320 895
16	Alternator, Main Power	124 125 286 320 836 846
18	Air Pressure Warning	320 486 838 840 877 880 882
19	Voltmeter	286 320 836 846

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
20	Headlamp, Left	27D 288 304 312 320 659
21	Headlamp, Right	27D 288 304 312 320 659
22	Headlamp, Low and High Beam	27D 288 304 312 320 659
23	Tail Lamps	288 294 296 301 302 304 30A 320 335
24	Horn, Electric	288 320 321 726
25	Horn, Air	288 320 321 726
27	Road Lamp	288 313 314 320
28	Fog Lamp	288 313 314 320
29	Instrument Panel Lamps	27D 288 296 302 304 30A 312 320 335 659 732 811 81B
30	Transmission Temperature and Filter	286 320 343 345 34B 34C 353 355 863 864
31	Transmission Aux Controls and Temp	286 320 343 345 34B 34C 353 355 863 864
34	Engine Oil Pressure	165 286 320 852
35	Engine Oil Temperature	286 320 854
36	Stop Lamps	288 294 296 301 320 335 486 838 840 877 880 882
38	Turn Signal	288 294 296 298 299 300 301 320 335 811
39	Stop/Turn Combination Lamp	288 294 296 301 320 335 880
40	Fan, Windshield/Sleeper	287 320 716 718
41	Dome/Interior Lamp	271 287 294 300 302 305 311 312 314 316 318 319 31A 31B 31C 31D 31E 320 322 324 325 327 328 32B 32C 469 470
42	Axle Oil Temperature, Forward	288 320 865 866
43	Axle Oil Temperature, Rear	288 320 865 866
44	Axle Oil Temperature, Center	288 320 865 866
45	Receptacle, Trailer	173 285 296 297 303 306 307 308 309 310 320 321 331 334 335
46	Marker Lamps	288 296 302 304 30A 320 335
47	Fuel Level	288 320 844 847
48	Fuel Control and Level, Natural Gas	148 150 152 162 164 283 286 288 320 811 814 844 847 860
52	Ignition Switch	156 285 306 320 321
55	Data Recorder	283 286 320 343 810 817
57	12V Power Outlet/Lighter	284 287 320 785
58	Heater, Auxiliary	130 287 320 700 703 70A 70C 723
73	Utility Lamps	287 288 318 31J 320 327 329 57W
74	Starter Mag Switch, Solenoid	155 156 157 158 286 320 895
75	Starter Mag Switch, Ground	146 155 156 157 158 286 895
76	Mirror Heat	320 656 744 74E

Circuit Numbers		
Circuit Number	Description	Modules
78	Spot Lamp	316 320 57V
81	Ignition Switch Control Devices	156 285 304 306 320 811 814 860
82	Starter Mag Switch Power	155 156 157 158 286 320 895
86	Axle Lock Solenoid	288 320 452 874 878 87A 87B 87F 896 900
87	Axle Lock	288 320 452 865 866 874 878 87A 87B 87F 896 900
88	Lubrication System, Automatic	288 594
90	Sander, Road	288 320 329
91	Heater, Diesel Fired Auxiliary	130 132 138 140 141 154 166 286 287 288 320 467 700 703 70A 70C 723
94	Air Dryer, Heated	288 480 48A 880
95	Speaker, Radio	287 320 746 74D 750 751 753 75B 75C 79F 79G
97	Air Conditioner	130 287 320 700 703 70A 70B 723
98	Heater – A/C Motor, Blower	130 156 283 285 286 287 320 321 700 703 70A 70B 70C 723
99	Fuel Solenoid, Engine Run	148 150 152 162 164 283 286 320
102	Parking Lamps	288 296 302 304 30A 320 335
108	Door Activated Lamps Courtesy/ Footwell/Door	320 324 325 32B 675 676 677 67E 67F 811 814 860
113	Baggage Compartment Lamps	287 320 322 324 325 32C
117	Speed Sensor +	283 286 320 343 810 817
118	Speed Sensor –	283 286 320 343 810 817
119	Coolant Temperature, Engine	198 199 286 320 732 810 812 830 836 838 83A 840 841 842 843 844 845 846 847 852 854 856 858 862 864 865 866 867 868 869
120	Back-Up Lamps	288 294 320 471 721
121	Brake, Engine	128 129 164 283 286
122	Back-Up Alarm	288 294 320 471 721
123	Alternator, Voltage Regulation/ Rectifier	124 125 156 286 836
125	Park Brake Indicator/Warning	288 294 296 301 320 335 486 838 840 877 880 882
132	Alternator Charge Monitor	124 125 156 286 836
137	Alternator Indicator/Relay	124 125 156 286 836
140	Oil Pressure, Engine	286 320 852
149	Fan Manual Controls, Engine	273 276 286 320
154	Auxiliary Air Pressure	288 320 486 838 840 865 866 877 880 882
155	Axle Lift Controls	288 320 452 874 878 87A 87B 87F 896 900
157	Power Mirror Controls	320 656 744 74E
162	Tachometer Sensor +	283 286 320 812 819
163	Tachometer Sensor –	283 286 320 812 819

Specifications

Circuit Numbers		
Circuit Number	Description	Modules
166	Engine Starting Aid, Ether	132 154 286 320 467
168	Hour Meter, Engine	286 320 812 813 81A 837 852
170	Fifth Wheel Slide Lock and Controls	173 296 297 303 307 308 309 310 331 334 581 87E
171	Brakesaver, Cat	128 129 286 343 34B 34C 34W 353
172	Clock	287 320 687 738
173	Coolant Level, Engine	152 286 320 856
182	Fuel Pressure	320 841 843 845
183	Air Cleaner Restriction, Engine	329 472
193	Cab Tilt Pump	288 320 670
196	Fuel Water Separator Heater	110 127 220 288
200	PTO Controls	148 283 286 288 320 372
203	Exhaust Brake	128 129 164 283 286
204	Seat Belt Indicator/Warning	320 74F 756 760 763
208	Axle Control, Tri Axle, Steer Lock	288 320 376 452 865 866 874 876 878 87A 87B 87C 87F 896 898 900
209	Axle, Two Speed Shift Control	283 286 288 320 343 376 810 817 876 87C 898
210	Power Distribution Module, Outside Cab	224 281 285 286 291 292 293 295 306 320 321
211	Security System, Rockwell	287 320 656 787
214	Generator, Auxiliary	124 125 286 599
218	Pyrometer	286 320 858
219	Turbo Pressure	286 320 842
221	Suspension Dump Controls	288 320 87D 888 910
222	Headlamp Dimmer Controls	27D 288 304 312 320 659
223	Transmission Controls, Auto Shift	160 283 285 286 288 320 330 343 345 34B 34C 355 376 732 736 810 811 813 814 817 876 87C 898
224	Transmission Controls	286 288 320 343 345 34B 34C 353 355 376 876 87C 898
225	Air Pressure Gauge, Primary	320 486 838 840 877 880 882
226	Air Pressure Gauge, Secondary	320 486 838 840 877 880 882
227	Air Pressure Gauge, Application	320 486 838 840 877 880 882
232	Transmission Controls Power Supply	160 283 285 286 320 330 343 345 34B 34C 353 355 732 736 811 813 814
234	Engine Fan Controls	273 276 286 320
236	Transmission Neutral Indicator	286 320 343 345 34B 34C 353 355
242	Seat Controls	320 74F 756 760 763
243	Shore Power, Power Inverter	274 277 284 287 307 320 336 337 33C 785
244	Speed Limiter, Vehicle, Hewitt	150 164 283 286

Circuit Numbers		
Circuit Number	Description	Modules
246	Electric Fuel Pump	148 150 152 162 164 283 286 320
250	Predictive Cruise Control	149 283 286
253	Cab Tilt Indicator	288 320 670
254	Roof Mounted Emergency Lamp/ Strobe	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
255	Advertising/Identification Lamp	288 296 302 304 30A 319 320 335
256	Optional Power Wire	285 286 306 320 321
261	Axle Lock, Controlled Differential	288 320 865 866
262	Retarder, Allison Transmission	128 129 286 343 34B 34C 34W 353
281	Oil Filter Change Indicator	165 286 320 852
285	Suspension Electric and Air Controls	288 320 87D 888 910
286	Fuel Water Separator Indicator	122 127 288 320 80F 844 845 847
294	Air Tank Auto Drain Valve	288 480 48A 880
295	Radio, AM/FM/CB/Disc	287 320 746 748 74D 750 751 752 753 75B 75C 79F 79G
299	Air Temperature, Exterior	320 860 867
300	Radio, Audio Signal	287 320 746 74D 750 751 753 75B 75C 79F 79G
303	Low Air Pressure	322 486 838 840 877 880 882
315	Windshield Wipers and Controls	320 321 660 66B
320	Windshield Washer	320 321 660 66B
331	Diagnostic Connector Power/Tach Ext Test	160 283 286 320 32A 330 338 343 725 732 733 736 811 812 813 819 835 888
338	HVAC Controls	130 287 320 700 703 70A 70B 70C 723
339	LBCU/ICU/Gauge Power/Data	320 732 811 814 860
347	Shutter, Engine Fan	273 276 286 320
359	Headlamp On Signal, LBCU/ICU	27D 288 304 312 320 659
363	Power Windows	320 654 656 66A
364	Power Windows, Rear	320 654 656 66A
372	Receptacle # 2, Trailer 7-Way, ISO 3731	173 296 297 303 307 308 309 310 331 334 335
376	Antilock Brake Controls	160 283 285 286 296 308 320 330 331 332 333 335 343 34B 414 447 44G 44H 454 490 493 732 736 811 813 814
377	Antilock Brake Sensors	308 330 331 332 333 414 447 44G 44H 454 490 493
378	Antilock Brake Valves	160 283 285 286 308 320 330 331 332 333 343 34B 414 447 44G 44H 454 490 493 732 736 811 813 814
379	Daytime Running Lamps (DRL)	271 27D 288 294 300 302 304 305 311 312 314 316 318 319 31A 31B 31C 31D 31E 31F 320 322 324 325 327 328 469 470 659
388	Hydraulic Brake Power/Controls	288 320 486 49A 880

Specifications

Circuit Numbers		
Circuit Number	Description	Modules
399	Optional Circuit, Cab/Chassis, Customer Specified	160 283 285 286 306 320 321 329 330 343 34B 472 732 736 811 813 814 860
400	Optional Circuit, Cab/Chassis, Customer Specified	329 472
402	Engine Start/Stop System, TAS	152 156 162 283 285 286 287 320 321
406	Emergency Lamp, Alternating, Access	264 271 275 27A 27B 27C 27E 287 288 318 31A 31B 31C 31D 31G 31J 320 327 33A 57W
407	—	—
408	Emergency Vehicle Accessory and Warning Lights	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
410	Emergency Siren and Bells	288 320 321 726
416	Refrigerator/Video Power	284 287 320 737 75B 785
417	Mobile Phone Power	320 789 79C
424	Headlamp Wiper/Washer	288 304 312 320
425	PNDB/CLDS Controls	224 277 281 285 291 292 293 295 306
427	Satellite Tracking System	287 320 786 78A 79H 80D
428	Battery Isolator Protection System	124 125 156 224 277 281 285 286 291 292 293 295 306 836
430	Windshield Wiper Heater	320 321 660 66B
431	Starting Aid, Engine Preheater	132 154 286 320 467
432	Seat Controls	320 74F 756 760 763
433	Data Recorder	160 286 320 813
434	Suspension Controls, ECAS	283 286 288 320 343 810 817 87D 888 910
435	Seat Belt Indicator/Warning	320 74F 756 760 763
436	Camera, Rear and Side View	160 288 320 736
437	Instrument Control Unit/LBCU	320 486 732 811 814 838 840 860 877 880 882
439	Engine ECU and Controls	106 128 129 148 152 156 162 164 283 286 372
440	Engine ECU and Controls	106 128 129 148 149 152 156 160 162 164 273 276 283 285 286 301 320 330 343 34B 732 736 811 813 814 856 880
441	Engine ECU and Controls	106 148 164 165 283 286 320 852
442	Data Recorder/Data Logger	160 286 320 813
443	Door Locks	320 655 656 787
444	Obstacle Detection System/VORAD	160 288 320 736 73B 73C
445	Body Controls/Dump Lock	288 320 329
446	Tire Pressure Monitor System	288 320 489
447	Battery Cutoff Protection System	130 156 224 277 281 285 287 291 292 293 295 306 320 700 703 70A 70B 723
448	Tail Gate Controls	288 320 329

Circuit Numbers		
Circuit Number	Description	Modules
449	Fueling Data Recording and Transmitter	198 199 283 286 288 320 343 732 810 812 817 830 836 838 83A 840 841 842 843 844 845 846 847 852 854 856 858 862 864 865 866 867 868 869
450	Mirror Dimming Controls	320 656 744 74E
453	Optional Customer Specified Wiring	164 283 285 286 306 320 321 329 343 345 34B 34C 353 355 472
454	Inflatable Restraint and Seat Pretension	160 283 285 286 320 330 343 34B 725 732 736 811 813 814
455	Instrument Left/Right Side Selection	320
457	Dash Controls, Datalink, (BPU)	164 283 286
458	Step Deployment Unit, Passenger Side	320 675 676 677 67E 67F
459	Steering Pump Controls	539
460	Transmission-Automatic, Controls	286 320 343 345 34B 34C 353 355
461	Transmission-Automatic, Controls	286 320 343 345 34B 34C 353 355
462	Headlamps, Auxiliary	27D 288 304 312 313 314 320 659
463	Headlamps, Auxiliary Right	27D 288 304 312 313 314 320 659
464	Transmission, Smart Shift Control	286 320 343 345 34B 34C 353 355
465	Headlamp, Flashing Control	27D 288 304 312 320 659
466	Land Departure System	160 288 320 736
467	Engine Coolant Flow Systems	152 286 320 856
468	Obstacle Detection System/VORAD	160 288 320 736 73B 73C
469	Level Control, Body/Chassis	288 320 329
470	Datalink Transmit	287 320 786 78A 79H 80D
471	Datalink Receive	287 320 786 78A 79H 80D
472	Engine ECU and Controls	106 128 129 148 152 156 162 164 283 286 320 343 34B 34C 34W 353 856
473	Multifunction Stalk Switch	329 472
474	Smart Switch, Resistance Identified, MUX	329 472
475	Engine Idler Controls	152 156 162 283 286
476	Adjustable Pedal Controls	288 320 486 49A 880
477	Hazard Lights, USPS	320 327 329
478	E-Stroke Brake Monitoring System	320 486 838 840 877 880 882
479	CB Radio Antenna Coaxial	320 748 751 752
480	Switched Auxiliary Air Pressure	288 320 486 49A 880
481	Chassis Expansion Module	160 283 285 286 320 329 330 343 34B 472 732 736 811 813 814

Specifications

Circuit Numbers		
Circuit Number	Description	Modules
482	Firetruck Pump Controls	148 283 286 372
483	Engine ECU and Controls	106 148 152 156 160 162 164 283 285 286 320 330 343 34B 372 732 736 811 812 813 814 819
484	Tire Chains	288 320 452 874 878 87A 87B 87F 896 900
485	Public Address System	287 320 746 74D 750 751 753 75B 75C 79F 79G
486	Vehicle Information Center	283 286 288 320 732 74F 756 760 763 811 812 814 819 860 867 877 882
487	Engine Emissions Detection and Monitor	148 150 152 162 164 283 286 320 811 814 860
488	Brake Wear Indicator	320 486 838 840 877 880 882
490	Bus Door and Window Sensing and Warning	287 288 294 300 320 327 329 654 655 656 66A 675 676 677 67E 67F 700 703 723 787 811 814 860
491	Engine Compartment Lights/Buzzer	287 320 327 329 656 787 811 814 860
492	Engine ECU and Controls	148 150 152 162 164 283 286 320 372
493	All Wheel Drive Controls	288 320 452 874 878 87A 87B 87F 896 900
494	Transmission Shift Controls	286 320 343 345 34B 34C 353 355
495	Emergency Medical Service Accessories	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
496	Steering Wheel Controls	329 472
497	Transmission Controls	286 320 343 345 34B 34C 353 355
498	Transmission Controls	286 320 343 345 34B 34C 353 355
499	Engine ECU and Controls	164 283 286
504	Dome/Interior Lamp	287 320 322 324 325 32C
506	Aerial Equipment Systems	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
507	MUX Control, MSF/CGW	287 320 786 78A 79H 80D
508	CAN Datalink	287 320 786 78A 79H 80D
509	Firetruck Pump And Hose Controls	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
510	Firetruck Pump And Hose Controls	265 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
511	Bus Door and Window Sensing and Warning	146 155 156 157 158 286 895
512	Emergency Vehicle Auxilixry Switches	—
513	Emergency Vehicle Door Switches	—
514	Emergency Vehicle Lights and Alarm	288 294 320 471 721

Circuit Numbers		
Circuit Number	Description	Modules
515	Emergency Vehicle Tank Level Systems	—
518	Emergency Vehicle Ladder and Rack Systems	—
519	Emergency Vehicle Body Lighting	—
520	Emergency Vehicle Body Lighting	—
521	Emergency Vehicle Body Lighting	—
522	Emergency Vehicle Body Lighting	—
523	Emergency Vehicle Body Lighting	—
524	Emergency Vehicle Power Source	—
525	Emergency Vehicle Warning Lights	—
526	Emergency Vehicle Body Lighting	—
527	Firetruck Pump And Hose Controls	—
528	Emergency Vehicle AC Power System	—
529	Windshield Defroster Grid	287 320 716 718
532	Aftertreatment Systems, Exhaust	160 164 283 285 286 320 330 343 34B 732 736 811 813 814
533	Engine ECU and Controls, Alternative Fuel	106 148 152 164 283 286 320 856
1587	J1587/J1708 Datalink	160 283 286 320 32A 330 338 343 725 732 733 736 811 812 813 819 835 888
1922	J1922 Datalink	160 283 286 330 343
1939	J1939 CAN Datalink	160 283 286 320 330 343 725 732 736 811 813 888

Table 2, Circuit Numbers

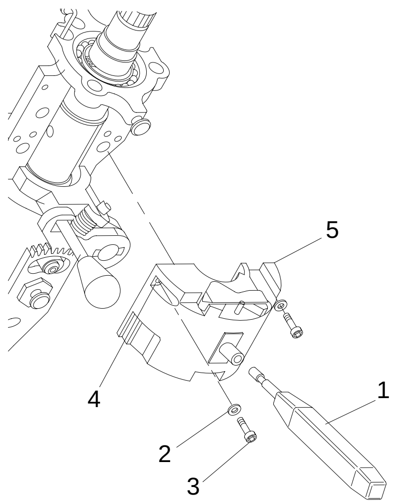
Instrument Cluster Bulb Replacement

1. Disconnect the batteries.
2. Remove the instrument cluster. For instructions, see Section 54.03, **Subject 100**.
3. On the back of the instrument cluster, remove the ten screws around the outside of the instrument cluster housing. Remove the housing to expose the instrument cluster light bulbs.
4. Remove each burned-out bulb by twisting it 1/8 turn counterclockwise and pulling it away from the bulb holder.
5. Install each new bulb. Press in and turn clockwise to insert it. Make sure the bulb is firmly in place.
6. Install the instrument cluster housing. Tighten all ten screws firmly.
7. Install the instrument cluster. For instructions, see Section 54.03, **Subject 100**.
8. Connect the batteries. Test the bulb(s) for proper operation.

Replacement

The turn signal switch is installed inside the steering column. The switch unit also contains circuitry for the headlight dimmer, cruise control, and hazard warning flasher.

1. Pry off the horn cover.
2. Remove the steering wheel nut. For more information, see Section 46.02, **Subject 110**.
3. Carefully separate and remove the upper and lower steering column covers. For more information, see Section 46.02, **Subject 110**.
4. Remove the two Allen-head screws that fasten the switch to the steering column. See **Fig. 1**.



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1. Turn Signal Lever
2. Washer
3. Allen-Head Screw
4. Screw Hole
5. Switch Housing

Fig. 1, Turn Signal Switch

5. Disconnect the wiring harness connectors from the old switch.
6. Attach the wiring harness connectors to the new switch.
7. Install the switch housing on the steering column.
8. Carefully assemble and install the upper and lower steering column covers. For more information, see Section 46.02, **Subject 110**.
9. Install the steering wheel nut. For more information, see Section 46.02, **Subject 110**.
10. Install the horn cover.

General Information

Lead-Acid Batteries

Batteries are electrochemical devices that store chemical energy. When the battery is connected to an external load, such as a starter, the chemical energy is converted into electrical energy and current flows through the circuit.

The battery has three functions:

- To supply power to start the engine.
- To stabilize the voltage in the electrical system. The battery filters high voltage transients and protects electronic components in the vehicle.
- To supply power when the vehicle's electrical load requirements go beyond what the charging system can supply or when the engine is not running.

All lead-acid batteries use plates made of two unlike metals held apart by separators. One of the metals becomes the positive plate, the other the negative plate. These plates are then grouped in pairs, alternating negative and positive. The groups are connected in series, and each plate group (cell) produces about two volts. Thus, a battery with six cells is a 12-volt battery.

In conventional liquid-electrolyte batteries (wet cells), each battery contains a group of plates immersed in a solution of electrolyte (dilute sulfuric acid).

Batteries may produce hydrogen gas when being charged. The vents allow the escape of gases produced in the battery.

NOTE: Liquid-electrolyte batteries must be kept in an upright position to prevent electrolyte leakage. Tipping a wet cell beyond a 45-degree angle in any direction can allow a small amount of electrolyte to leak out the vent holes.

Proper testing will indicate the battery condition. For more information, see **Troubleshooting 300**.

Absorbed Glass Mat (AGM) Batteries

Absorbed Glass Mat (AGM) batteries are lead-acid batteries in which the electrolyte is contained in a fiberglass mat. AGM batteries are physically similar to standard batteries. Carefully check the label on every battery to be certain it is AGM, and **never install AGM batteries in the same circuit with other types of batteries.**

AGM batteries are designed for high cranking amps and repeated cycle service to accommodate many of the auxiliary loads on vehicle electrical systems. They offer good protection against damage due to vibration, and are leak- and spill-proof, even if cracked or broken. Also, they self-discharge more slowly, and generate less heat when charging or discharging.

IMPORTANT: AGM batteries may be damaged or ruined by equipment designed for other types of batteries. AGM battery chargers must be regulated to a charge voltage less than 15.4 DCV; many chargers provide excessive voltage. To get full service from AGM batteries, carefully follow the battery manufacturer's instructions regarding charging rates and procedures.

Parasitic Battery Drain

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough that the starter will not be able to crank the engine.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off.

A typical parasitic drain falls into the 25 to 325 mA (0.025 to 0.325 amps) range. Multiply the drain (in amps) by the time (in hours) the batteries sit without being recharged. The result is the amount of ampere-hours consumed by the parasitic drain. The actual drain may be small, but over time the batteries grow steadily weaker.

At warm temperature of 77°F (25°C), using approximately 40 percent of the total available ampere-hours will bring fully charged batteries to a no-start condition. In colder temperatures, the batteries will reach a no-start condition sooner.

Battery Safety Precautions

General Safety Precautions

WARNING

Keep sparks, flames, burning cigarettes, etc. away from batteries. Batteries generate explosive gases, which could cause a battery to explode, causing serious personal injury, including blindness.

When charging the batteries, gas forms in each cell and escapes through the vent holes. In poorly ventilated areas, the gas lingers around the battery several hours after it has been charged. The gas is explosive around sparks, flame, or other intense heat; if ignited, it could cause the battery to explode. Follow these precautions when charging the batteries.

- Wear safety glasses or a face shield when working with batteries. When many batteries are handled, wear rubber gloves and an apron to protect clothing.
- Make sure that the area is well ventilated.
- Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.
- Make sure that the charger cable leads are clean and making good connections. A poor connection could cause an electrical arc which could ignite the gas mixture and explode the battery.
- Do not break live circuits at the terminals because a spark usually occurs at the point where a live circuit is broken. Use care when connecting or disconnecting booster leads or cable clamps on chargers.
- Do not smoke near batteries that are being charged or have recently been charged. Keep the batteries away from open flames or sparks.
- If the battery is frozen, let it reach room temperature and completely thaw before trying to charge it. Check for leaks and cracks before charging the battery. Replace the battery if leaks or cracks are seen.
- Take care that tools or metal objects do not fall across the battery terminals.

WARNING

Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.

CAUTION

If a metal object connects an ungrounded battery terminal to a nearby metal part of the vehicle which is grounded, it could short out the batteries, causing sparks and possible property damage.

Battery Electrolyte Safety Precautions

WARNING

Protect skin and eyes from battery electrolyte (acid). Electrolyte is corrosive and could result in serious personal injury if splashed on your skin or in your eyes.

If electrolyte is splashed on your skin or in your eye, force the eye open, rinse it with cool, clean water for about five minutes and call a doctor immediately. Do not add eye drops or other medication unless advised by the doctor.

If electrolyte is swallowed, drink several large glasses of milk or water. Follow with milk of magnesia, a beaten raw egg, or vegetable oil. Call a doctor immediately.

Use extreme care to avoid spilling or splashing electrolyte. Electrolyte spilled or splashed on your body or clothing should be neutralized with baking soda or household ammonia, then rinsed with clean water.

Electrolyte can also damage painted or unpainted metal vehicle parts. If electrolyte is spilled or splashed on any metal surface, neutralize and rinse it with clean water.

To prevent possible skin burns, do not wear watches, rings, or other jewelry while performing maintenance work on the batteries.

Battery Safety Precautions

WARNING

Do not apply pressure to the end walls of a plastic-case battery. This could cause electrolyte to squirt from the vents, possibly resulting in serious injury to skin or eyes.

When handling plastic-case batteries, use a battery carrier. If one is not available, lift these batteries with your hands placed at opposite corners of the battery.

Emergency Starting Using Booster Cables

WARNING

Before jump-starting a vehicle, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

WARNING

Batteries release explosive gas. Do not smoke when working around batteries. Put out all flames and remove all sources of sparks or intense heat in the vicinity of the battery. Do not allow the vehicles to touch each other. Do not lean over the batteries when making connections, and keep all other persons away from the batteries. Failure to follow these precautions could lead to severe personal injury as a result of an explosion or acid burns.

NOTICE

Make sure both electrical systems are the same voltage. Electronic devices on both vehicles can be damaged when connected to a vehicle with a different operating voltage.

1. Apply the parking brakes and turn off all lights and other electrical devices. Ensure that the vehicles are not touching and both ignition switches are turned to the OFF position.

IMPORTANT: Do not attempt to jump start a damaged battery.

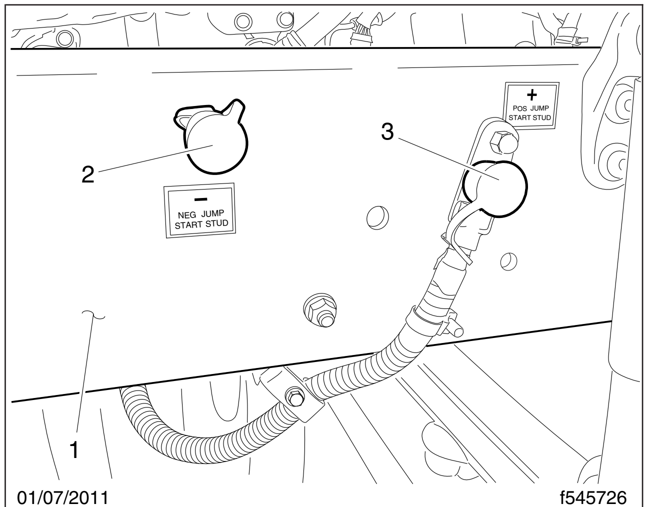
2. Remove the battery box cover.

NOTICE

Always connect the batteries and jumper cables correctly (positive-to-positive and negative-to-negative). Connecting a charging device backwards (positive-to-negative) can severely damage the vehicle electrical content and cause non-warrantable failures.

IMPORTANT: On vehicles equipped with optional jump start posts, connect to these posts instead of the battery terminals. Jump start posts may be installed in various locations on the vehicle. See **Fig. 1**.

3. Connect the positive (+) jumper cable to the positive terminal or jump start post on the discharged battery. See **Fig. 2**.



1. Frame Rail
2. Negative Jump Start Post
3. Positive Jump Start Post

Fig. 1, Possible Jump Start Post Location (passenger-side engine compartment)

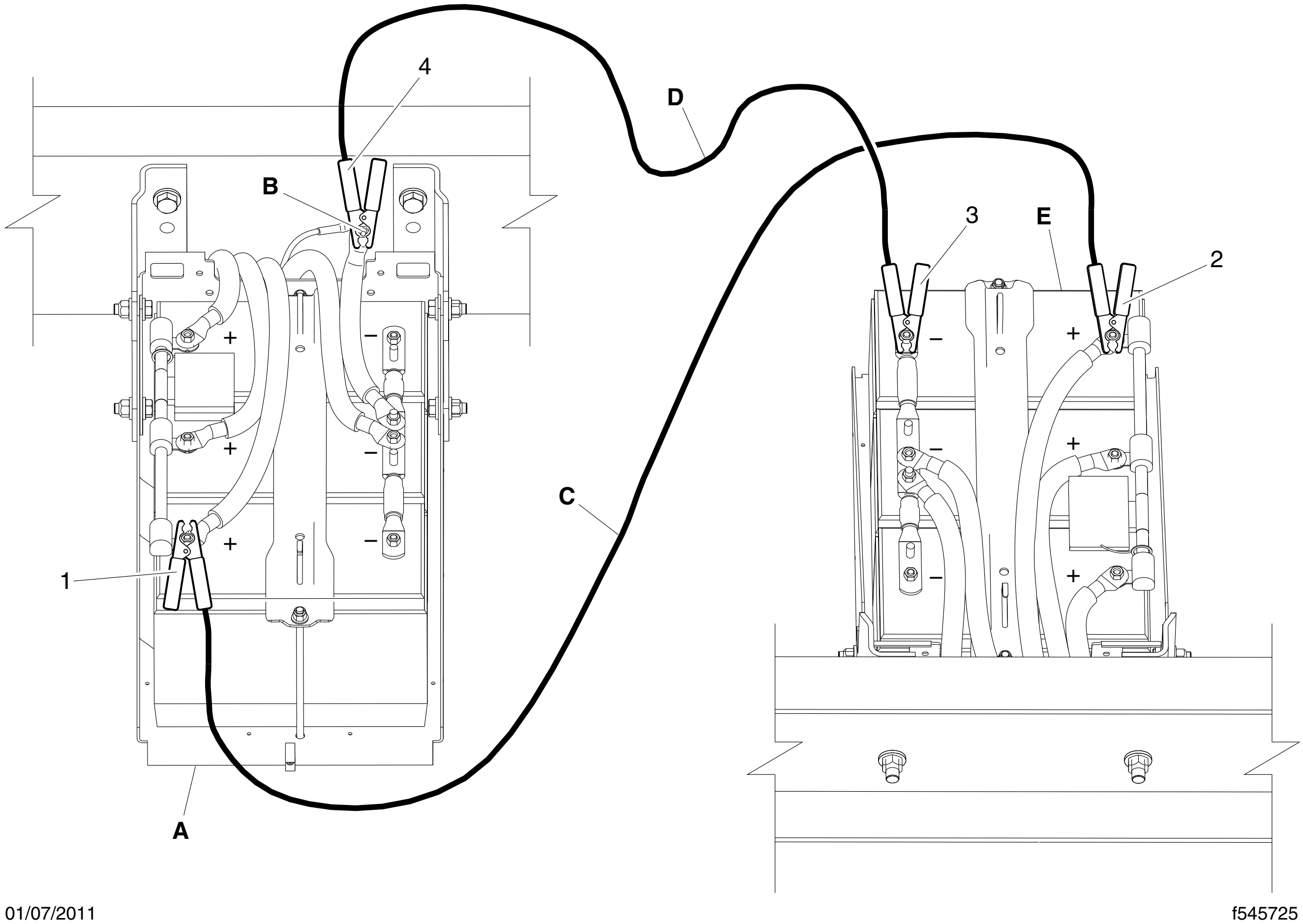
4. Connect the other end of the positive jumper cable to the positive terminal or jump start post on the booster battery providing the charge.

WARNING

Do the next step exactly as instructed and do not allow the clamps of one cable to touch the clamps of the other cable. Otherwise, a spark could occur near a battery, possibly resulting in severe personal injury from explosion and acid burns.

5. Connect the negative (-) jumper cable to the negative terminal or jump start post on the booster battery.
6. Connect the other end of the negative jumper cable to the negative ground stud on the vehicle requiring the jump start.
7. Start the engine of the vehicle providing the jump start and let the engine run a few minutes to charge the batteries of the other vehicle.

Emergency (Jump) Starting a Battery



Disconnect jumper cables in the REVERSE order that they were connected.

A. Discharged Battery
B. Negative Ground Stud
C. Positive Jumper Cable
D. Negative Jumper Cable
E. Booster Battery

1. 1st Connection: Positive Jumper Cable to Discharged Battery
2. 2nd Connection: Positive Jumper Cable to Booster Battery
3. 3rd Connection: Negative Jumper Cable to Booster Battery
4. 4th Connection: Negative Jumper Cable to Negative Ground Stud (discharged battery)

Fig. 2, Jumper Connections

8. Attempt to start the engine of the vehicle receiving the jump. Do not operate the starter longer than 30 seconds, and wait at least two minutes between starting attempts to allow the starter to cool.
9. When the engine starts, let it idle a few minutes.

WARNING

Do the next step exactly as instructed and do not allow the clamps of one cable to touch the clamps of the other cable. Otherwise, a spark could occur near a battery, possibly resulting in severe personal injury from explosion and acid burns.

Emergency (Jump) Starting a Battery

10. Disconnect the negative jumper cable from the negative cable stud on the jump-started vehicle.
11. Disconnect the negative jumper cable from the booster battery.
12. Disconnect the positive cable from the booster battery.
13. Disconnect the other end of the positive jumper cable from the jump-started vehicle.
14. Install the battery box cover; be sure it is positioned properly before fastening the latch.

WARNING

Before charging a battery, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

Battery Charging

AGM batteries may be charged only with a charger that is specified for AGM batteries. Many older chargers operate at a voltage that is too high for AGM batteries and will cause permanent damage. Never combine AGM and flooded batteries together for charging or for use in a vehicle.

See **Table 1** for voltage to approximate battery state of charge for flooded batteries.

Voltage to Approximate Battery State of Charge for Flooded batteries		
Voltage		State of Charge
Flooded	AGM	
12.6	12.8	100%
12.4	12.6	75%
12.2	12.3	50%
12.0	12.0	25%
11.8	11.8	0%

Table 1, Voltage to Approximate Battery State of Charge for Flooded batteries

1. If the batteries are not installed in the vehicle, install the lead adapters on the battery positive and negative posts.
2. Connect the charger to the battery following the manufacturer's instructions. Slightly rock the charger's clamps to insure a complete connection.

IMPORTANT: If the battery feels hotter than 125°F (52°C) or if rapid gassing or spewing of electrolyte occurs, lower the charging rate or stop charging the battery and allow it to cool.

3. When finished, turn the charger off.

WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

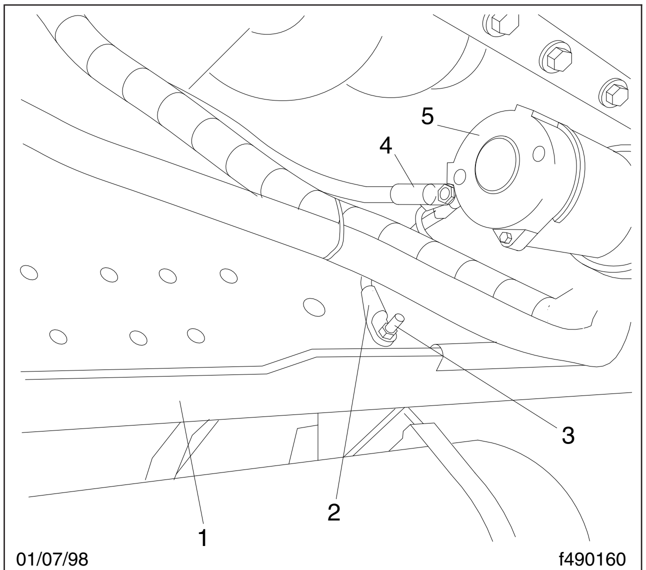
Battery Removal and Installation

⚠ WARNING

Before doing any of the following procedures, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Removal

1. Set the parking brakes; then chock the tires.
2. Make sure all electrical loads (lights, ignition, accessories) are turned off.
3. Disconnect battery power from the vehicle.
4. Disconnect the battery cables. See **Fig. 1**. For ease of installation, note the locations of the battery positive and negative terminals in relation to the vehicle.



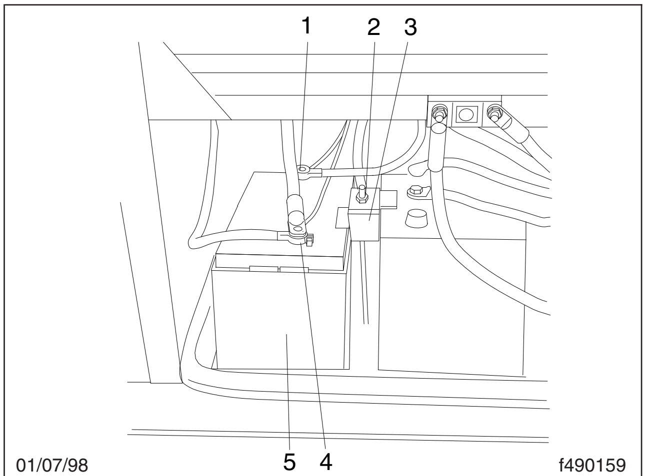
1. Frame Rail
2. Negative Cable
3. Ground Stud
4. Positive Cable
5. Starter Solenoid

Fig. 1, Battery Cables

4.1 First, disconnect the battery negative cable.

4.2 Disconnect the battery positive cable after the negative cable has been disconnected.

5. Remove the battery hold-down fasteners; then remove the batteries from the battery box. See **Fig. 2**.



1. Negative Terminal
2. Hold-Down Nut
3. Battery Hold-Down
4. Positive Terminal
5. Battery

Fig. 2, Battery Box

Cleaning and Inspection

1. Inspect all battery cables and interconnectors for wear, and replace them if necessary. Remove corrosion from cables, terminals, and battery posts with a wire brush and a solution of baking soda and water. Rinse thoroughly with clean water, and dry.
2. Clean and tighten the battery ground cable at the weld stud on the frame rail. Inspect and ensure that the nut is self-locking and that a flat washer is used. Do not use a split-lock washer or star washer. Torque the nut 15 to 18 lbf·ft (20 to 24 N·m). Seal the area with red dielectric enamel.
3. Inspect the retainer assembly and battery box. Replace worn or damaged parts. Remove any corrosion with a wire brush and wash with a weak solution of baking soda and water. Rinse with clean water and dry. To prevent rusting, paint the retainer assembly if needed.
4. Be sure foreign objects, such as stones, bolts, and nuts, are removed from the battery box.

Battery Removal and Installation

Installation

1. Be sure that the batteries to be installed have a sufficient capacity to cover the electrical needs of the vehicle.

CAUTION

Using an under-capacity battery will result in poor performance and premature battery failure, resulting in starter damage or reduced starter life.

2. Be sure each battery is at full charge when installed. If the batteries have been in storage for some time, or if the installation is being made in subfreezing temperatures, give the batteries a boost-charge before installing them. For instructions, see **Subject 120**.
3. Place the batteries in the carrier with the terminals in the proper position, as removed. The batteries should rest level in the carrier.
4. Position the battery hold-down over the battery, and install the hold-down nut. Tighten the nut until the battery is secure. See **Fig. 2**.

CAUTION

Do not overtighten the battery hold-downs. Overtightening could damage the battery.

5. For corrosion protection, liberally apply pumpable dielectric grease, part number 48–0239–000, to the battery terminal pads.
6. Connect the battery cables to the batteries.
   - 6.1 First connect the positive cable to the positive terminal.
   - 6.2 Connect the negative cable to the negative terminal.

CAUTION

Reversed polarity may cause serious damage to the electrical system.

7. Tighten all battery connections to the torque specifications listed on the battery. On Freightliner batteries, tighten them 10 to 15 lbf·ft (1360 to 2040 N·cm). The correct torque is important for proper electrical system operation.
8. Start the engine, and check the operation of the charging system. If needed, adjust or repair the charging system to obtain the correct charging output. For instructions, see the applicable alternator or starter subject in **Group 15**.
9. Cover the battery terminals with protective plastic caps.

CAUTION

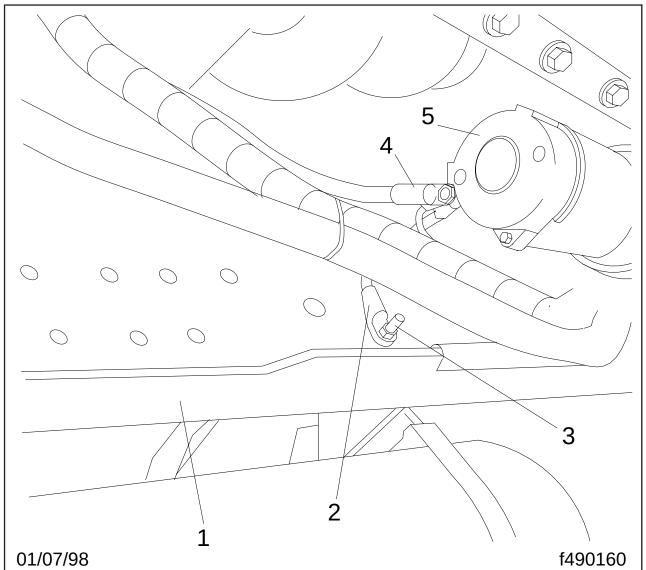
Make sure all battery terminals are covered with protective caps. Failure to cover the battery terminals could cause accidental shorting across the posts.

WARNING

Before doing any of the following procedures, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Removal

1. Set the parking brakes; then chock the tires.
2. Make sure all electrical loads (lights, ignition, accessories) are turned off.
3. Disconnect battery power from the vehicle.
4. Disconnect the battery cables. See Fig. 1. For ease of installation, note the locations of the battery positive and negative terminals in relation to the vehicle.



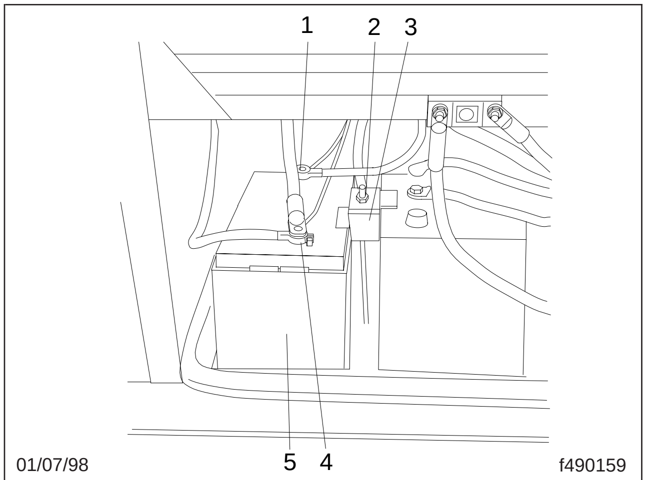
1. Frame Rail
2. Negative Cable
3. Ground Stud
4. Positive Cable
5. Starter Solenoid

Fig. 1, Battery Cables

4.1 First, disconnect the battery negative cable.

4.2 Disconnect the battery positive cable after the negative cable has been disconnected.

5. Remove the battery hold-down fasteners; then remove the batteries from the battery box. See Fig. 2.



1. Negative Terminal
2. Hold-Down Nut
3. Battery Hold-Down
4. Positive Terminal
5. Battery

Fig. 2, Battery Box

6. Clean and inspect the batteries following the guidelines in Subject 150.

Installation

1. Be sure that the batteries to be installed have a sufficient capacity to cover the electrical needs of the vehicle. See Subject 170.

CAUTION

Using an under-capacity battery will result in poor performance and premature battery failure, resulting in starter damage or reduced starter life.

2. Be sure each battery is at full charge when installed. If the batteries have been in storage for some time, or if the installation is being made in subfreezing temperatures, give the batteries a boost-charge before installing them. For instructions, see Subject 120.
3. Place the batteries in the carrier with the terminals in the proper position, as removed. The batteries should rest level in the carrier.

Battery Removal and Installation

4. Position the battery hold-down over the battery, and install the hold-down nut. Tighten the nut until the battery is secure. See **Fig. 2**.

CAUTION

Do not overtighten the battery hold-downs. Over-tightening could damage the battery.

5. For corrosion protection, liberally apply pumpable dielectric grease, part number 48–0239–000, to the battery terminal pads.
6. Connect the battery cables to the batteries.
   6.1 First connect the positive cable to the positive terminal.
   6.2 Connect the negative cable to the negative terminal.

CAUTION

Reversed polarity may cause serious damage to the electrical system.

7. Tighten all battery connections to the torque specifications listed on the battery. On Freightliner batteries, tighten them 10 to 15 lbf·ft (1360 to 2040 N·cm). The correct torque is important for proper electrical system operation.
8. Start the engine, and check the operation of the charging system. If needed, adjust or repair the charging system to obtain the correct charging output. For instructions, see the applicable alternator or starter subject in **Group 15**.
9. Cover the battery terminals with protective plastic caps.

CAUTION

Make sure all battery terminals are covered with protective caps. Failure to cover the battery terminals could cause accidental shorting across the posts.

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.
2. Clean and tighten the battery ground cable, terminals, and hold-downs.
3. Inspect the hold-down fasteners 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.

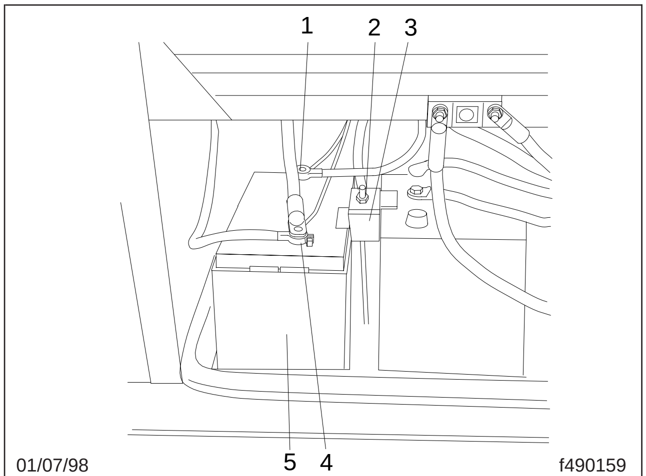
Battery Cable Removal and Installation

⚠ WARNING

Before doing any of the following procedures, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Removal

1. Set the parking brakes; then chock the tires.
2. Make sure all electrical loads (lights, ignition, accessories) are turned off.
3. Disconnect battery power from the vehicle.
4. Disconnect the battery cables from the batteries. See Fig. 1.



1. Negative Terminal
2. Hold-Down Nut
3. Battery Hold-Down
4. Positive Terminal
5. Battery

Fig. 1, Battery Box

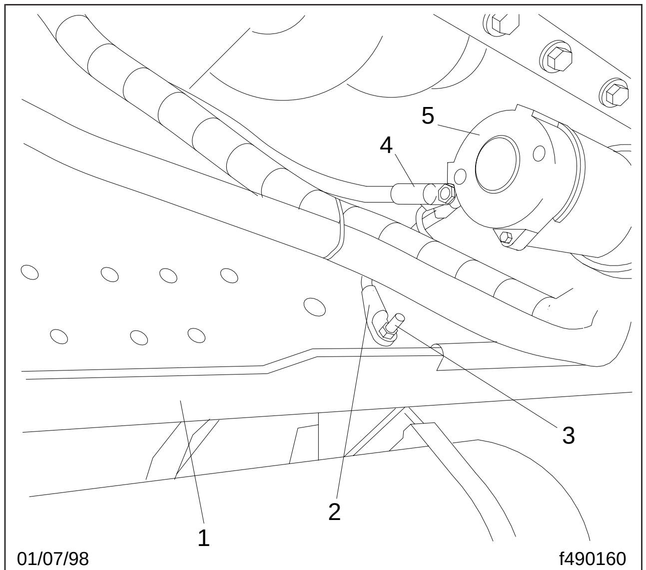
 4.1 First, disconnect the battery negative cable.

 4.2 Disconnect the battery positive cable after the negative cable has been disconnected.

5. Remove the battery cables. See Fig. 2.

 5.1 Remove the positive cable from the starter solenoid.

 5.2 Remove the negative cable from the ground stud on the frame rail.



1. Frame Rail
2. Negative Cable
3. Ground Stud
4. Positive Cable
5. Starter Solenoid

Fig. 2, Battery Cables

 5.3 Remove all tie straps.

Installation

1. Install the battery cables. See Fig. 2.

 1.1 Install the negative cable on the ground stud.

 1.2 Install the positive cable on the starter solenoid.

 1.3 Install new tie straps, as removed.

2. For corrosion protection, liberally apply pumpable dielectric grease, part number 48–0239–000, to the battery terminal pads.
3. Connect the battery cables to the batteries.

 3.1 First connect the positive cable to the positive terminal.

 3.2 Connect the negative cable to the negative terminal.

⚠ CAUTION

Reversed polarity may cause serious damage to the electrical system.

Battery Cable Removal and Installation

4. Tighten all battery connections to the torque specifications listed on the battery. On Freightliner batteries, tighten them 10 to 15 lbf·ft (14 to 20 N·m). The correct torque is important for proper electrical system operation.
5. Start the engine, and check the operation of the charging system. If needed, adjust or repair the charging system to obtain the correct charging output. For instructions, see the applicable alternator or starter subject in **Group 15**.
6. Cover the battery terminals with protective plastic caps.

CAUTION

Make sure all battery terminals are covered with protective caps. Failure to cover the battery terminals could cause accidental shorting across the posts.

Troubleshooting

If the batteries pass testing, check for the following causes:

1. Accessories were left on overnight.
2. A slipping alternator belt, high resistance in the wiring, or a defective alternator is causing the batteries to discharge.
3. The electrical loads are exceeding the charging system capacity.
4. Wires in the electrical system are shorted or pinched.
5. There are loose or damaged battery cable-to-terminal connections.
6. The batteries are still connected in a vehicle that has been out of service. Small current drains of accessories that are connected all the time can discharge the batteries in a few days. Batteries left in a discharged condition are subject to freezing.

Electrical Drain and Parasitic Load

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough to cause a no-start condition.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off. Some devices, such as the electronic control unit (ECU), the bulkhead module (BHM), the chassis module (CHM), the antilock braking system (ABS), and radio memory are intended to draw a very small current continuously. These draws are measured in milliamps (mA). Current draw should be less than 325 milliamps with no circuits active and the ECU, BHM, CHM, and ABS turned off.

Problem—The Batteries Are Undercharged

Problem—The Batteries Are Undercharged	
Possible Cause	**Remedy**
The drive belt is loose.	Check the drive belt and tensioner. Refer to the drive belt subject in the appropriate engine section in **Group 01** for instructions. If necessary, tighten to the manufacturer's specifications. Start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the alternator section in **Group 15** for instructions.
The drive belt is damaged or missing.	Check the drive pulleys for locked bearings. Repair or replace any damaged components. Replace the drive belt and start the engine. Check the alternator voltage and output. Refer to the troubleshooting subject in the alternator section in **Group 15** for instructions.
The batteries are undercharged.	Perform a battery test. Charge or replace batteries as needed. If the batteries were discharged, start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The alternator or battery cables are undersized.	Perform a cable load drop test.
The alternator is malfunctioning.	Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The isolator relay is not operating correctly (optional battery isolator system only).	Refer to **Group 82, Subject 300** in this manual for instructions.

Troubleshooting

Battery Troubleshooting

1. **Check battery pack voltage to determine state of charge**.

   If equipped, set Load Disconnect Switch to "Off." With the DMM probes on the positive and negative posts of the battery pack, record the voltage. Due to differences in their design and operation, flooded cell and AGM batteries have different voltages at the same state of charge.

   Batteries should be fully charged before further testing. If batteries are not fully charged, they will draw current to recharge during testing, invalidating the troubleshooting test results. Fully charged batteries ensure reliable diagnosis.

   See **Table 1** for voltage as an approximate indicator of state of charge for AGM and flooded batteries.

   If the battery pack will not charge to 100% state of charge, there may be a shorted cell. Break the pack into individual batteries and test individually using an approved tester. Go to **Check 3, Individual Battery Testing**. After batteries have been tested individually, verify pack voltage once again.

Flooded	AGM	SoC
12.6	12.8	100%
12.4	12.6	80%
12.3	12.4	60%
12.1	12.2	40%
12	12	20%
11.8	11.8	0%

Table 1, Voltage to Approximate State of Charge (SoC)

2. **Remove surface charge: HVAC blower, lights on, 5 min.**

   Surface charge refers to a higher initial charge (volts), when discharging, in recently-charged batteries. This charge is a "shallow" charge, meaning that the charging-induced chemical reaction has mostly occurred at the surface of the lead plates, and has not equalized throughout the lead. Drawing current from the batteries before testing removes the surface charge, allowing for a better assessment of the "deep charge" state of the lead plates.

   After the surface charge is removed, the batteries need to be at least 80% SoC for further testing. See **Table 1** for voltage as an approximate indicator of state of charge.

3. **Test Individual Batteries**.

   IMPORTANT: Batteries should only be tested individually.

   3.1 Remove the negative cables of the batteries first, and secure the leads out of the way before touching the positive cables. Remove the battery cables and clean the terminal pads with a wire brush. The adapters will not make sufficient contact with dirty or corroded contact pads.

   3.2 Connect the battery tester's positive and negative clamps to the lead base terminal pads at the positive and negative studs. See **Fig. 1**.

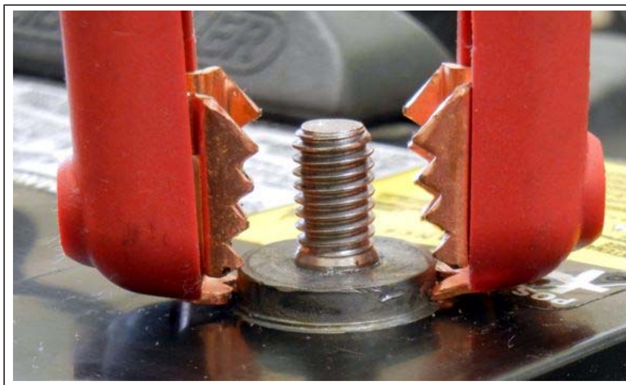


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Fig. 1, Tester Clamps Attached to the Post

The threaded portion of the battery posts are *not* the right place to clip: the steel threads won't make a good connection. The base of the post, on the lead, is the best place to clip. Taking a few extra seconds to make sure the tester, DMM, and carbon pile clips are well-connected can be the difference between a useful and a useless test.

NOTE: If the lead base is too small to clamp to, only lead stud adapters should be used, never nuts. The lead stud adapters must be screwed down tight against the cleaned lead base using a hand tool. Lead adapters are available at most tool vendors.

Refer to the battery tester instruction manual for complete testing instructions.

If the battery tester requires the CCA rating of the battery, it should be on the battery label. See **Fig. 2**.

3.3 If the battery fails, enter the battery serial number and print out the result. The sensor windows on the tester and printer must be aligned to transmit the test results to the printer.

06/24/2013 f151184

Fig. 2, Battery Label

Specifications

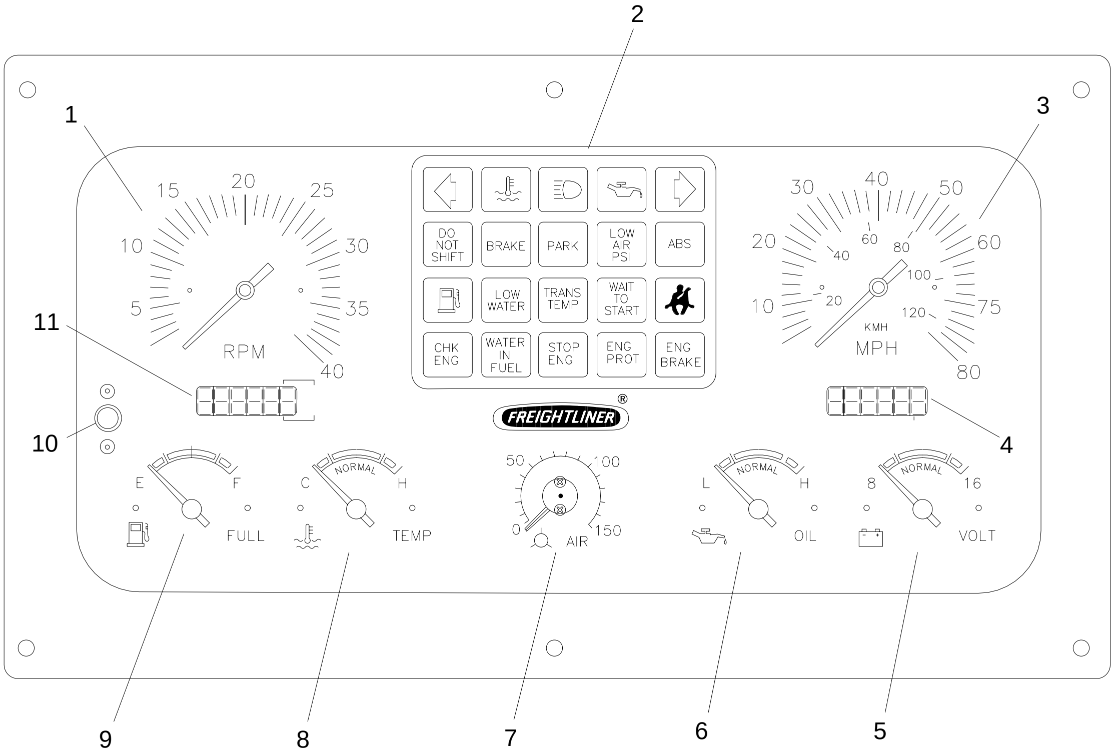
See **Table 1** for recharge times. Refer to the commercial batteries page at **www.dekabatteries.com** for more information.

Recharge Time Using a Typical Charger (hours)						
Open Circuit Voltage		State of Charge	Charger Maximum Rate			
Flooded	AGM		50 Amps	30 Amps	20 Amps	10 Amps
12.6V	12.8V	100%	Ready to Use			
12.4V	12.6V	75%	0.6	0.9	1.3	2.5
12.2V	12.3V	50%	1.2	1.9	2.7	5.1
12.0V	12.0V	25%	1.8	2.9	4.3	10.7
11.8V	11.8V	0%	2.5	4.0	5.7	10.7

Table 1, Recharge Time Using a Typical Charger

General Information

The instrument cluster is a one-piece unit that contains all the gauges and indicators required for safe operation of the vehicle. See **Fig. 1**.



01/27/98 f610035

1. Tachometer
2. Driver Information Center
3. Speedometer
4. Odometer
5. Voltmeter
6. Oil Pressure Gauge
7. Air Pressure Gauge
8. Coolant Temperature Gauge
9. Fuel Level Gauge
10. Trip Reset Button
11. Trip Odometer

Fig. 1, Instrument Cluster

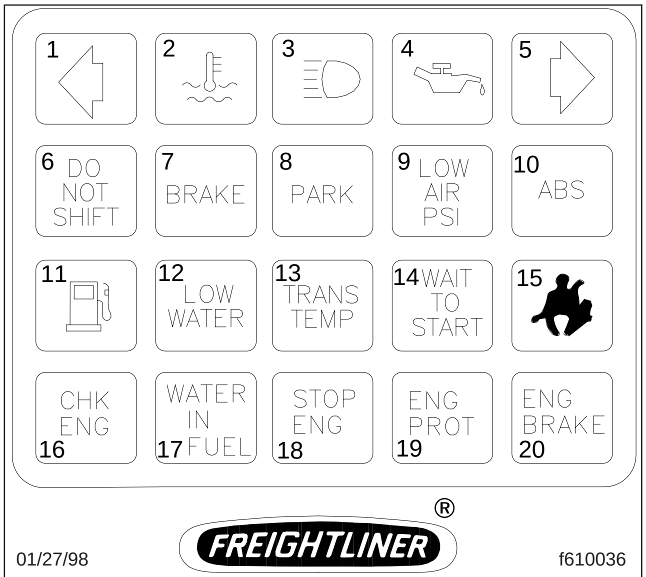
Each gauge is an integral part of the cluster and cannot be replaced without replacing the entire unit. For instrument cluster installation, see **Subject 100**.

The instrument cluster contains a driver information center bearing the warning and indicator lights. See **Fig. 2** for a typical installation. These lights include warnings about low engine oil pressure, low brake fluid, high coolant temperature, and low air pressure. If a problem occurs, the light illuminates.

An alarm sounds, in addition to the warning light, whenever one of the following conditions occurs:

- The engine oil pressure drops below 7 psi (50 kPa); or
- The coolant temperature rises above 220°F (105°C).

General Information



NOTE: The warning and indicator light layout shown is typical; arrangement of lights may vary.

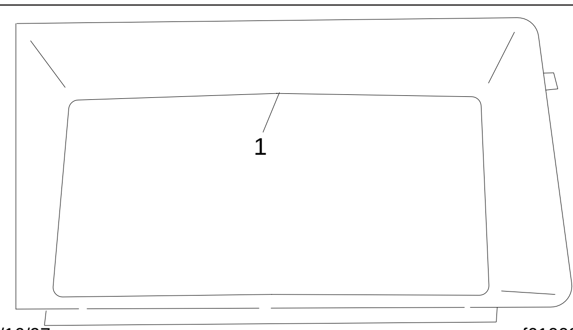
1. Left Turn Indicator
2. High Coolant Temperature Warning
3. High Beam Indicator
4. Low Oil Pressure Warning
5. Right Turn Indicator
6. Do Not Shift Warning
7. Low Brake Fluid Warning
8. Parking Brake Warning
9. Low Air Warning
10. ABS Warning
11. Low Fuel Indicator
12. Low Coolant Level Warning
13. Transmission Temperature Warning
14. Wait To Start Warning
15. Seat Belt Warning
16. Check Engine Indicator
17. Water In Fuel Indicator
18. Stop Engine Warning
19. Engine Protection Indicator
20. Engine Brake Indicator

Fig. 2, Warning and Indicator Lights

Instrument Cluster Removal and Installation

Removal

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the radio and rear-view TV monitor to gain access to the rear support strap. For detailed information, see the body builder's manual and/or vendor manuals provided by the body builder.
4. Remove the right-hand side and upper dash panels. For detailed information, see the body builder's manual.
5. Remove the instrument panel bezel by flexing the two side tabs. See **Fig. 1**.



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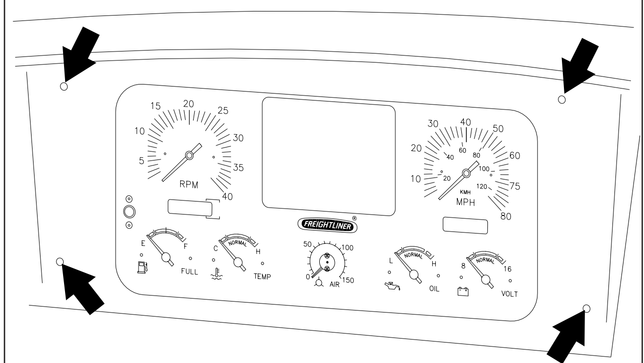
Flex the two side tabs to remove the bezel.

1. Bezel

Fig. 1, Instrument Panel Bezel

6. Remove the four screws that hold the instrument cluster to the panel. See **Fig. 2**.
7. Pull back the HVAC housing as necessary to free the cluster. If needed, disconnect the HVAC electrical connectors.
8. Rock the cluster back and forth to expose the left-hand side hidden fastener. Remove the screw as as shown in **Fig. 3**.
9. With the first hidden fastener removed, rock the cluster the other way to expose the right-hand side hidden fastener. Remove the screw as as shown in **Fig. 4**.
10. Remove the screw attaching the cluster to the support bracket underneath the dash. See **Fig. 5**.



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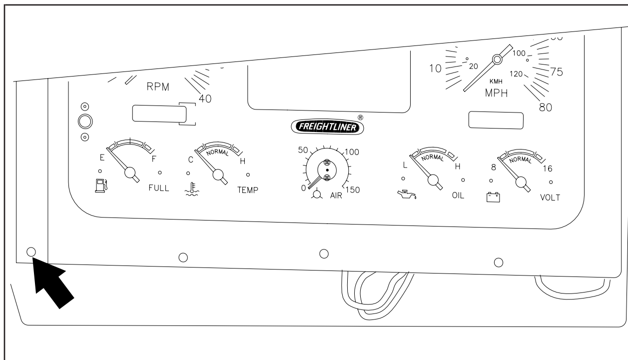
Remove the four fasteners indicated by the arrows.

NOTE: A typical instrument cluster installation is shown; the procedure is the same for all installations.

Fig. 2, Instrument Cluster



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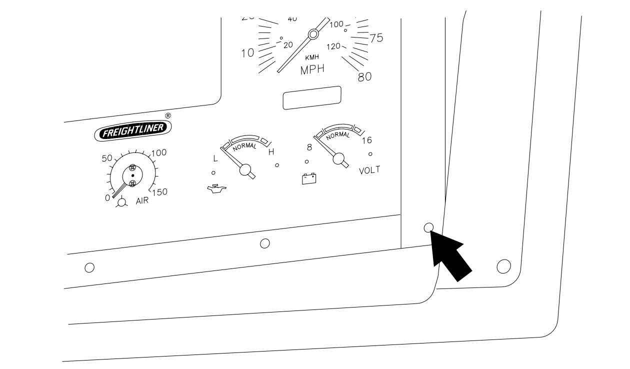
Remove the fastener indicated by the arrow.

NOTE: A typical instrument cluster installation is shown; the procedure is the same for all installations.

Fig. 3, Instrument Cluster Hidden Fastener, LH Side

11. Remove the cluster from the instrument panel. See **Fig. 6**.
    - 11.1 Disconnect the four electrical harnesses from the back of the instrument cluster.
    - 11.2 Disconnect the two air lines from the back of the instrument cluster in the area below the driver information center.

Instrument Cluster Removal and Installation



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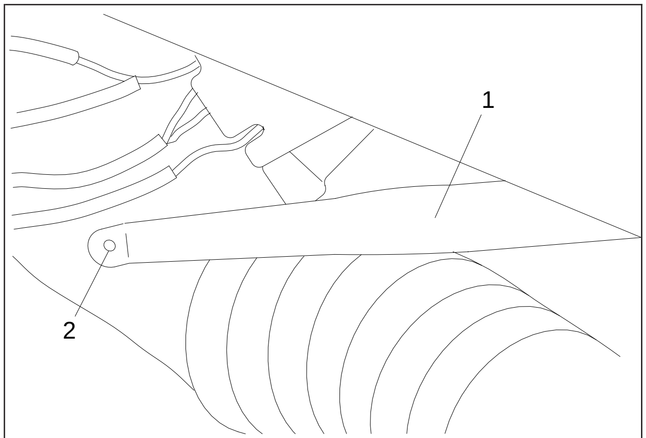
Remove the fastener indicated by the arrow.

NOTE: A typical instrument cluster installation is shown; the procedure is the same for all installations.

Fig. 4, Instrument Cluster Hidden Fastener, RH Side



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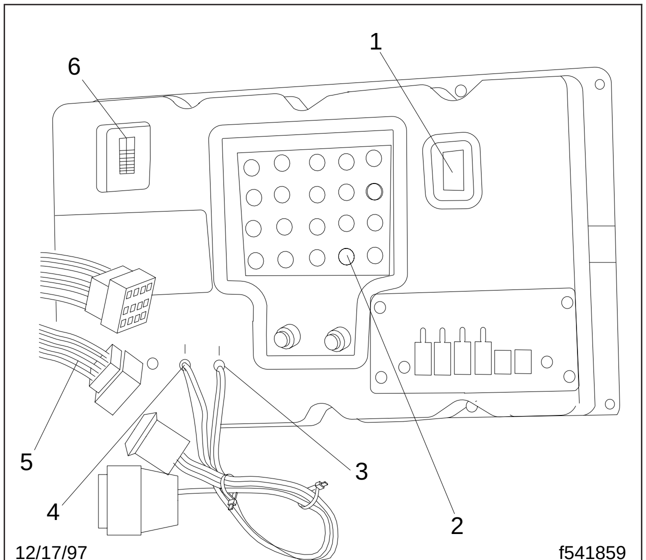
1. Bracket
2. Screw Hole

Fig. 5, Rear Support Bracket, LH Side

Installation

1. Position the instrument cluster in the dash. Connect the instrument cluster air and electrical connectors.
   1.1 Connect all four electrical connectors, as removed.
   1.2 Connect both air lines, as removed.
2. Install the six fasteners attaching the cluster to the instrument panel, as removed.



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1. Tachometer DIP Switches
2. Light Bulbs
3. Low Coolant Harness
4. Transmission Temperature Harness
5. Main Cab Harness
6. Speedometer DIP Switches

Fig. 6, Back of Instrument Cluster

   2.1 Attach the two hidden fasteners behind the instrument panel, left-hand and right-hand.
   2.2 Attach the four external fasteners to the instrument panel.
3. Install the screw attaching the instrument cluster to the support bracket underneath the dash, as removed.
4. Tighten all fasteners firmly.
5. Install the instrument panel bezel onto the instrument panel.
6. Connect the batteries.
7. Start the engine and verify that the gauges and lights are operating properly.
8. Remove the chocks from the tires.

Warning and Indicator Light Replacement

Replacement

1. Disconnect the batteries.
2. Remove the instrument cluster. For detailed instructions, see **Subject 100**.
3. From the back of the instrument cluster, twist out each bulb that needs replacing.
4. Insert a new bulb in each empty socket and twist it clockwise until it locks into place.
5. Install the instrument cluster, as removed.
6. Connect the batteries.
7. Turn on the ignition keyswitch and verify that the lights are all operating properly.

Calibration

1. Determine the pulses per mile (pul/mi).
   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 (pul/mi) using this formula:

   Pul/mi = 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

Example: For a vehicle with a rear axle ratio of 4.11 and tires having 211 revolutions per mile, the calculations would be as follows:

211 x 4.11 x 16 = 13875.36 pul/mi

2. Determine the divide number.
   2.1 Divide the pul/mi by 4000.
   2.2 Round off the divide number to the nearest fractional value given in **Table 1**.

Program Chart, Fractional Part of Divide Number			
Divide Number	**6**	**7**	**8**
0.000	OFF	OFF	OFF
0.125	OFF	OFF	ON
0.250	OFF	ON	OFF
0.375 *	OFF	ON	ON
0.500	ON	OFF	OFF
0.625 †	ON	OFF	ON
0.750	ON	ON	OFF
0.875	ON	ON	ON

* On clusters with microprocessor MPU-100, this setting is 0.333.

† On clusters with microprocessor MPU-100, this setting is 0.666.

Table 1, Program Chart, Fractional Part of Divide Number

   2.3 Make a note of the divide number for later use.

Example: Start with 13875.36, as calculated above.

13875.36 ÷ 4000 = 3.46884

Round off the divide number to 3.500.

3. Determine the DIP switch settings.
   3.1 The whole number part of the divide number is used to find the settings for the first five DIP switches. Look up the whole number value of the divide number in **Table 2**. Then read off the settings for the first five DIP switches.

Program Chart, Whole Number Part of Divide Number					
Divide Number	**1**	**2**	**3**	**4**	**5**
1	OFF	OFF	OFF	OFF	ON
2	OFF	OFF	OFF	ON	OFF
3	OFF	OFF	OFF	ON	ON
4	OFF	OFF	ON	OFF	OFF
5	OFF	OFF	ON	OFF	ON
6	OFF	OFF	ON	ON	OFF
7	OFF	OFF	ON	ON	ON
8	OFF	ON	OFF	OFF	OFF
9	OFF	ON	OFF	OFF	ON
10	OFF	ON	OFF	ON	OFF
11	OFF	ON	OFF	ON	ON
12	OFF	ON	ON	OFF	OFF
13	OFF	ON	ON	OFF	ON
14	OFF	ON	ON	ON	OFF
15	OFF	ON	ON	ON	ON
16	ON	OFF	OFF	OFF	OFF

Speedometer Head Calibration

Program Chart, Whole Number Part of Divide Number					
Divide Number	1	2	3	4	5
17	ON	OFF	OFF	OFF	ON
18	ON	OFF	OFF	ON	OFF
19	ON	OFF	OFF	ON	ON
20	ON	OFF	ON	OFF	OFF
21	ON	OFF	ON	OFF	ON
22	ON	OFF	ON	ON	OFF
23	ON	OFF	ON	ON	ON
24	ON	ON	OFF	OFF	OFF
25	ON	ON	OFF	OFF	ON
26	ON	ON	OFF	ON	OFF
27	ON	ON	OFF	ON	ON
28	ON	ON	ON	OFF	OFF
29	ON	ON	ON	OFF	ON
30	ON	ON	ON	ON	OFF
31	ON	ON	ON	ON	ON
32	OFF	OFF	OFF	OFF	OFF

Table 2, Program Chart, Whole Number Part of Divide Number

3.2 The fractional part of the divide number is used to find the settings for the last three DIP switches (switches numbered six through eight). Look up the whole number value of the divide number in **Table 1**. Then read off the settings for the last three DIP switches.

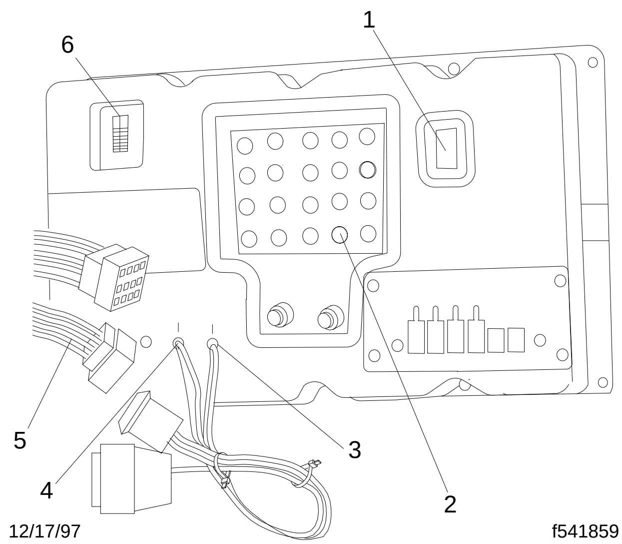
Example: Start with a divide number of 3.500.

Look up "3" in **Table 2**. Read off the settings for the first five DIP switches (the first five switches from the top): OFF, OFF, OFF, ON, ON.

Look up "0.500" in **Table 1**. Read off the settings for the last three DIP switches (the bottom three switches): ON, OFF, OFF.

4. Remove the instrument cluster from the dash. For detailed instructions, see **Subject 100**.

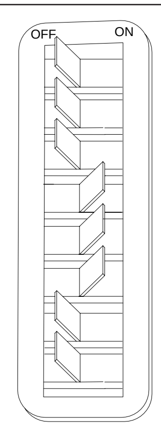
5. Locate the speedometer DIP switch panel on the back of the instrument cluster, to the left of the driver information center light panel. See **Fig. 1**.



1. Tachometer DIP Switches
2. Light Bulbs
3. Low Coolant Harness
4. Transmission Temperature Harness
5. Main Cab Harness
6. Speedometer DIP Switches

Fig. 1, Back of Instrument Cluster

6. Set each of the eight DIP switches to the correct calibration settings. There will be eight switches in the panel, ranging from #1 at the top to #8 at the bottom (switches are not numbered on the panel). See **Fig. 2**.



Push the pin to the right to turn the switch ON; Push the pin to the left to turn it OFF.

Fig. 2, Speedometer DIP Switch Panel

6.1 Write down the correct setting for each switch, either ON or OFF.

6.2 Using a tool that will not break off, push the pin up to turn it ON; push the pin down to turn it OFF.

7. Install the instrument cluster. For detailed instructions, see **Subject 100**.

8. Test drive the vehicle over a measured course to check the accuracy of the speedometer.

9. If the speedometer is reading slower or faster than the true speed, correct the divide number.

9.1 Divide the speedometer reading by the true ground speed and multiply the result by the current divide number.

Example: If the speedometer is reading 54 miles per hour (mph) at a true ground speed of 60 mph, divide 54 (indicated speed) by 60 (true speed) and multiply by 3.500 (the current divide number):

$54 \div 60 \times 3.50 = 3.15$

9.2 Round off the divide number to the nearest fractional value given in **Table 1**.

Example: Round off 3.15 to 3.125.

9.3 Read off the corrected DIP switch settings from **Table 1**.

Example: The corrected settings are OFF, OFF, ON.

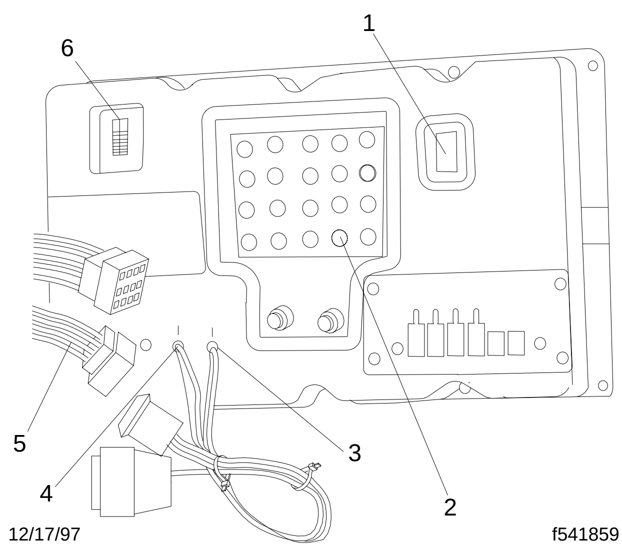
9.4 Compare the corrected settings with the actual settings on the back of the instrument cluster, and adjust as necessary.

Example: Since the corrected settings are OFF, OFF, ON, and the current settings are ON, OFF, OFF, adjust the speedometer by turning switch #6 OFF and switch #8 ON.

9.5 Check the speedometer again for accuracy as above.

Calibration

1. Remove the instrument cluster from the dash. For detailed instructions, see **Subject 100**.
2. Locate the tachometer DIP switches on the back of the instrument cluster, to the right of the driver information center light panel. See **Fig. 1**.



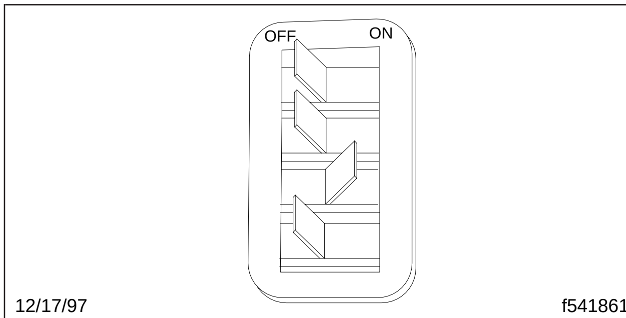
1. Tachometer DIP Switches
2. Light Bulbs
3. Low Coolant Harness
4. Transmission Temperature Harness
5. Main Cab Harness
6. Speedometer DIP Switches

Fig. 1, Back of Instrument Cluster

3. Set each of the four DIP switches to the correct calibration settings. There will be four switches in the panel, ranging from #1 at the top to #4 at the bottom (switches are not numbered on the panel).

   If the vehicle is equipped with an electronic engine, set the DIP switches as follows, starting at the top of the panel and working down: OFF, OFF, ON, OFF.

   If the vehicle is equipped with an non-electronic engine, set the DIP switches as follows, starting at the top of the panel and working down: OFF, ON, OFF, OFF.



Push the pin to the right to turn the switch ON; Push the pin to the left to turn it OFF.

Fig. 2, Tachometer DIP Switch Panel

   3.1 Write down the correct setting for each switch, either ON or OFF.

   3.2 Using a tool that will not break off, push the pin up to turn it ON; push the pin down to turn it OFF.

4. Install the instrument panel. For detailed instructions, see **Subject 100**.

General Information

A spring-loaded air restriction indicator indicates how much air filter capacity has been used and how much remains. It registers the actual maximum restriction of the filter element when the engine is operating at full load. See **Fig. 1**.

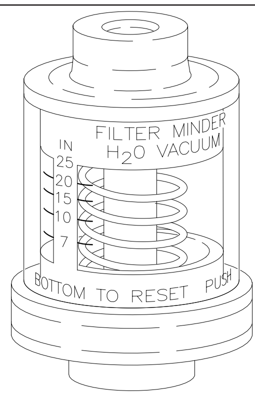


Fig. 1, Air Restriction Indicator

The standard air restriction indicator is mounted on bracket attached to a metal railing above the radiator and has a push-type reset button located at the end opposite the air line attachment.

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.

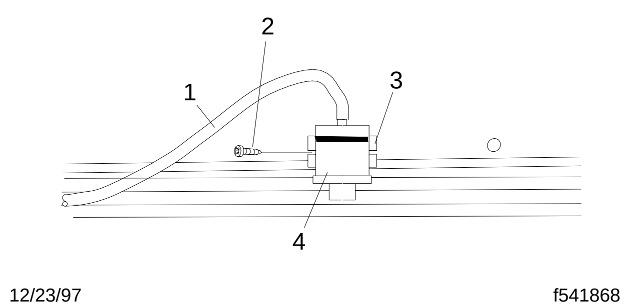
IMPORTANT: Many of the fluids used in vehicles, including brake fluid, fuel, antifreeze, engine oil, engine cleaners, windshield washer fluid, automatic transmission fluid, and power steering fluid, are harmful to the polycarbonate (Lexan) plastics that are used in air restriction indicators. Keep these fluids away from the air restriction indicator.

Air Restriction Indicator Replacement

Replacement

MOUNTED ABOVE THE RADIATOR

1. Chock the tires, then open the rear engine compartment door.
2. Remove the mounting screw attaching the indicator body to the bracket on the railing above the radiator. If necessary, hold the fitting with a wrench. See **Fig. 1**.



1. Air Line
2. Mounting Screw
3. Bracket
4. Indicator Body

Fig. 1, Air Restriction Indicator

3. Remove the air line from the top of the indicator.
4. Install the new air restriction indicator onto the bracket and tighten the mounting screw until firm.
5. Install the air line onto the top of the indicator.
6. Close the rear engine compartment and remove the chocks from the tires.

Troubleshooting

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.	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.

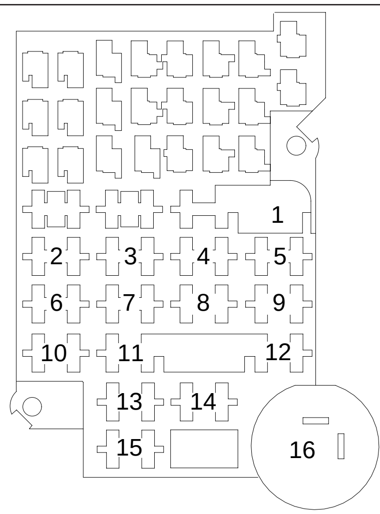
Problem—High Restriction Readings

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 intake screens or ducts are plugged.	Check the system upstream from the air restriction indicator and remove any debris. Check for damage or improper installation, and take any necessary corrective action.
Heavy snow or rain.	Temporary high restriction can occur during a rain or snow storm and disappear after drying out. However, the cold air may be so dense that high restriction may not reduce the engine power before the air cleaner filter element is damaged. If the indicator reads maximum restriction (red line), check the element for damage and replace if necessary. NOTE: Before replacing the indicator, check the reading twice to be sure the high restriction reading is correct.

General Information

The wiring is protected by fuses (or optional blade-type push-to-reset circuit breakers) mounted on a fuse panel in the electrical power center. The hazard warning flasher is also installed on the fuse panel. See **Fig. 1**.

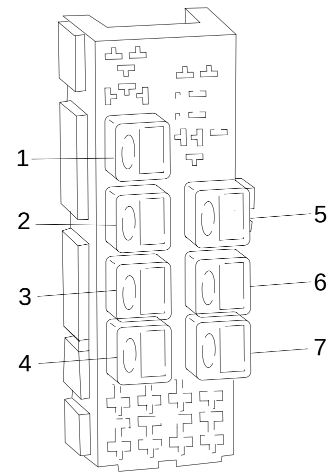
In addition to the fuse panel, the electrical power center also contains the relay panel. See **Fig. 2**.



01/08/98 f541874

1. Instrument Light 5-Amp
2. Horn/Dimmer 15-Amp
3. IGN Power 20-Amp
4. Radio 15-Amp
5. Not Used
6. Taillight 20-Amp
7. Gauge 20-Amp
8. Heater 25-Amp
9. Wiper 25-Amp
10. Brake Light 15-Amp
11. Turn Signal 15-Amp
12. Air Dryer 10-Amp
13. BAT Auxiliary 25-Amp
14. Drain Valve 15-Amp
15. IGN Auxiliary 30-Amp
16. Hazard Warning Flasher

Fig. 1, Fuse Panel



09/03/96 f541875

1. Heater
2. Brake Lights
3. Auxiliary IGN
4. Horn
5. Ignition
6. Accessory
7. Parking Brake

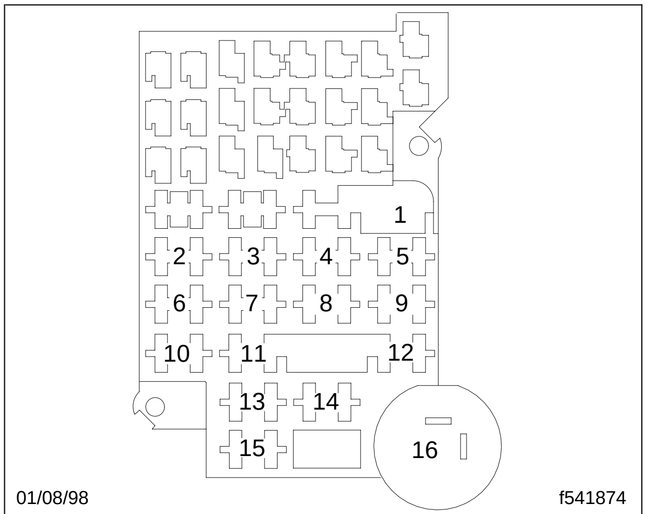
Fig. 2, Relay Panel

Replacement

To remove blade-type fuses, pull outward on the fuse body and release the two prongs. When installing blade-type fuses, insert one prong in each cavity, and press in. Be careful not to bend back the prongs. The cavities are color-coded to make installation easier.

To remove relays, pull outward on the body of the unit. When installing relays, insert the pins in the correct cavities, and press in.

For location of the fuses on the fuse panel, see **Fig. 1**.

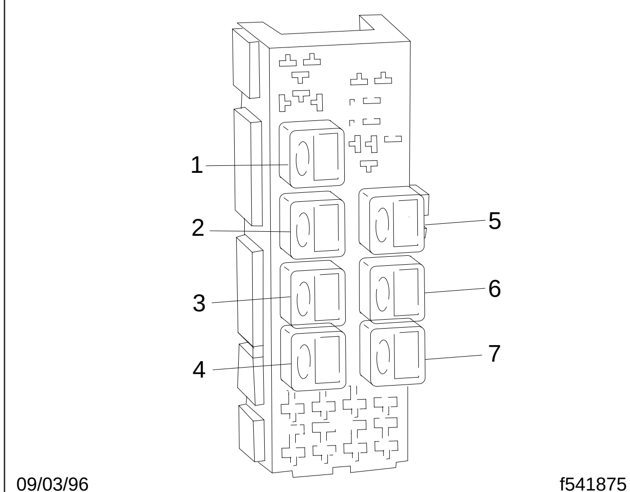


NOTE: Positions are marked on the panel, but not all of them are used.

1. Instrument Light 5-Amp
2. Horn/Dimmer 15-Amp
3. IGN Power 20-Amp
4. Radio 15-Amp
5. Not Used
6. Taillight 20-Amp
7. Gauge 20-Amp
8. Heater 25-Amp
9. Wiper 25-Amp
10. Brake Light 15-Amp
11. Turn Signal 15-Amp
12. Air Dryer 10-Amp
13. BAT Auxiliary 25-Amp
14. Drain Valve 15-Amp
15. IGN Auxiliary 30-Amp
16. Hazard Warning Flasher

Fig. 1, Fuse Panel

For location of the relays on the relay panel, see **Fig. 2**.



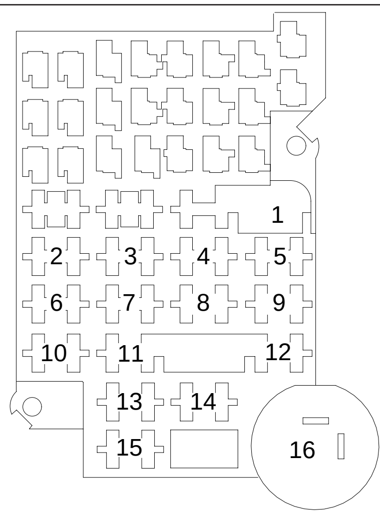
1. Heater
2. Brake Lights
3. Auxiliary IGN
4. Horn
5. Ignition
6. Accessory
7. Parking Brake

Fig. 2, Relay Panel

Replacement

MODEL VB–3 CIRCUIT BREAKER

1. Slide the old circuit breaker out of the fuse panel. See **Fig. 1**.
2. Snap the new circuit breaker into place. Take care not to damage the two blades while inserting them into the panel.



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NOTE: Positions are marked on the panel, but not all of them are used.

1. Instrument Light 5-Amp
2. Horn/Dimmer 15-Amp
3. IGN Power 20-Amp
4. Radio 15-Amp
5. Not Used
6. Taillight 20-Amp
7. Gauge 20-Amp
8. Heater 25-Amp
9. Wiper 25-Amp
10. Brake Light 15-Amp
11. Turn Signal 15-Amp
12. Air Dryer 10-Amp
13. BAT Auxiliary 25-Amp
14. Drain Valve 15-Amp
15. IGN Auxiliary 30-Amp
16. Hazard Warning Flasher

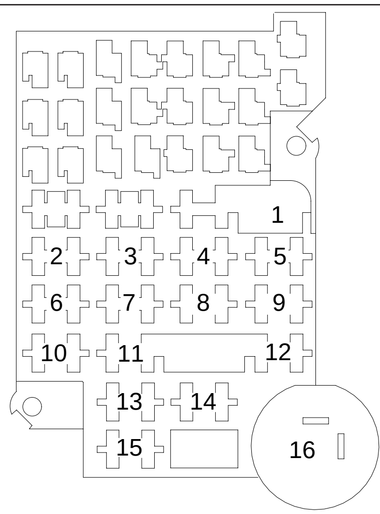
Fig. 1, Model VB-3 Circuit Breaker Location

Troubleshooting

To troubleshoot malfunctioning fuses, circuit breakers (C/Bs), and relays, do the following:

1. Check the location on the applicable figure.
2. For fuses or circuit breakers, check the amperage in the callouts on **Fig. 1**.
3. Replace the C/B or relay.
4. Check the circuit again.

For location of fuses (or circuit breakers, if installed) on the fuse panel, see **Fig. 1**.



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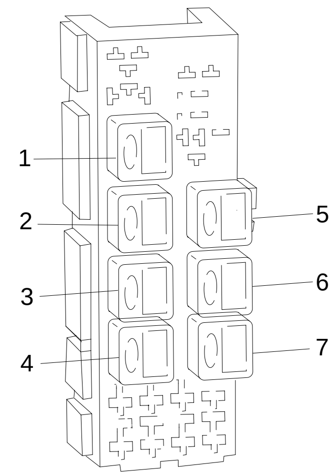
NOTE: Positions are marked on the panel, but not all of them are used.

1. Instrument Light 5-Amp
2. Horn/Dimmer 15-Amp
3. IGN Power 20-Amp
4. Radio 15-Amp
5. Not Used
6. Taillight 20-Amp
7. Gauge 20-Amp
8. Heater 25-Amp
9. Wiper 25-Amp
10. Brake Light 15-Amp
11. Turn Signal 15-Amp
12. Air Dryer 10-Amp
13. BAT Auxiliary 25-Amp
14. Drain Valve 15-Amp
15. IGN Auxiliary 30-Amp
16. Hazard Warning Flasher

Fig. 1, Fuse Panel

For location of relays on the relay panel, see **Fig. 2**.



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1. Heater
2. Brake Lights
3. Auxiliary IGN
4. Horn
5. Ignition
6. Accessory
7. Parking Brake

Fig. 2, Relay Panel

General Description

The ICU3-M2 is a basic electronic dashboard that accepts input from the fuel level sensor, the transmission temperature sensor (if installed), the J1587 datalink, and the J1939 datalink. The information is processed by a micro-computer and displayed on electronic gauges driven by stepper motors. Only the air gauges operate mechanically.

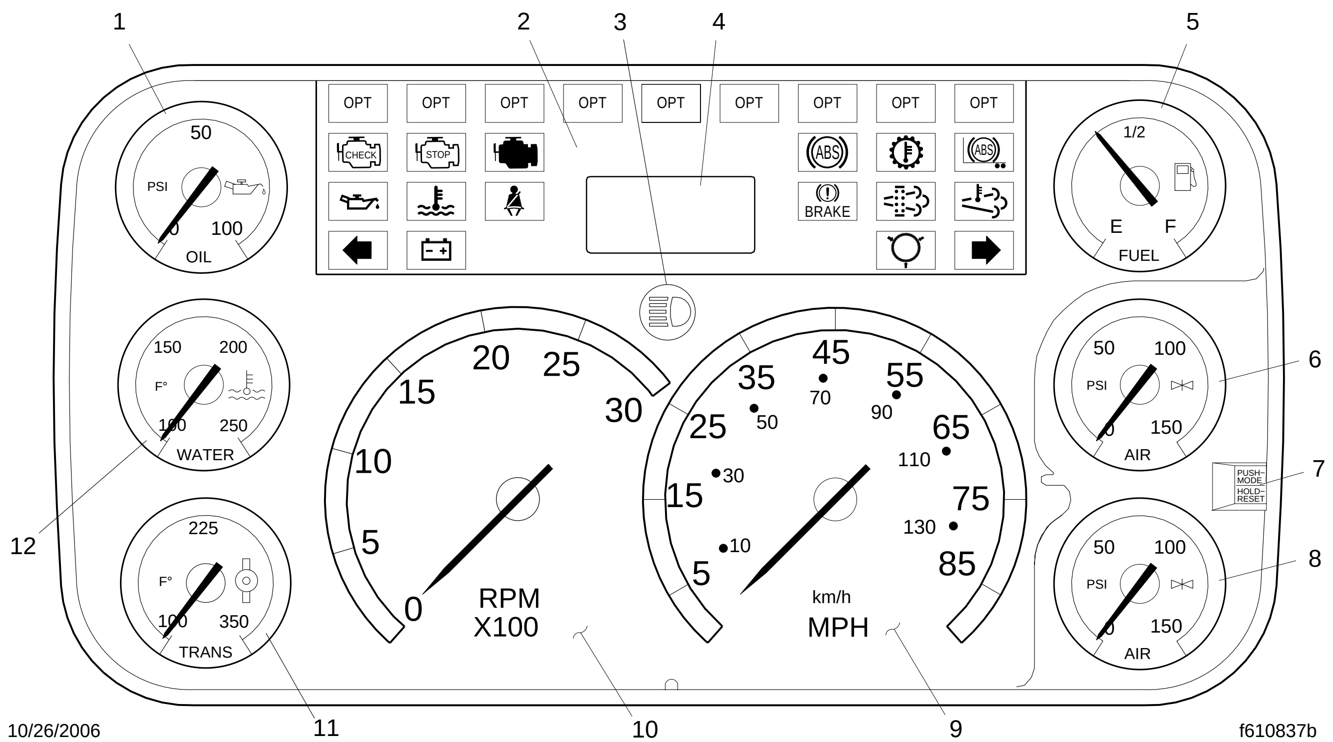
The following gauges are available:

- Speedometer
- Tachometer (optional)
- Engine Oil Pressure
- Coolant Temperature
- Fuel Level
- Transmission Fluid Temperature (optional)
- Primary Air Pressure (optional)
- Secondary Air Pressure (optional)

The transmission fluid temperature gauge is required on vehicles with automatic transmissions.

The speedometer and tachometer are large-faced electronic gauges located below the dash message center. See **Fig. 1**.

The other gauges are small-faced gauges on the driver's instrument panel, on either side of the speedometer and tachometer. The engine oil pressure, coolant temperature, transmission fluid temperature, and fuel level gauges are electronic; the air pressure gauges are mechanical. The ICU3-M2 cannot drive gauges located on the auxiliary instrument panel.



1. Engine Oil Pressure Gauge
2. Dash Message Center
3. Headlight High-Beam Indicator
4. Dash Driver Display Screen
5. Fuel Level Gauge
6. Primary Air Pressure Gauge
7. Mode/Reset Switch
8. Secondary Air Pressure Gauge
9. Speedometer (U.S. version)
10. Tachometer (optional)
11. Transmission Temperature Gauge
12. Coolant Temperature Gauge

Fig. 1, Gauge Layout (typical, U.S.)

General Information

The following items are replaceable:

- air pressure gauges
- mode/reset button
- top row light bulbs
- top row warning and indicator lenses (telltales)

NOTE: The two air pressure gauges and the mode/reset button are one assembly. All three must be replaced at the same time.

Dash Message Center

The dash message center is the heart of the instrument cluster. It has two parts, a set of 26 warning and indicator lights similar to those found on a conventional lightbar, and a dash driver display screen. The driver display screen is a one-line by seven-character liquid crystal display (LCD) that normally shows odometer readings. Below that is a smaller one-line by three-character LCD that shows voltmeter readings.

Information provided by the dash driver display screen includes:

- odometer readings (in miles or kilometers)
- trip and total engine distance
- trip and total engine hours
- service screens
- a listing of active faults

Mode/Reset Switch

The mode/reset switch (located on the right side of the instrument cluster) is used to scroll through the displays on the driver display screen, and to reset the trip distance and trip hours values to zero.

There are two basic functions: the mode function and the reset function. To activate the mode function, press and release the mode/reset switch. This will take you to the next screen in the series. To activate the reset function, press and hold the mode/reset switch for at least one second. In most cases, this will allow you to change the information on that screen. In some cases, this will take you to new screens that give you more information.

When the odometer reading is displayed and the parking brake is applied:

- Press the mode/reset switch once to display the trip odometer.
- Press the mode/reset switch again to display trip engine hours.
- Press the mode/reset switch once more to display the select (SELECt) screen and the current units, MI or KM.
- Press the mode/reset switch once more to display the diagnostic (DiAG) screen. If the vehicle has gone past its next scheduled service, the service screen will appear as an active fault.
- Press the mode/reset switch once more to display total engine miles.
- Press the mode/reset switch once more to display total engine hours.
- Press the mode/reset switch once more to display engine oil level (if the oil level message is enabled).

  NOTE: If the ICU3-M2 senses an oil level message from the MBE900 engine, the oil level screen displays automatically. Otherwise, this screen will not appear.
- Press the mode/reset switch once more to display the setup (SEt UP) screen. The setup screen can be used to reset the service interval.
- Press the mode/reset switch once more to return to the odometer reading.

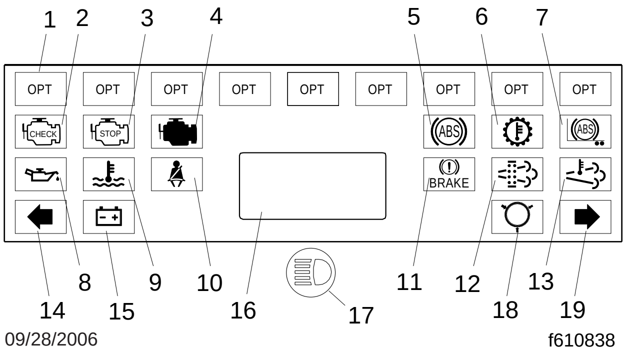
To toggle between MI (miles) or KM (kilometers), go to the select screen and hold the mode/reset switch. To see more information about active faults, go to the diagnostic screen and hold the mode/reset switch.

To reset trip miles and/or trip hours to zero, go to that screen and hold the mode/reset switch. To reset the service interval, and for detailed information about mode/reset switch function, go to the flow charts in **Subject 410**.

Warning and Indicator Lights

The ICU3-M2 has spaces for 26 warning and indicator lights. See **Fig. 2** for a typical installation.

There are four rows of warning and indicator lights. The lights (also called "telltales") in the top row are optional, and may be installed in any order. The light in position 8 (counting left to right across the top row)



1. Optional Indicator
2. Check Engine Indicator
3. Stop Engine Warning
4. Malfunction Indicator Lamp
5. ABS Indicator
6. Check Transmission Indicator
7. Trailer ABS Indicator (not used)
8. Low Oil Pressure Warning
9. High Coolant Temperature Warning
10. Fasten Seat Belt Warning
11. Brake System Warning/Parking Brake On Indicator
12. Diesel Particulate Filter (DPF) Lamp
13. High Exhaust System Temperature (HEST) Lamp
14. Left-Turn Signal Arrow
15. Low Battery Voltage Warning
16. Dash Driver Display Screen
17. Headlight High-Beam Indicator
18. Low Air Pressure Warning
19. Right-Turn Signal Arrow

Fig. 2, Warning and Indicator Lights

is a permanently mounted amber LED. The remaining top row positions use replaceable incandescent lamps.

NOTE: Positions 1 through 8 are ground and datalink-activated circuits; position 9 is power-activated and datalink-activated.

The lights on the other three rows are installed at fixed positions that do not vary. Some lights are optional; if an optional light is not requested, the position is blank (does not light up).

The following fixed-position lights are standard:

- Check Engine Indicator (amber)
- Engine Protection Warning (red)
- Low Air Pressure Warning (red)
- Low Engine Oil Pressure Warning (red)
- High Coolant Temperature Warning (red)
- Fasten Seat Belt Warning (red)
- Low Battery Voltage Indicator (red)
- Parking Brake On Warning (red)
- Tractor ABS Indicator (amber)
- Left Turn Signal (green)
- Right Turn Signal (green)
- High Beams On Indicator (blue)

The following fixed-position lights are optional:

- Air Filter Restriction Indicator (amber)
- Alternator No Charge Indicator (amber)
- High Transmission Temperature Warning (amber)—installed on vehicles with automatic transmissions
- Recirculated Air Indicator (amber)

The following lights are optional and their location may vary anywhere in the top row:

- Stop Engine Warning (red)
- Low Coolant Level Warning (red)
- EBS (Electronic Braking System) Warning (red)
- Check Transmission Indicator (amber)
- Intake Heater Indicator (amber)
- Low Washer Fluid Indicator (amber)
- Optimized Idle Indicator (amber)
- Wait To Start Indicator (amber)
- Water In Fuel Indicator (amber)
- Wheel Spin Indicator (amber)

Other optional lights may be specified.

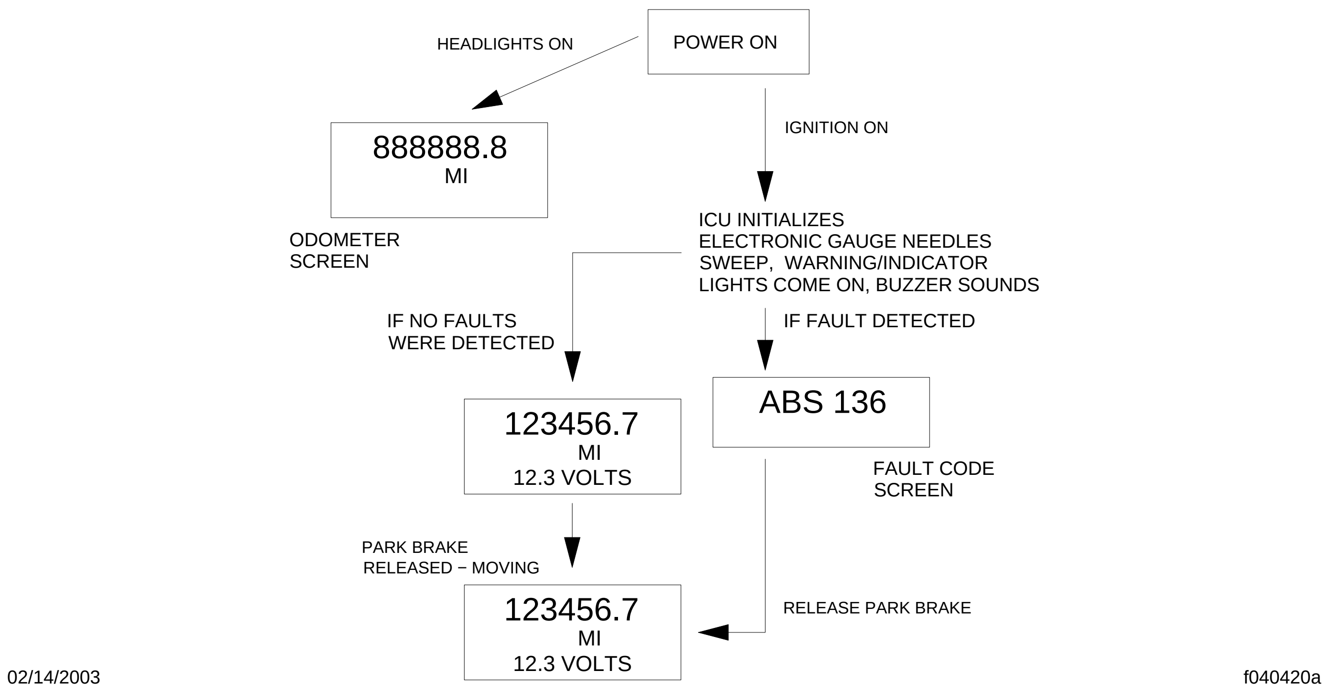
Principles of Operation

Ignition Sequence

When the ignition keyswitch is turned on, the ICU3-M2 runs through the ignition sequence. See Fig. 3. If the headlights are turned on, the screen displays the odometer and waits for the ignition to be turned on.

IMPORTANT: When the ignition keyswitch is first turned on, all the electronic gauges complete a

General Information



During the first half of the self-test, all segments of the display illuminate. During the second half of the self-test, the software revision level is displayed.

NOTE: If there is more than one fault, the ICU3-M2 displays them, one after another, changing every 3 seconds, until the park brake is released.

Fig. 3, ICU3-M2 Ignition Sequence

full sweep of their dials, the warning and indicator lights light up, and the buzzer sounds for 3 seconds.

The following warning and indicator lights go on during the ignition sequence:

- Low Engine Oil Pressure Warning
- High Coolant Temperature Warning
- Low Air Pressure Warning
- Parking Brake On Warning
- Low Battery Voltage Indicator
- Fasten Seat Belt Warning
- All engine warning and indicator lights, including Engine Protection, Check Engine, and Stop Engine
- All ABS warning and indicator lights, including Wheel Spin and Tractor ABS

NOTE: While the engine and ABS warning lights go on during the ignition sequence, they are not controlled by the ICU3-M2, but by their own system ECU (electronic control unit).

Once the ignition keyswitch has been turned on, the ICU performs a self-test, looking for active faults. During the first half of the self-test, all segments of the display illuminate as follows: "888888.8." During the second half of the self-test, the software revision level is displayed.

If there are no active faults, the screen displays the odometer.

If, however, the ICU3-M2 has received active fault codes from other devices, it displays the three-letter acronym and MID number for each for 3 seconds, one after the other, until the parking brake is released or the ignition keyswitch is turned off.

The screen displays a code, called the message identifier (MID), indicating the ECU or system that is not functioning properly.

General Information

NOTE: If the ICU3-M2 receives a message from an ECU that has not been pre-programmed into the ICU's memory, it displays "SYS ###" instead, where ### is replaced by the MID of the broadcasting device.

Once the parking brake is released, the ICU3-M2 displays the odometer again.

Odometer

The odometer is set to display in either miles or kilometers, depending on the primary scale of the speedometer. The legend, either "MI" or "KM," illuminates between the odometer and the volts display when the engine is running or the headlights are turned on.

The odometer is a seven-digit display with a decimal point, until the vehicle has traveled 999,999.9 miles or kilometers (km). At one million miles (km), the odometer rolls over to "1000000," without the decimal point, and can continue up to 9,999,999. The odometer only displays significant figures (no leading zeros).

IMPORTANT: Although the odometer uses data supplied by the engine ECU to update its count, it keeps its own mileage starting from zero, when it was first installed. The ICU odometer may not match the engine ECU odometer. This may occur if the engine has been operated with the ICU disconnected, as may occur during factory break-in or engine service, or if the ICU has been replaced.

Buzzer

The buzzer sounds during the ignition sequence and whenever one of the following conditions exist.

- The engine oil pressure falls below the preset level, which is 5 to 9 psi (35 to 60 kPa) on most engines.
- The coolant temperature rises above the preset level, which is 189°F (87°C) on MBE900 engines, and 215°F (101°C) on Caterpillar engines.
- The air pressure falls below the preset level of approximately 70 psi (483 kPa).
- The parking brake is set with the vehicle moving at a speed greater than 2 miles per hour.
- The J1939 brake failure message is received from the ABS.
- The J1939 heartbeat message is not received from the ABS.

Instrumentation Control Unit (ICU3-M2) Removal and Installation

Removal

The instrumentation control unit (ICU3-M2) is a self-contained one-piece unit, including housing, gauges, and the dash message center. See **Fig. 1**.

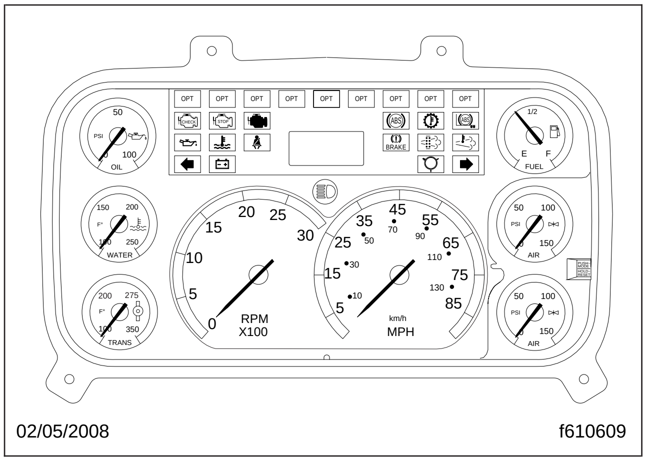


Fig. 1, ICU3-M2

IMPORTANT: The air gauge, mode push button, and some of the bulbs are serviceable. The mode switch is part of the air gauge module, and is replaced as part of that subassembly.

1. Disconnect all negative leads from the batteries.
2. Drain the primary and secondary air tanks.
3. Remove the top steering column (clam-shell) cover.

CAUTION

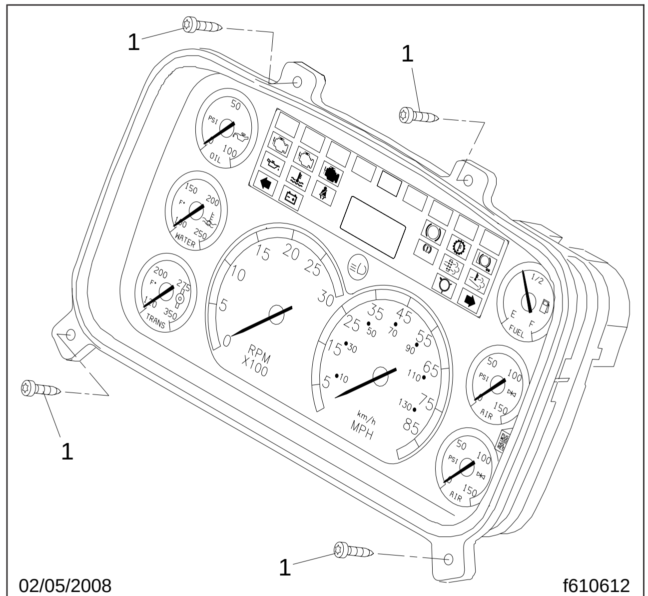
Electronic components of the ICU3-M2 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU3-M2 circuitry.

4. Remove the dash trim piece by removing the Phillips-head screws that secure it.

CAUTION

Do not forcibly pull the ICU3-M2 from the dash. This may dislodge or damage electrical connections or air hoses from the back of the ICU3-M2, or damage the dash.

5. Remove the four screws that secure the ICU. Carefully remove the ICU from the dash. See **Fig. 2**.



1. Phillips-Head Screws

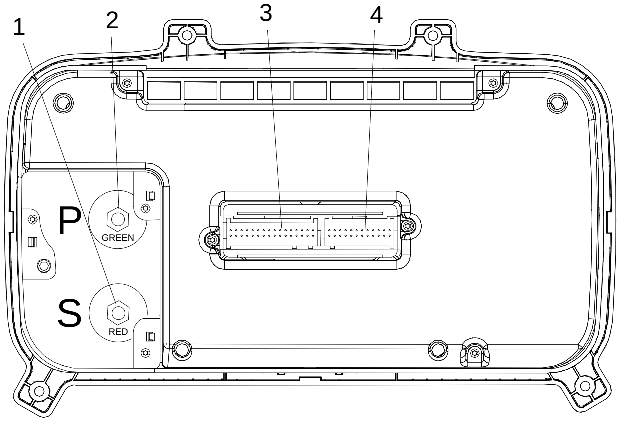
Fig. 2, ICU3-M2 Installation

6. Unplug the two electrical connectors from the back of the ICU. See **Fig. 3**.
7. Remove the air hoses by pressing the push-lock connectors, then pulling the air hoses away from the gauges. The hoses are color-coded for ease of installation. The primary air hose is green and is connected to the upper gauge. The secondary air hose is red and is connected to the lower gauge.

Installation

1. Connect the air hoses to the air gauges by pressing the correct air line firmly into its push-lock connector on the back of the gauge. The primary (upper) gauge connects to the green air line. The secondary (lower) gauge connects to the red air line. See **Fig. 3**.
2. Plug the electrical connectors into the back of the ICU3-M2.

Instrumentation Control Unit (ICU3-M2) Removal and Installation



1. Secondary Air Pressure Gauge
2. Primary Air Pressure Gauge
3. 32-Pin Electrical Connector
4. 24-Pin Electrical Connector

Fig. 3, ICU3-M2, Rear View

3. Place the ICU3-M2 in the dash opening and secure it with the Phillips-head screws. Tighten the screws 30 lbf·in (340 N·cm).
4. Install the dash trim piece and secure it with the Phillips-head screws. Tighten the screws 30 lbf·in (340 N·cm).
5. Connect the negative battery leads.
6. Turn the ignition switch to RUN and test the operation of the cluster. All the electronic gauges should make one complete sweep and return to their normal indicating positions; the warning and indicator lights should turn on, then off.

   If any gauges are not working properly, the ICU3-M2 will need to be serviced or replaced.

NOTE: Mechanical (air) gauges do not make a sweep.

7. Install the top steering column cover.

Replacement

NOTE: The mode/reset switch is part of the air gauge module and is replaced when the air gauges are replaced.

The only replaceable gauges on the ICU3-M2 are the air pressure gauges. If any other gauge fails, the entire unit must be replaced. See **Fig. 1**.

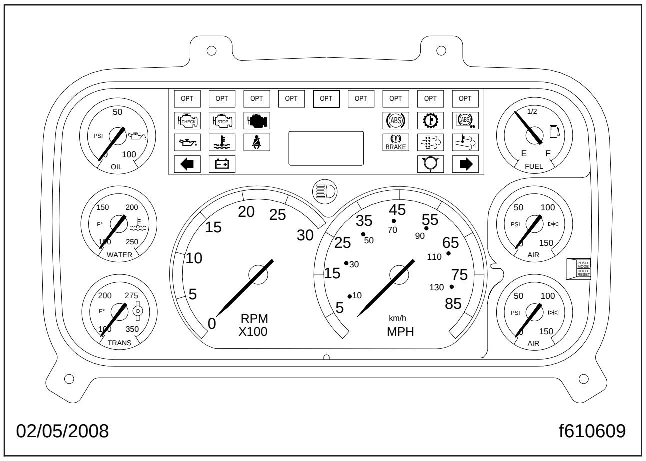


Fig. 1, ICU3-M2

1. Drain the primary and secondary air tanks.

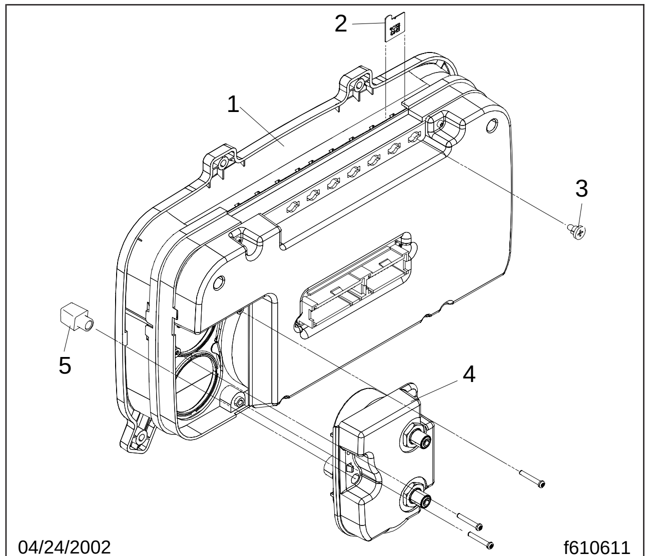
CAUTION

Electronic components of the ICU3-M2 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU3-M2 circuitry.

2. Remove the ICU3-M2 from the dash, including disconnecting the electrical connectors and the air lines. For detailed instructions, see **Subject 100**.

NOTE: Be careful not to damage the ribbon electrical connector or the air gauge needles when removing the air gauge module. The gauge needles are exposed once the module is removed. A thin-ribbon electrical connector connects the air gauge module and the ICU3-M2 housing. Once the fasteners that secure the air gauge module are removed, take care in separating the module from the ribbon electrical connector.

3. Carefully place the ICU3-M2 face down on a smooth surface. Using a Torx 8 screwdriver remove the screws that secure the air gauge module to the ICU. Do not remove the air gauge module cover. See **Fig. 2**.



1. ICU3-M2
2. Telltale
3. Light Bulb
4. Air Gauge Module
5. Mode/Reset Button

Fig. 2, ICU3-M2, Rear View (exploded)

4. Remove the button from the mode/reset switch.
5. Separate the air gauge module slightly from the ICU to allow access to the electrical ribbon that connects the module to the ICU.
6. Remove the electrical connection ribbon from the ICU, not from the air gauge module. Grip the ribbon firmly at each side and lift out, then remove the air gauge module.
7. Place the ICU3-M2 face down on a clean, smooth surface. Placing the unit on a clean towel or cloth will help keep the plastic face from getting scratched during this procedure.
8. Place the air gauge module close to the opening it belongs in and connect the electrical ribbon connector in its slot. Gripping the ribbon end

Air Pressure Gauge Replacement

firmly at the edges, place the ribbon end into the slot and push it straight in until it stops.

9. Place the air gauge module into its opening in the ICU3-M2. Make sure the rubber alignment pin in the ICU cavity lines up with the matching alignment receptacle in the air gauge module when placing the module in the ICU.
10. Install and tighten the screws to secure the air gauge module. See **Fig. 2**.
11. Install the button on the mode/reset switch, as removed.
12. Install the ICU3-M2, including the electrical connectors and the air lines. For detailed instructions, see **Subject 100**.
13. After installing the ICU3-M2, start the engine and verify the proper operation of the air gauge module as the air pressure builds.

Light Bulb/Telltale Replacement

Replacement

The instrumentation control unit (ICU3-M2) is a self-contained one-piece unit, including housing, gauges, and the dash message center. See **Fig. 1**.

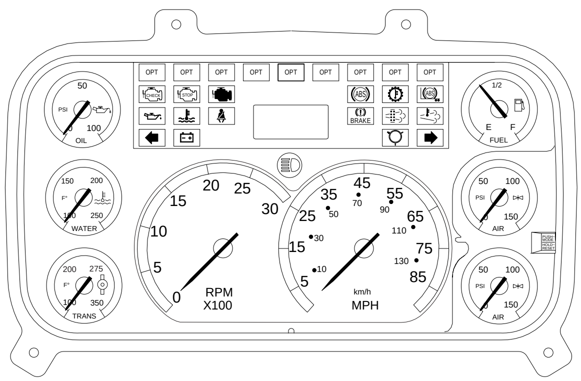


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Fig. 1, ICU3-M2

IMPORTANT: The air gauge, mode push button, and some of the bulbs are serviceable. The mode switch is part of the air gauge module, and is replaced as part of that subassembly.

CAUTION

Electronic components of the ICU3-M2 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU3-M2 circuitry.

NOTE: Since the top-row warning and indicator lights are optional, not all positions in the row may have a bulb and telltale installed.

The nine top-row warning and indicator bulbs are all replaceable except for the bulb in position 8, counting left to right; the bulb in that position is a permanent LED. The replaceable light bulbs are incandescent.

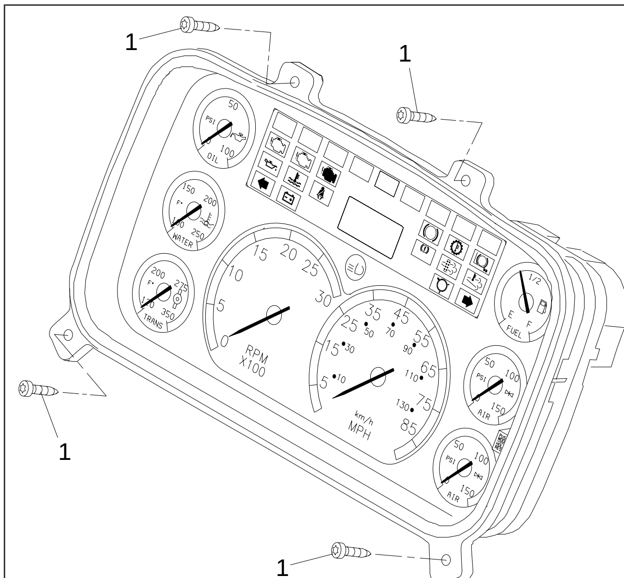
The term "telltale" refers to the small plastic bezel in the top row with a warning or indicator message printed on it. These are also replaceable.

1. Remove the dash trim piece by removing the Phillips-head screws that secure it.

CAUTION

Do not forcibly pull the ICU3-M2 from the dash. This may dislodge or damage electrical connections or air hoses from the back of the ICU3-M2, or damage the dash.

2. Remove the four screws that secure the ICU. Carefully remove the ICU from the dash. See **Fig. 2**.



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1. Phillips-Head Screws

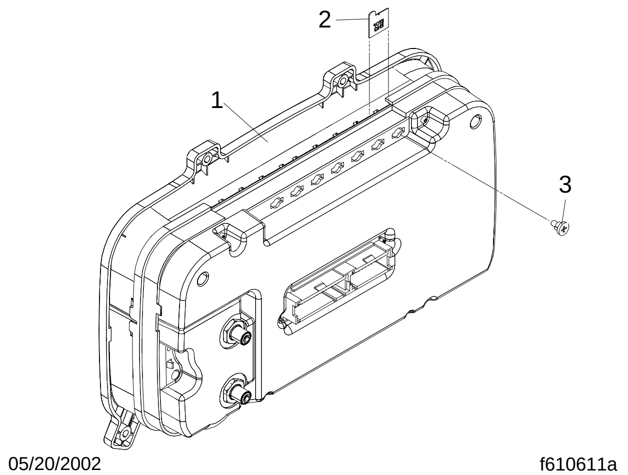
Fig. 2, ICU3-M2 Installation

3. Carefully pull the unit forward to access the top row of replaceable light bulbs and telltales. Take care not to scratch the clear plastic front of the unit. Placing a clean towel over the front of the unit before pulling it forward may help prevent scratches.

To Replace Light Bulbs

1. Use a small screwdriver or flat blade to twist out the bulb by its base behind the affected telltale. Turn the bulb 1/4 turn and remove. See **Fig. 3**.
2. Place a good bulb in the opening and twist 1/4 turn to install.

Light Bulb/Telltale Replacement



NOTE: For clarity, air gauge and electrical connections are shown removed.

1. ICU3-M2
2. Telltale
3. Light Bulb

Fig. 3, ICU3-M2, Rear View (exploded)

To Replace Telltales

1. Using a pair of needlenose pliers or a similar tool, grab the exposed tab at the top of the telltale slot and carefully pull the telltale out from the top of the ICU. See **Fig. 3**.
2. Place the telltale in its correct slot the same way it was removed. Properly orient the telltale so the text is readable from the front, then grab the top tab of the telltale and slide it into the slot.

Turn on the ignition keyswitch. Check all bulbs and telltales for correct operation.

See **Table 1** for an ICU symptom chart.

ICU Symptom Chart	
Problem	**Where to Begin Diagnosis**
Gauges (except air pressure gauges) are not working or are inaccurate.	See **Table 2** for initial gauge test procedures.
Single-datalink-driven gauge is not working or is inaccurate.	See **Table 3** to diagnose the single-datalink-driven gauge.
Multiple-datalink-driven gauges are not working or are inaccurate.	See **Table 4** to diagnose multiple-datalink-driven gauges.
Air pressure gauges are not working or are inaccurate.	See **Table 5** for air pressure gauge diagnosis.
Fuel gauge is not working or is inaccurate.	See **Table 6** for fuel gauge diagnosis.
Transmission temperature gauge is not working or is inaccurate.	See **Table 7** for transmission temperature gauge diagnosis.
Active ICU fault codes (MID 140) are inaccurate.	See **Table 8** for ICU3-M2 fault code (MID 140) diagnosis.
Backlighting is not working.	See **Table 9** for gauge backlighting diagnosis.
Mode/Reset button is not working.	See **Table 10** for Mode/Reset button diagnosis.
The parking brake and ABS warning lights stay on with the key off.	Feedback in the ignition circuit is providing power to the ICU while the key is off. Isolate the source of this feedback and repair as necessary.
LCD displays seven hyphens.	Indicates a program memory failure. Fault code 140 s240 12 may be active in Servicelink. See **Table 8**, "ICU3-M2 Fault Code (MID 140) Diagnosis" for more information. This failure requires replacement of the ICU.
LCD displays "no Eng” or "no ABS."	These are roll call faults indicating the engine or ABS is not detected by the ICU on the J1587 datalink. This does not indicate an ICU problem, nor does it indicate a J1587 datalink problem to the ICU.
LCD displays "no data."	The ICU is unable to detect any data on the J1587 datalink. If the ICU is the only ECU not showing up in the Servicelink ECU list, check J1587 datalink to ICU. If no ECUs show up in the Servicelink ECU list, the problem could be anywhere in the J1587 datalink—troubleshoot accordingly.
LCD displays "no J1939."	The ICU is unable to detect any data on the J1939 datalink. Use the "M2 J1939 Test" Datalink Monitor template in Servicelink to troubleshoot. If only the ICU is not communicating, then check the J1939 branch circuit to the ICU. If no ECUs are communicating, the problem could be anywhere in the J1939 datalink—troubleshoot accordingly.
The "No Charge" light stays on after replacing the bulkhead module.	Apply reference parameter 26-01001-000 to the bulkhead module.

Table 1, ICU Diagnosis Symptom Chart

Troubleshooting

Initial Test Gauge Procedure			
Test	**Test Description**	**Test Result**	**Action**
1	Turn the ignition on. All the gauges, except air pressure gauges, should sweep full scale and back in unison. Do the gauges sweep correctly when the ignition is turned on?	Yes	Go to test 3.
		No	Go to test 2.
2	Check the power and ground to the ICU. • +12V Battery on D14 • +12V Ignition on D15 • Ground on D13 Are the power and ground supplies OK?	Yes	Replace the ICU.
		No	Repair the power and/or ground supply as necessary.
3	Are any engine fault codes active (MID 128)?	Yes	Correct any active engine fault codes first. If the gauge problem is still present, go to test 4.
		No	Go to test 4.
4	Are any ICU fault codes active (MID 140)?	Yes	See **Table 8** – ICU3-M2 Fault Code (MID 140) Diagnosis.
		No	Go to test 5.
5	Which gauge(s) has a problem? NOTE: Datalink-driven gauges include the following: speedometer, tachometer, engine oil pressure, and engine coolant temperature.	Single-datalink-driven gauge	See **Table 3** – Diagnosis for Single-Datalink-Driven Gauge Not Working or is Inaccurate.
		Multiple-datalink-driven gauges	See **Table 4** – Diagnosis for Multiple-Datalink-Driven Gauges Not Working.
		Air pressure gauge	See **Table 5** – Air Pressure Gauge Diagnosis.
		Fuel level gauge	See **Table 6** – Fuel Gauge Diagnosis.
		Transmission temperature	See **Table 7** – Transmission Temperature Gauge Diagnosis.

Table 2, Initial Test Gauge Procedure

Diagnosis for Single-Datalink-Driven Gauge not Working or is Inaccurate			
Test	Test Description	Test Result	Action
1	Connect Servicelink and open the "ICU3-M2 J1587 Gauges" Datalink Monitor template. Make sure the operating conditions are such that the gauge would be registering (e.g. engine at operating temperature). Start the engine. NOTE: A test drive may be necessary if diagnosing the speedometer. Do the readings closely match?	Yes	Go to test 2.
		No	Replace the ICU.
2	Which best describes the problem with the ICU gauge?	Gauge not working	Check the sensor that the engine ECM uses to supply data to the ICU (e.g. if the oil pressure gauge is not working, check the oil pressure sensor and wiring). Refer to engine manufacturer’s service information if necessary.
		Gauge inaccurate	Go to test 3.
3	It is necessary to independently verify the gauge accuracy. For the speedometer, drive the vehicle with another vehicle pacing to note the speed or monitor the ABS wheel speed sensors using Meritor Toolbox. For engine coolant temperature and oil pressure, it may be necessary to connect a mechanical gauge. For the tachometer, it will be necessary to use a tool that measures engine speed. Does the independent verification confirm the ICU gauge is inaccurate?	Yes	Check the sensor the engine ECM uses to supply data to the ICU (e.g. if the oil pressure gauge is inaccurate, check the oil pressure sensor). Refer to the engine manufacturer’s service information if necessary.
		No	No problem found.

Table 3, Diagnosis for Single-Datalink-Driven Gauge not Working or is Inaccurate

Diagnosis for Multiple Datalink-Driven Gauges Not Working			
Test	Test Description	Test Result	Action
1	Connect Servicelink to the vehicle. Will Servicelink connect?	Yes	Go to test 2.
		No	Assuming Servicelink and the vehicle adapter are functioning, check the J1587 datalink for shorts or opens. Repair as necessary.
2	Does the engine ECM (MID 128) show up in the Servicelink J1708 ECU list?	No	Go to test 3.
		Yes	Check the J1587 datalink to the engine ECM. If OK, see engine OEM’s literature for further diagnosis.

Troubleshooting

Diagnosis for Multiple Datalink-Driven Gauges Not Working			
Test	**Test Description**	**Test Result**	**Action**
3	Does the ICU3-M2 (MID 140) show up in the Servicelink J1708 ECU list?	No	Go to test 4.
		Yes	Check the J1587 datalink to the ICU, repair as necessary. If OK, replace the ICU.
4	In Servicelink, open the ICU3-M2 Datalink Monitor template. Start the engine. Make sure the operating conditions are such that the gauge would be registering (e.g. engine at operating temperature). NOTE: A test drive may be necessary if diagnosing the speedometer. Monitor the problem gauges on both the ICU and on the template. Do the affected gauges function in the template?	Yes	Replace the ICU.
		No	Refer to engine OEM service literature for further diagnosis.

Table 4, Diagnosis for Multiple-Datalink-Driven Gauges Not Working

Air Pressure Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Which air pressure gauge is not functioning correctly?	Primary or secondary	Go to test 2.
		Application	Go to test 3.
		Suspension	Go to test 4.
2	Drain the air tanks. Connect an accurate pressure gauge to the primary or secondary air tank (whichever one corresponds with the problem gauge). Start the engine and build air pressure until the compressor cuts out. Is the air pressure gauge in the cluster within 6 psi of the test gauge?	Yes	The gauge is OK.
		No	Check the air line to gauge for kinks. If OK, replace the air pressure gauge module.
3	Connect an accurate pressure gauge to a delivery port on the foot valve. Make a 90 psi brake application while observing the application air pressure gauge in the cluster and the test gauge. Is the air pressure gauge in the cluster within 3 psi of the test gauge?	Yes	The gauge is OK.
		No	Check the air line to gauge for kinks. If OK, replace the gauge.

Air Pressure Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
4	Connect an accurate pressure gauge to the air suspension. Is the air pressure gauge in the cluster within 3 psi of the test gauge?	Yes	The gauge is OK.
		No	Check the air line to gauge for kinks. If OK, replace the gauge.

Table 5, Air Pressure Gauge Diagnosis

Fuel Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Is there an accuracy problem with the gauge? NOTE: A "YES" answer means the gauge registers, but does not read accurately. A "NO" answer means the gauge is not working and registers empty all the time except during the ignition power on sweep.	Yes	Go to test 3.
		No	Go to test 2.
2	Disconnect the fuel level sender connector. Apply 30 ohms across the terminals on the fuel level sender harness connector. Turn the ignition on. Does the fuel gauge read to the FULL mark or slightly above?	Yes	Make sure there is fuel in the tank for the gauge to register. If there is, replace the fuel level sender.
		No	Check the wiring between the fuel level sender and the ICU. If a problem is found, repair as necessary. If the wiring is OK, replace the ICU.
3	Disconnect the fuel level sender connector. Apply 30 ohms across the terminals on the fuel level sender harness connector. Turn the ignition on. Does the fuel gauge read to the FULL mark or slightly above?	Yes	Go to test 4.
		No	Check circuits 47 and 47G between the ICU and the fuel level sender for excess resistance. If none is found, replace the ICU.
4	Apply 103 ohms across the terminals on the fuel level sender harness connector. Turn the ignition on. Does the fuel gauge read approximately 1/2 full (within about 2 needle widths above or below 1/2 full)?	Yes	The fuel level gauge and the wiring between the ICU and the sender is functioning normally. If the fuel level displayed on the gauge is still suspected to be inaccurate, check the fuel level sender.
		No	Check circuits 47 and 47G between the ICU and the fuel level sender for excess resistance. If none is found, replace the ICU.

Table 6, Fuel Gauge Diagnosis

Troubleshooting

Transmission Temperature Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	What best describes the problem with the transmission oil temperature gauge?	Reads minimum scale all the time	Go to test 2.
		Reads maximum scale all the time	Go to test 3.
		Reads inaccurate	Go to test 4.
2	Disconnect the transmission oil temperature sensor connector. Short the terminals on the transmission oil temperature sensor harness connector. Turn the ignition on. Does the transmission oil temperature gauge now read full scale (350°F / 177°C)?	Yes	Replace transmission temperature sensor.
		No	Check circuits 30 and 30G between the ICU and the transmission oil temperature sensor; there may be an open in one of these circuits. If the wiring is OK, replace the ICU.
3	Disconnect the transmission oil temperature sensor connector. Turn the ignition on. Does the transmission oil temperature gauge now read minimum scale?	Yes	Replace transmission temperature sensor.
		No	Check circuits 30 and 30G between the ICU and the transmission oil temperature sensor; circuit 30 may be shorted to ground or circuit 30 and 30G may be shorted together. If the wiring is OK, replace the ICU.
4	Disconnect the transmission oil temperature sensor. Now, apply 267 ohms across the terminals on the transmission oil temperature sensor harness connector. Turn the ignition on. Does the transmission oil temperature gauge read approximately 2 needle widths above or below 275°F (135°C)?	Yes	The transmission oil temperature gauge and the wiring between the ICU and the sensor are functioning normally. If the temperature displayed on the gauge is still suspected to be inaccurate, check the transmission oil temperature sensor.
		No	Check circuits 30 and 30G between the ICU and the transmission oil temperature sensor for excess resistance. If none is found, replace the ICU.

Table 7, Transmission Temperature Gauge Diagnosis

ICU3-M2 Fault Code (MID 140) Diagnosis				
MID	**PID/SID**	**FMI**	**Fault Description**	**Action**
140	p168	01	"ICU3-M2 low voltage—less than 10.5 volts."	Check the power and ground circuits to the ICU and repair as necessary. If OK, check vehicle batteries and charging system.
	s240	12	"ICU3-M2 program memory failure—odometer read/write to EEPROM fails." NOTE: When this failure occurs, the ICU will be unable to display the fault on the LCD, but the fault will display in Servicelink. However, when this fault is active, the LCD display will show a series of seven hyphens.	Replace ICU.
	s254	12	"ICU3-M2 Controller Failure—ICU self test detects checksum errors."	Replace ICU.

Table 8, ICU3-M2 Fault Code (MID 140) Diagnosis

Gauge Backlighting Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Is only the air pressure gauge backlighting affected?	Yes	Go to test 2.
		No	Go to test 3.
2	Remove the three air gauge module screws and carefully lift the air gauge module off the back of the ICU while leaving the ribbon cable connected. Inspect the ribbon cable connection to the ICU PC board. Make sure there is no corrosion and that it is plugged in all the way. Is the ribbon cable connection OK?	Yes	Replace the air pressure gauge module.
		No	Repair the ribbon cable connection as necessary.
3	Access the back of the ICU and disconnect the two electrical connectors. Turn the headlights on. Measure voltage in pins A1(+) and D3(–) while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (full dim) and 11.3V (full bright). Is the backlighting voltage OK?	Yes	Replace the ICU.
		No	Go to test 4.

Troubleshooting

Gauge Backlighting Diagnosis			
Test	Test Description	Test Result	Action
4	Access the back of the ICU and disconnect the two electrical connectors. Turn the headlights on. Measure voltage in pins A1(+) and a known good ground while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (full dim) and 11.3V (full bright). Is the backlighting voltage OK?	Yes	Repair the backlighting ground circuit to ICU pin D3 as necessary.
		No	Check circuit 29A between the BHM and the ICU. If OK, check dimmer switch and BHM. Repair as necessary.

Table 9, Gauge Backlighting Diagnosis

Mode/Reset Button Diagnosis			
Test	Test Description	Test Result	Action
1	Does the mode reset button stick or fail to spring back when released?	Yes	Replace the air pressure gauge module.
		No	Go to test 2.
2	Remove the three air gauge module screws and carefully lift the air gauge module off the back of the ICU. Leave the ribbon cable connected. Inspect the ribbon cable connection to the ICU PC board. Make sure there is no corrosion and that it is plugged in all the way. Is the ribbon cable connection OK?	Yes	If the mode/reset button is not working and the ribbon cable connection is OK, replace the air gauge module.
		No	Repair the ribbon cable connection as necessary.

Table 10, Mode/Reset Button Diagnosis

Specifications

The two ICU3-M2 main cab harness connectors are pink and plug into pins located in the center of the unit, on the back. Connector #1 has 24 cavities, numbered A1 through A12, and B1 through B12. See **Table 1**.

Connector #2 has 32 cavities, numbered C1 through C16, and D1 through D16. See **Table 2**.

See **Table 3** for Message Identifiers (MIDs).

See **Table 4** for fuel level sensor resistance.

See **Table 5** for transmission oil temperature sensor resistance, standard gauge.

See **Table 6** for transmission oil temperature sensor resistance, metric gauge.

ICU3-M2 Connector #1 Pin Assignments, Pins A1 Through B12		
Pin	**Description**	**Wire**
A1	Panel Backlight Power (+)	29A
A2	Multifunction Switch Windshield Wiper Input	473C
A3	Low Air Pressure Input	18B
A6	Traction Control Switch (Optional Indicator #2)	376T
A7	Preheater Relay #1 Coil Signal (Optional Indicator #3)	431B1
B1	Wheel Spin Warning Lamp (Optional Indicator #5)	376S
B3	J1708 Network (–)	1587–
B5	Multifunction Switch Common Input	473
B6	Multifunction Switch Turn Signal Input	473A
B7	Multifunction Switch High Beam/Washer Input	473B
B9	Cruise Control Switch Input	440D
B10	J1708 Network (+)	1587+
B11	Tractor ABS Indicator	376L

Table 1, ICU3-M2 Connector #1 Pin Assignments, Pins A1 Through B12

ICU3-M2 Connector #2 Pin Assignments, Pins C1 Through D16		
Pin	**Description**	**Wire**
C1	Do Not Shift Warning Lamp (Optional Indicator #8)	E115
C5	Park Brake Indicator	125S
C11	Wheel Spin Warning Lamp (Optional Indicator #7)	376S
C12	Transmission Oil Temperature (–)	30G
C13	Transmission Oil Temperature (+)	30
C15	Check Engine Warning Lamp	440A
C16	Engine Protection Warning Lamp	440S
D1	Fuel Level (+)	47
D2	Fuel Level (–)	47G
D3	Panel Backlight Ground (–)	GND
D5	J1939 (+)	1939+

Specifications

ICU3-M2 Connector #2 Pin Assignments, Pins C1 Through D16		
Pin	**Description**	**Wire**
D9	J1939 (–)	1939–
D12	Trailer ABS Warning Lamp	376F1
D13	PC Board Ground (–)	GND
D14	Battery Power (+)	81
D15	Ignition Power (+)	81C
D16	Headlamp Power (+)	81C

Table 2, ICU3-M2 Connector #2 Pin Assignments, Pins C1 Through D16

Message Identifiers (MIDs)		
MID	**Description**	**Text Message**
128	Engine Control Unit	ECU128
130	Transmission Control Unit	tCU130
136	Antilock Brake System (ABS)	AbS136
140	Instrumentation Control Unit	ICU140
181	Satellite Communications	SAT181
219	Collision Detection Unit	CdU219
223	Transmission Shift Unit	tSU223
231	Cellular Phone	CEL231
232	SPACE (Seat Belt Unit)	SbU232
###	Generic MID	SYS###

Table 3, Message Identifiers (MIDs)

Fuel Level Sensor Resistance (Stewart-Warner)		
Gauge Reading	**Sensor Resistance: ohms**	
	Acceptable Range	**Nominal**
Empty	244.0 to 249.0	246.5
Empty Stop	232.0 to 239.2	235.6
1/8	190.8 to 196.9	193.8
1/4	149.6 to 154.5	152.1
3/8	126.1 to 129.0	127.5
1/2	102.5 to 103.5	103.0
5/8	84.4 to 85.7	85.0
3/4	66.2 to 67.8	67.0
7/8	47.8 to 49.2	48.5
Full	29.4 to 30.6	30.0

Table 4, Fuel Level Sensor Resistance (Stewart-Warner)

Transmission Oil Temperature Sensor (Hi-Stat) Resistance Standard Gauge (ºF)	
Gauge Temperature: ºF	**Sensor Resistance: ohms**
125	3318
163	1626
200	837
238	460
275	267
313	162
350	102

Table 5, Transmission Oil Temperature Sensor (Hi-Stat) Resistance Standard Gauge (ºF)

Transmission Oil Temperature Sensor (Hi-Stat) Resistance Metric Gauge (ºC)	
Gauge Temperature: ºC	**Sensor Resistance: ohms**
60	2490
80	1255
100	680
120	390
140	234
160	145
180	95

Table 6, Transmission Oil Temperature Sensor (Hi-Stat) Resistance Metric Gauge (ºC)

Mode/Reset Switch Functions

Use the following flow charts to cycle through the Mode/Reset switch functions and screens.

See **Fig. 1** for the start sequence. See **Fig. 2** for the trip miles and hours screens, and **Fig. 3** for the engine miles and service interval setup screens.

See **Fig. 4** for the fault code screens, and **Fig. 5** for the service hour screens. See **Fig. 6** for the oil level screens, and **Fig. 7** for the reset and toggle function screens.

Mode/Reset Switch Functions

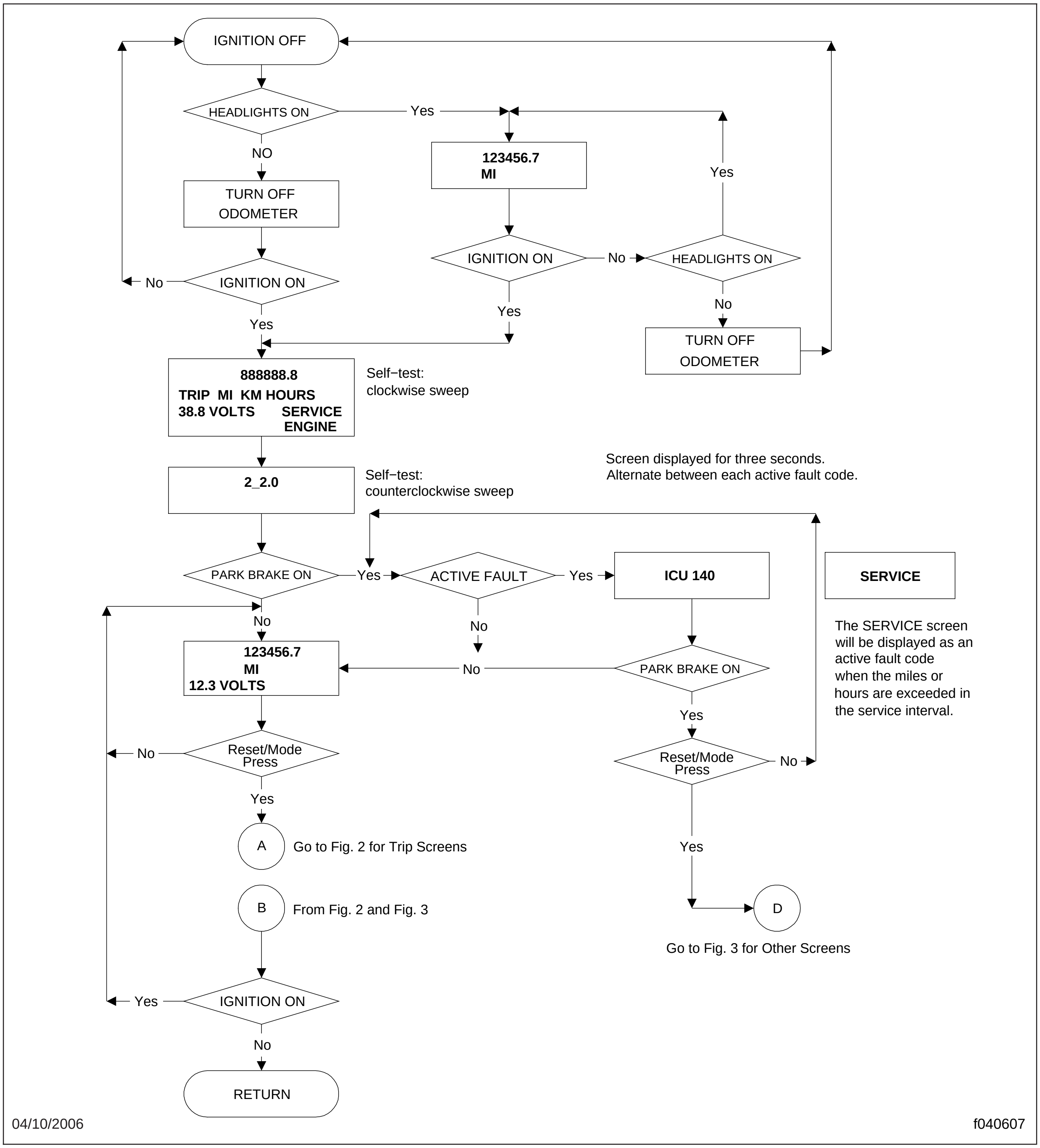


Fig. 1, Start Sequence

Mode/Reset Switch Functions

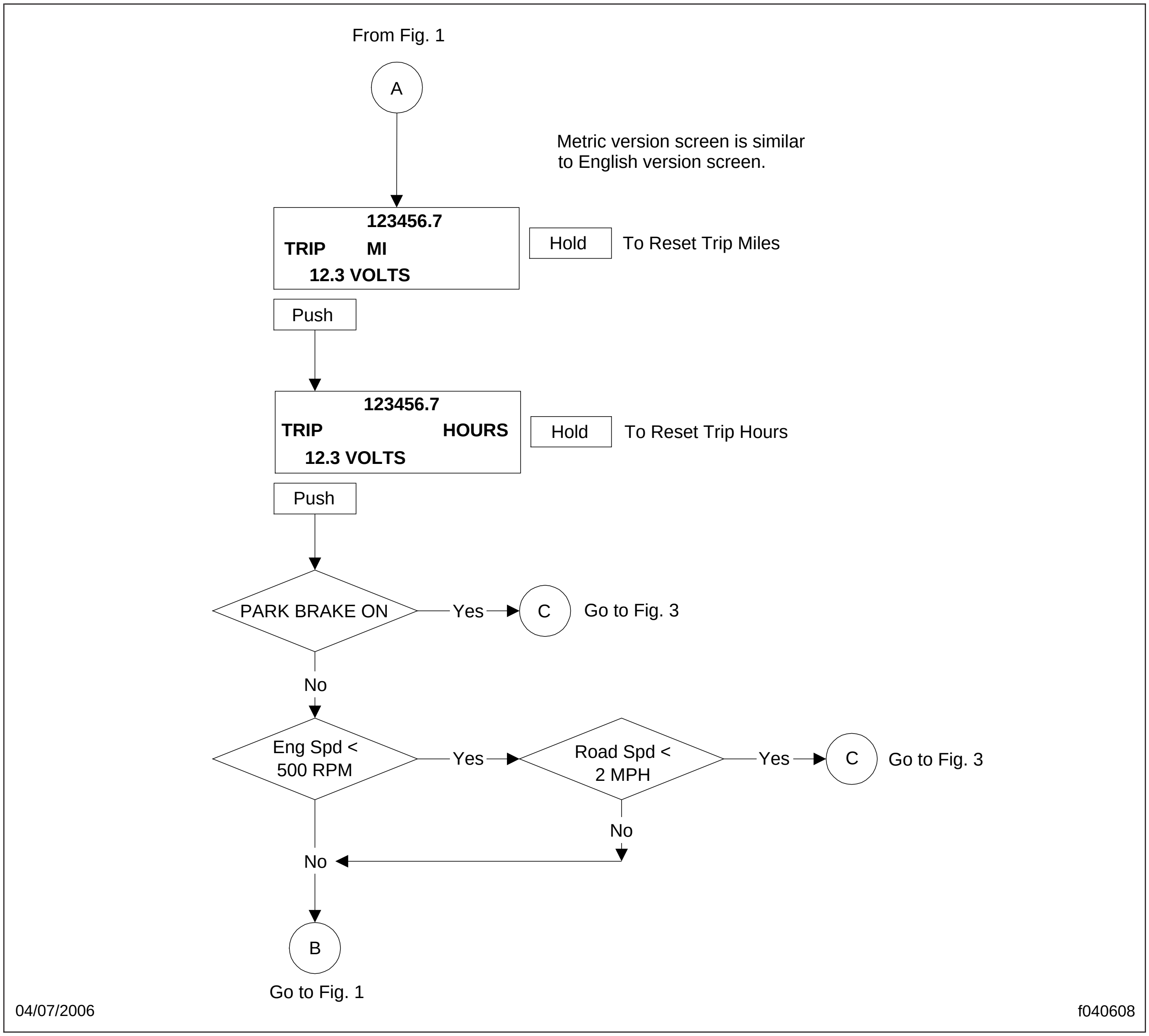


Fig. 2, Trip Screens

Mode/Reset Switch Functions

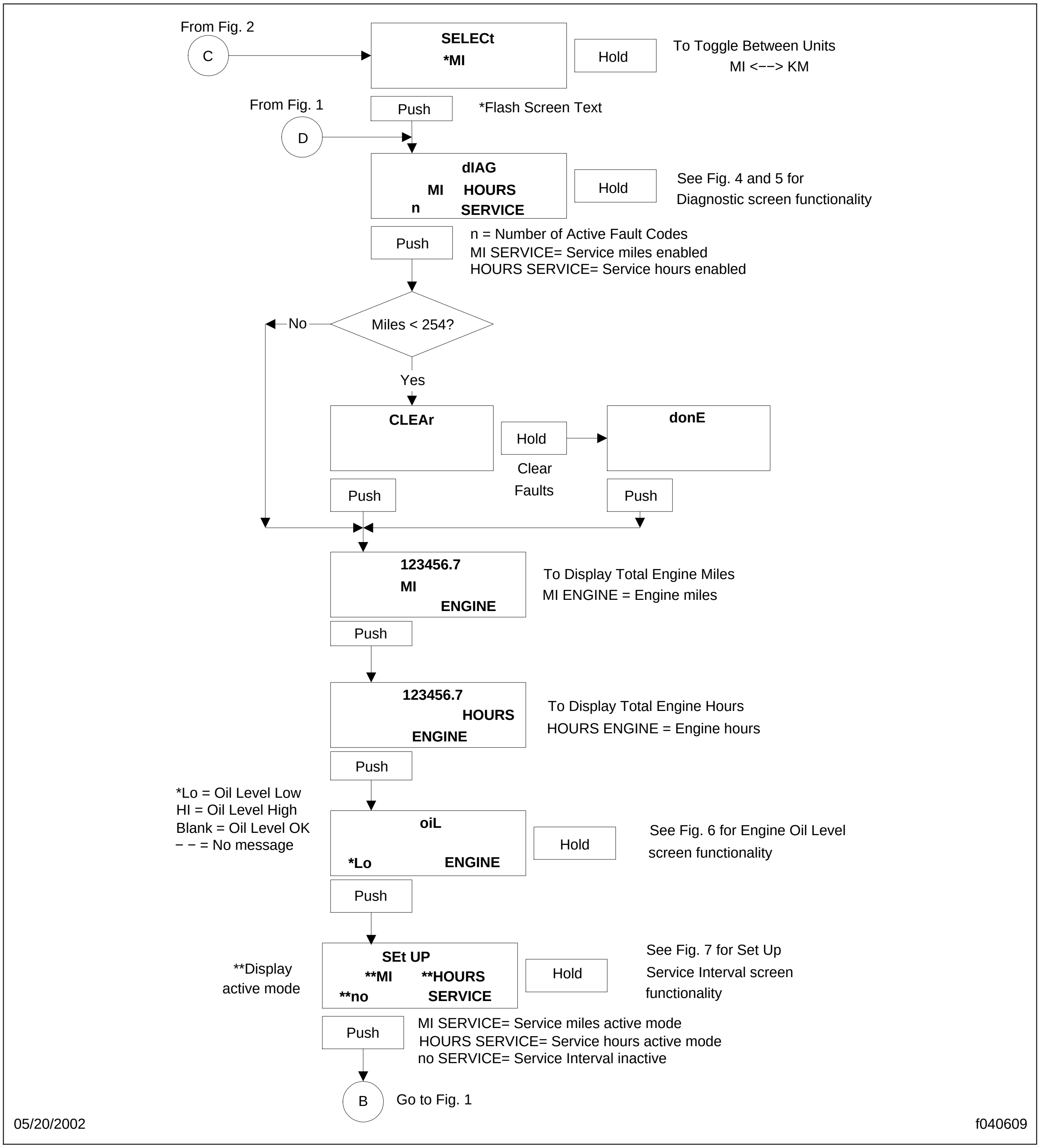


Fig. 3, Engine Miles and Service Interval Setup Screens

Mode/Reset Switch Functions

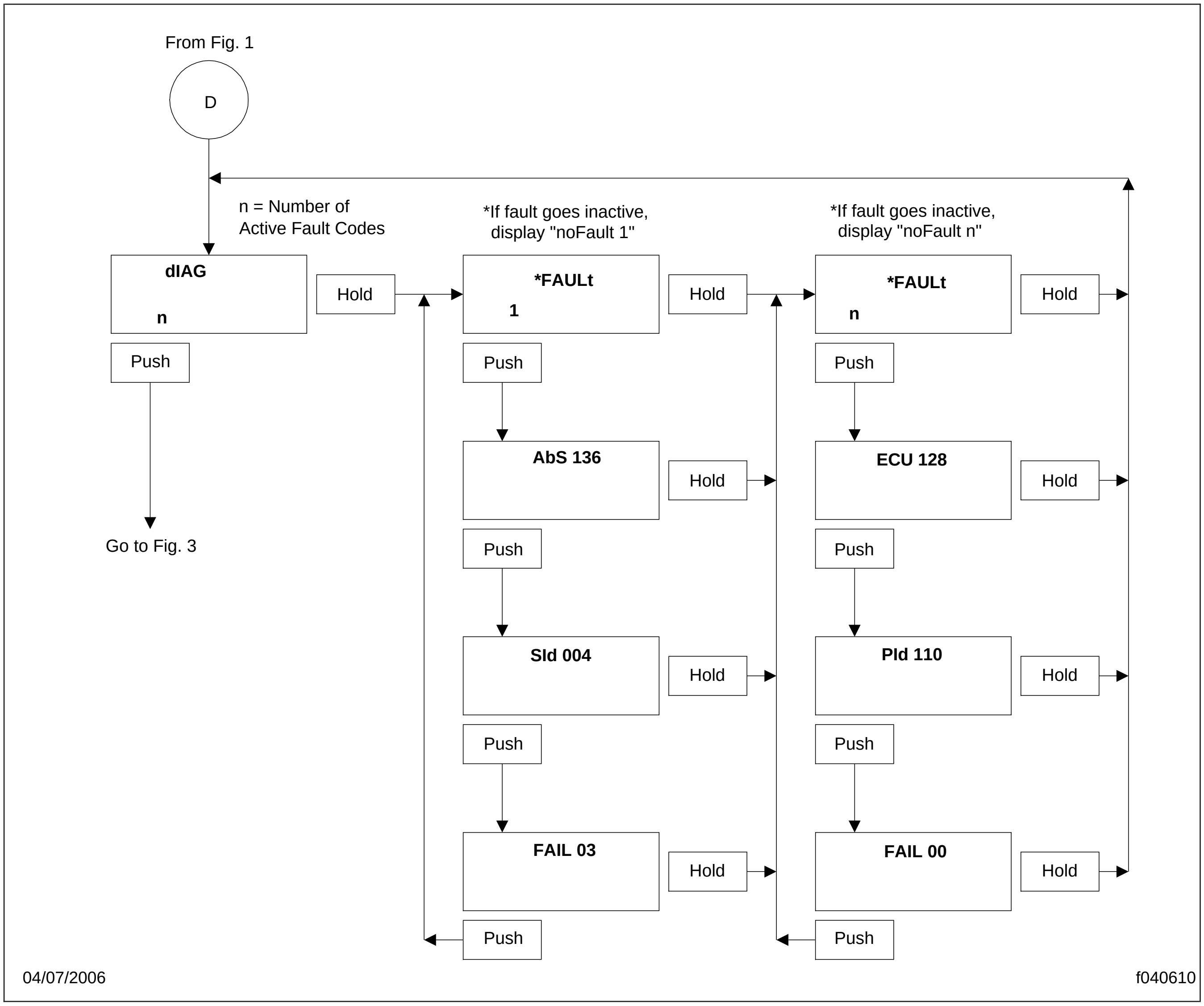


Fig. 4, Fault Screens

Mode/Reset Switch Functions

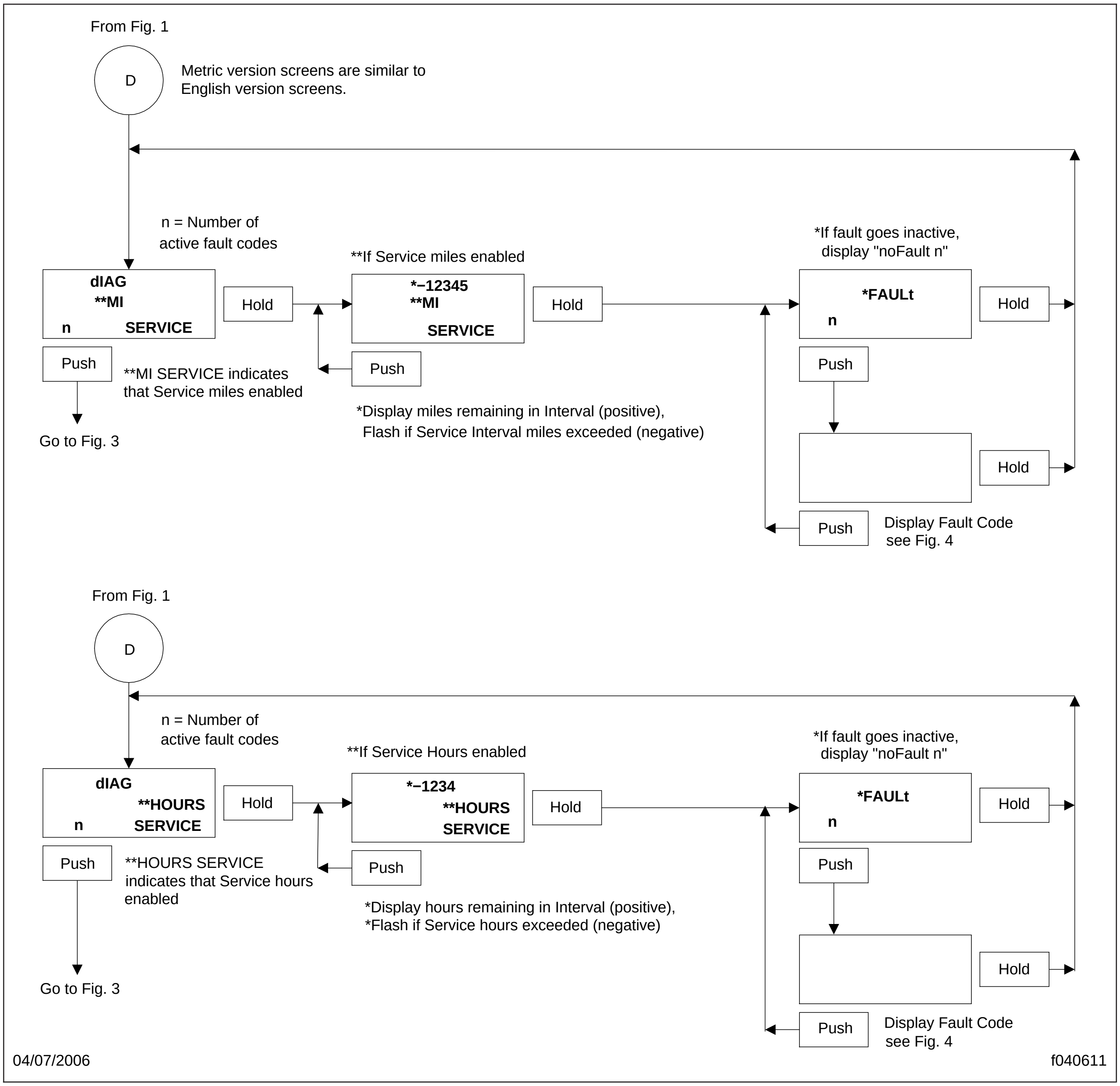


Fig. 5, Service Hour Screens

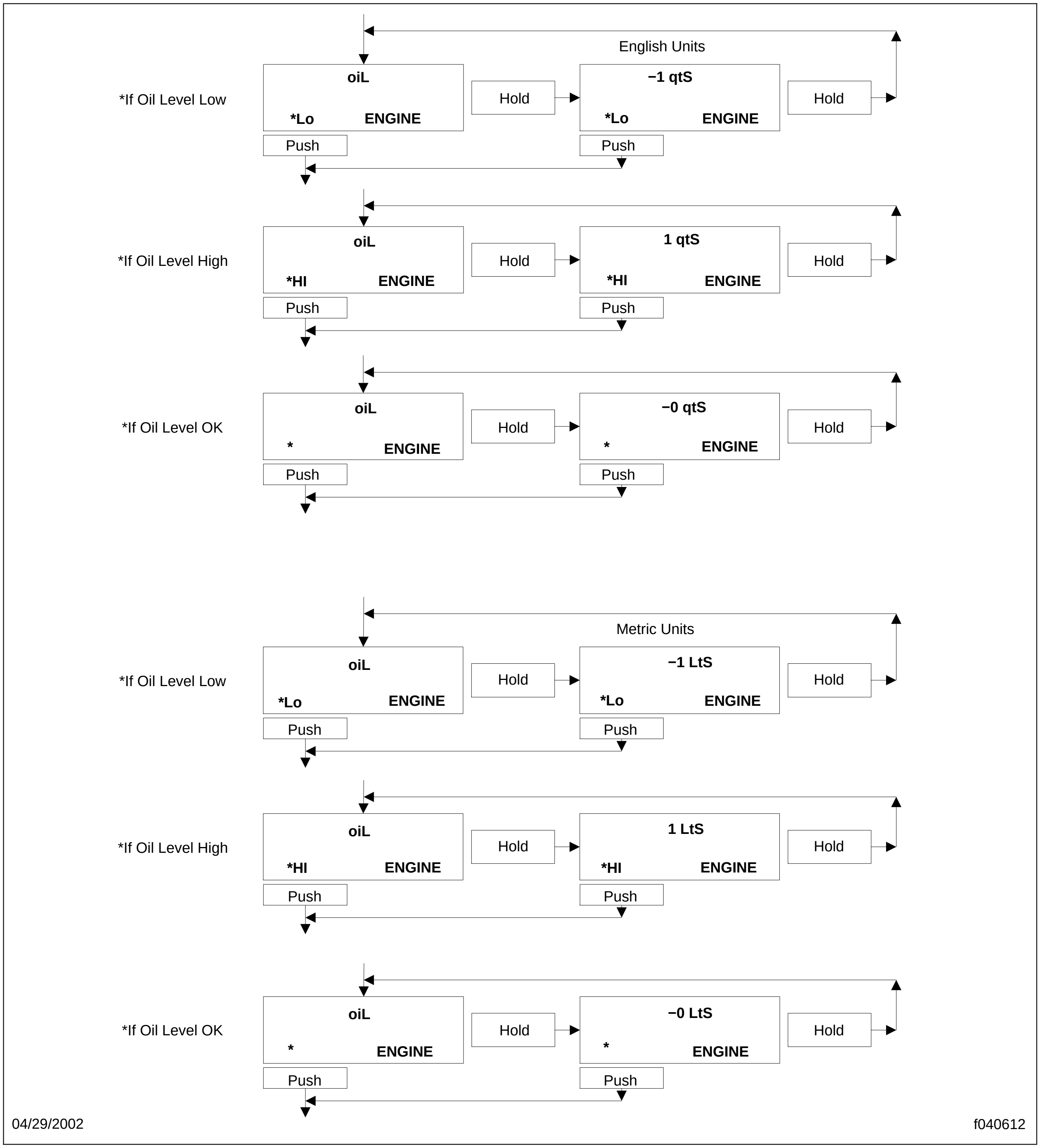


Fig. 6, Oil Level Screens

Mode/Reset Switch Functions

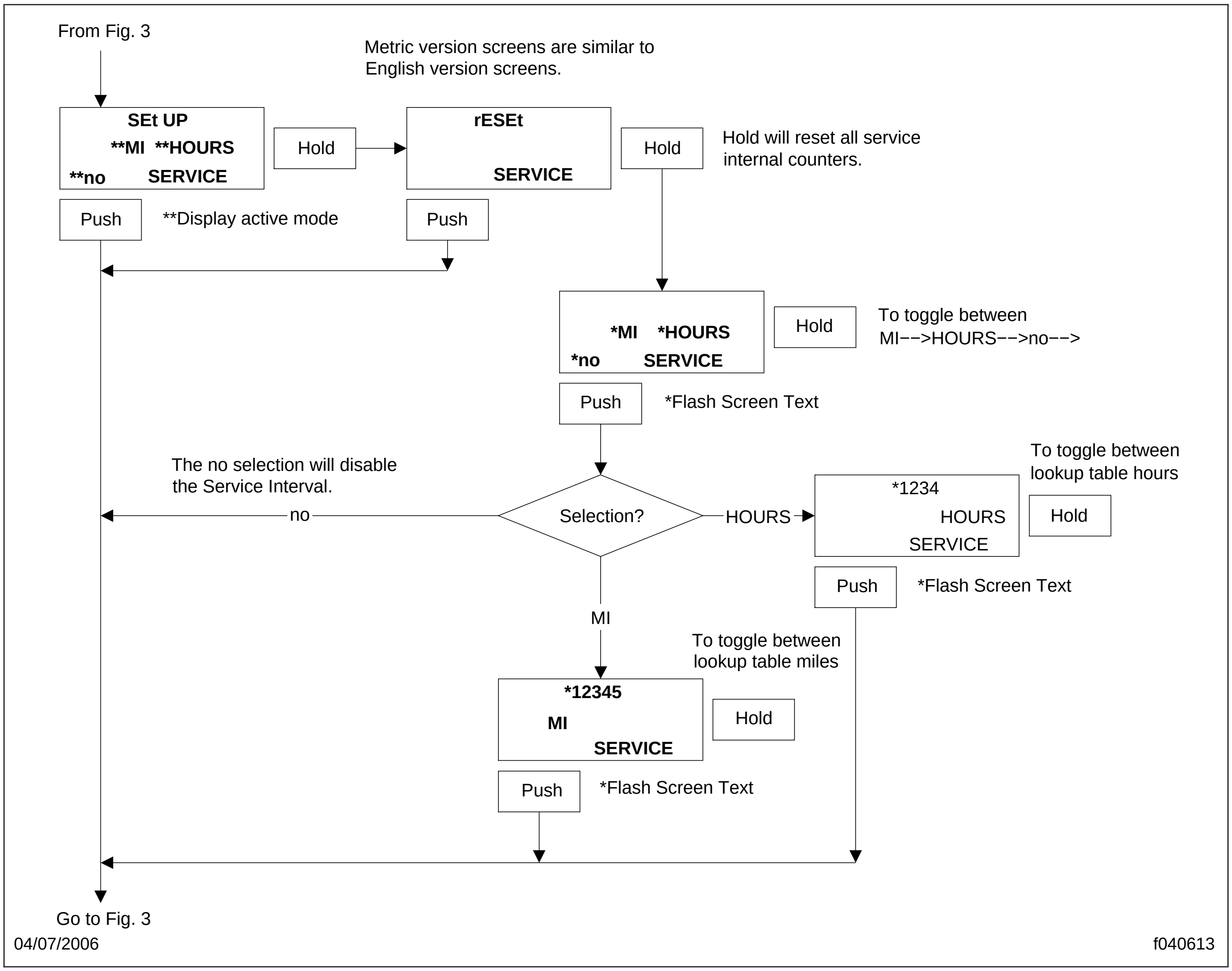


Fig. 7, Reset and Toggle Function Screens

Replacement

NOTE: The vehicle data computer (VDC) is located at the rear of the vehicle, in the engine compartment area. See **Table 1** to determine the VDC mounting location for a particular body builder.

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the tires.
2. Locate and gain access to the VDC.
3. Disconnect the negative battery cable from the battery.
4. Drain the air tanks to remove all pressure from the compressed air system.

CAUTION

Always remove all pressure from the compressed air system before removing any hoses. Failure to do so can cause the hoses to move uncontrollably when disconnected, possibly resulting in personal injury or property damage.

5. Identify the fittings, then disconnect the red and green air lines from the VDC.
6. Disconnect the two harness connectors from the VDC.
7. If the VDC mounting bracket is welded to the chassis, remove the nuts, washers, and bolts that hold the VDC to the mounting bracket.

   If the VDC mounting bracket is not welded to the chassis, remove the mounting bracket and VDC as an assembly. Remove the VDC from the mounting bracket.
8. If the VDC mounting bracket was not welded to the chassis, install the new VDC onto the original mounting bracket. Install the new VDC and mounting bracket onto the chassis and tighten the nuts and bolts 15 to 20 lbf·in (170 to 230 N·cm).

   If the VDC mounting bracket is welded to the chassis, install the new VDC onto the mounting bracket, using the original nuts and bolts. Tighten the nuts and bolts 15 to 20 lbf·in (170 to 230 N·cm).
9. Connect the red and green air lines to the same fittings from which they were removed.
10. Connect the electrical harness connectors to the new VDC.
11. Connect the negative battery cable to the battery post and tighten 15 lbf·ft (20 N·m).
12. Start the engine and make sure that all of the instruments are working.
13. Shut down the engine.
14. Remove the chocks from the tires.

VDC Locations by Body Builder	
Body Builder	**VDC Location**
Airstream	Near the liquefied petroleum (LP) tank, on the passenger-side of the vehicle
Damon	Right-side compartment, behind the rear wheels
Holiday Rambler/Monaco	Right-rear compartment, behind the battery box on the roof, under the black cover
Fleetwood	Battery box, at the left-side rear of the vehicle
Georgie Boy	Underneath the bed box
Newmar	Compartment on the passenger-side of the vehicle, behind the control panel*, or in the bed box
Tiffin	Passenger side, front of the battery box, or behind the rear wheel
National	Battery box, on the passenger-side of the vehicle, behind the rear wheels†
Triple E	Bed box, covered with plywood and a rug
Coachman	Left-side of the bed box, no cover

Replacement

VDC Locations by Body Builder	
Body Builder	**VDC Location**
Winnebago	Bed box, under the second cover to gain engine access
Odessa	Behind the storage box and rail, on the passenger-side rear of the vehicle, underneath‡

* It is necessary to remove the control panel to see the VDC.

† Beginning mid-September 1999, the VDC is located in the compartment behind the battery box.

‡ The 1/4-inch (6-mm) air line is spliced to extend it to the VDC.

Table 1, VDC Locations by Body Builder

Specifications

Table 1 lists the location of the vehicle data computer (VDC) by body builder.

VDC Locations by Body Builder	
Body Builder	**VDC Location**
Airstream	Near LP (liquefied petroleum) tank, on the passenger-side of the vehicle
Damon	Right-side compartment, behind the rear wheels
Holiday Rambler/Monaco	Right-rear compartment, behind the battery box on the roof, under the black cover
Fleetwood	Battery box, at the left-side rear of the vehicle
Georgie Boy	Underneath the bed box
Newmar	Compartment on the passenger-side of the vehicle, behind the control panel*, or, in the bed box
Tiffin	Passenger side, front of the battery box, or behind the rear wheel
National	Battery box, on the passenger-side of the vehicle, behind the rear wheels†
Triple E	Bed box, covered with plywood and a rug
Coachman	Left-side of the bed box, no cover
Winnebago	Bed box, under the second cover to gain engine access
Odessa	Behind the storage box and rail, on the passenger-side rear of the vehicle, underneath‡

* It is necessary to remove the control panel to see the VDC.

† Beginning mid-September 1999, the VDC, VIM, and the transmission ECU are located in the compartment behind the battery box.

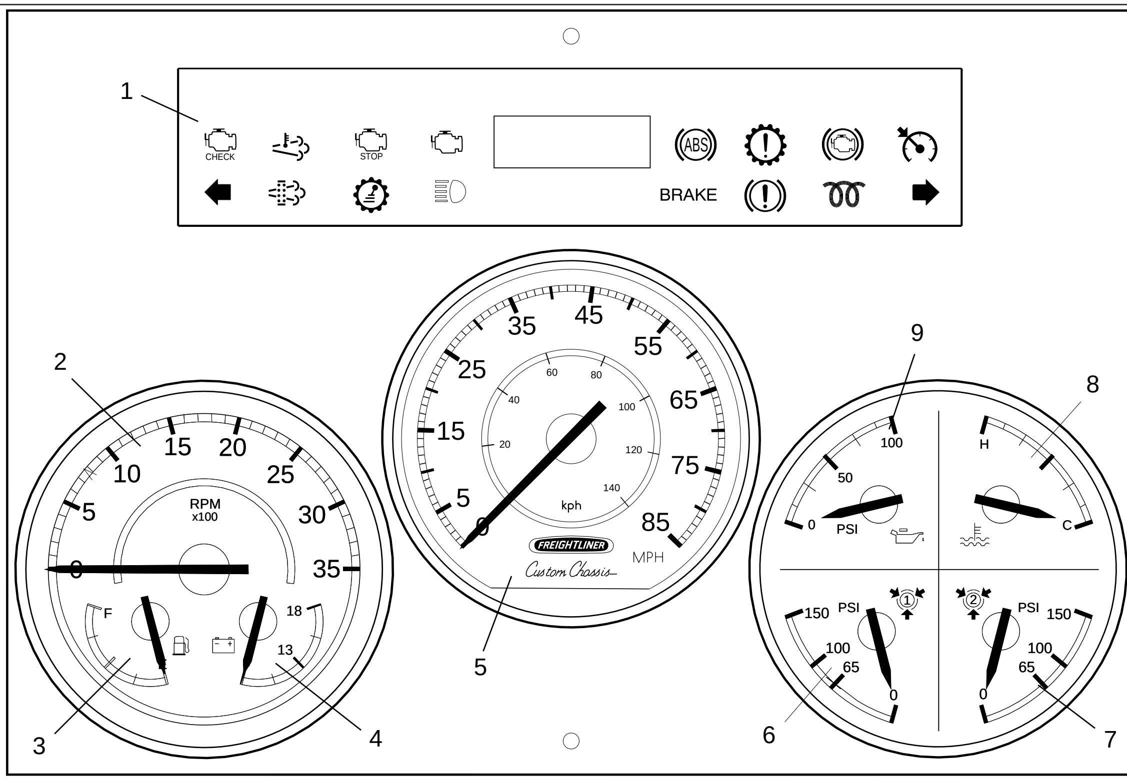
‡ The 1/4-inch (6-mm) air line is spliced to extend it to the VDC.

Table 1, VDC Locations by Body Builder

General Description

The lightbar control unit (LBCU) instrument cluster is a full-featured, individual-gauge cluster with an intelligent lightbar (ILB). The individual gauges have light-emitting diode (LED) backlighting. The lightbar control unit receives inputs for the gauges. See **Fig. 1** for a typical instrument gauge panel, and see **Fig. 2** for the LBCU message center.

- The amber check engine indicator light (CHECK ENGINE legend) illuminates when certain faults are detected. If a critical engine condition exists (for example, low oil pressure or high coolant temperature), the check engine light will illuminate to alert the driver to correct the condition as soon as possible. See the **Cummins or Mercedes-Benz Operation and Maintenance Manual** for more information.



10/04/2006 f610849

1. Lightbar Control Unit
2. Tachometer
3. Fuel Gauge
4. Voltmeter
5. Speedometer
6. Primary Air Gauge
7. Secondary Air Gauge
8. Coolant Temperature Gauge
9. Oil Pressure Gauge

Fig. 1, Typical Instrument Panel, EPA07 Compliant

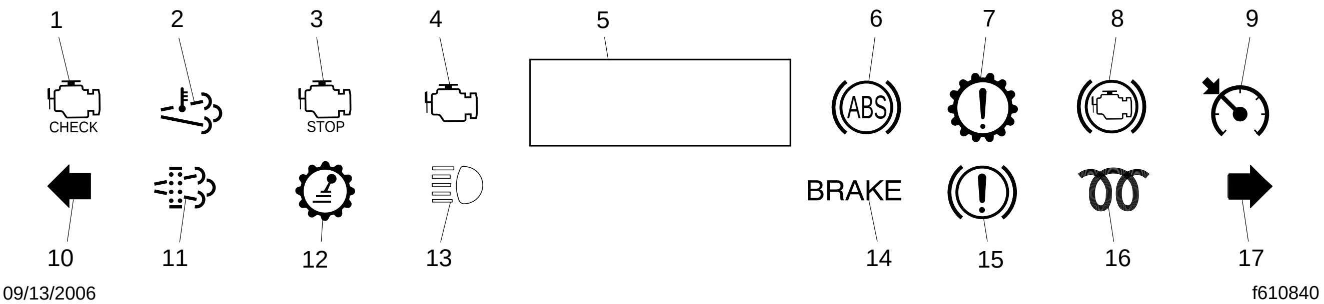
Warning and Indicator Lights

There are 17 warning and indicator lights installed in the LBCU message center. These indicator lights are listed by their position in the dash message center.

The warning and indicator lights operate as follows:

- The High Exhaust System Temperature (HEST) light alerts the operator of high exhaust temperature during the regeneration (regen) process when the speed is below 5 mph (8 km/h), or during a manual regen. The HEST lamp does not signify the need for any kind of vehicle or engine service; it only alerts the vehicle operator to high exhaust temperatures.

General Information



1. Check Engine Indicator
2. High Exhaust System Temperature (HEST) Lamp
3. Stop Engine Warning
4. Malfunction Indicator Lamp
5. Dash Driver Display Screen
6. ABS Indicator
7. Check Transmission Indicator
8. Engine Brake Engaged Indicator
9. Cruise On Indicator
10. Left-Turn Signal Arrow
11. Diesel Particulate Filter (DPF) Lamp
12. Shift Inhibit Indicator
13. Headlight High-Beam Indicator
14. Parking Brake Indicator
15. Low Air Pressure Indicator
16. Wait to Start Indicator
17. Right-Turn Signal Arrow

Fig. 2, LBCU Message Center, EPA07 Compliant

- The red stop engine warning light indicates a serious fault that requires the engine be shut down immediately. The driver must safely bring the vehicle to a stop on the side of the road and shut down the engine as soon as the red light is seen. If the engine shuts down while the vehicle is in a hazardous location, the engine can be restarted after turning the key to the OFF position for a few seconds. See the **Cummins or Mercedes-Benz Operation and Maintenance Manual** for more information.
- The Malfunction Indicator Lamp (MIL) indicates an engine emissions-related fault, including, but not limited to, the aftertreatment system. The MIL applies to the Mercedes-Benz engine only. See the engine operation manual for details.
- The LBCU's interactive graphical display screen communicates real-time information about the status and performance of the vehicle.
- The ABS indicator illuminates when a problem is detected with the ABS. This telltale is directly controlled by the ABS via hard wire input to the cluster.
- The check transmission warning light will come on during vehicle operation (not during start-up) if the electronic control unit (ECU) has signalled a diagnostic code. Diagnostic codes indicate malfunctions in transmission operation. This telltale is directly controlled by the transmission via hard wire input to the cluster.
- The green engine brake indicator illuminates when the engine brake is applied. Wait until the indicator light goes off to start the engine.
- The green cruise control indicator illuminates when the cruise control is on.
- The green left-turn and right-turn signal indicator lights flash on and off when the outside turn signal lights are flashing.
- The solid yellow Diesel Particulate Filter (DPF) lamp indicates that a manual regen is required soon, and should be scheduled for the earliest convenient time. A blinking yellow (DPF) lamp indicates that a manual regen is required immediately, or an engine derate may occur.
- The yellow shift inhibit indicator illuminates when the transmission ECU is prohibiting shifting.
- The blue high-beam indicator light illuminates when the headlights are on high beam.
- The red parking brake light indicates when the parking brake is activated and the ignition switch is in the ON position.
- The red low air warning light normally illuminates when the air pressure in the air tanks falls below 65 psi (448 kPa). The light will normally come on when the engine is first started,

but goes off when the air pressure in the air tanks reaches approximately 65 to 76 psi (448 to 524 kPa).

- The yellow wait-to-start indicator light illuminates when the intake heater is active. This telltale is directly controlled by the engine via hard wire input to the cluster.

Audible Alarms

During start-up, the LBCU will perform a self-test and an audible alarm will sound until the self-test is completed. If any faults are found during the self-test, ERROR will appear on the display screen. Acknowledge any alarms before proceeding. The alarm will also sound if any of the following conditions occur:

- Air pressure falls below 65 psi (448 kPa).
- Anytime the low air warning light is activated. On the air system, the low air light/audible alarm will normally come on when the engine is first started, but will go off when the air pressure in the air tanks reaches approximately 65 to 76 psi (448 to 524 kPa). The parking brake will not disengage until the air pressure has reached 65 psi (448 kPa).
- Emergency engine shutdown is activated.
- The parking brake is applied and the transmission is not in neutral.
- The transmission is in neutral or the ignition is off, and the parking brake is not set and the service brake is not depressed.
- The turn indicator is active.
- Anytime the ignition is turned off when the panel lamps are still illuminated.

Power Initialization

When the ignition is turned on, the information center will illuminate with the Freightliner Custom Chassis logo. If there are no alarms detected from the self-test, the driver checklist is displayed.

Menu Structure and Navigation

The LBCU is an interactive graphical display that is capable of displaying text messages and graphics to communicate real-time information to the operator about the status and performance of the vehicle. This information is organized in a menu-structured format.

Navigate the menu structure using the toggle switch, located in the driver's area. The "up" arrow of the toggle switch is yellow. See **Fig. 3**.

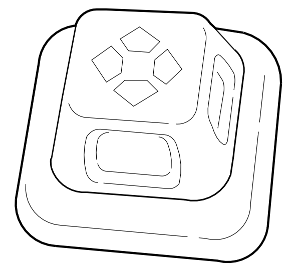


Fig. 3, Toggle Switch

The menu structure is organized around three menu screens: the ignition off screen, the home screen, and the setup/maintenance/diagnostics screen. Each of these screens contains lists of the sub-menu screens that can be accessed by highlighting the desired sub-menu and clicking the right arrow on the toggle switch.

Ignition Off Screen

When the ignition is OFF and the headlights are ON, the odometer is displayed. When the ignition is OFF and the generator is ON, the generator hours are displayed (if connected by the body builder).

Home Screen

NOTE: Alarm messages have priority over other display screens. If no alarms are present or all alarms have been acknowledged, the driver checklist will be displayed.

The following options are found in the menu and sub-menus of the home screen.

- A pretrip inspection checklist that includes 19 items and 10 driver-entered options. Once each item has been reviewed, click the right arrow of the toggle switch to place a check by the item. Click the left arrow to exit the checklist.

General Information

- Driver's Favorite Categories—There are nine categories that the driver can select from; three can be viewed at one time. Select the category desired by using the up/down toggle switch. Then, click the right arrow of the toggle switch for three seconds to access the sub-menus within each category. Finally, click the left arrow of the toggle switch to exit.
- Setup/Maintenance/Diagnostics screen is actually three different categories for the driver to use. They are as follows:

  1. Setup—Includes set time and date, configure checklist, select metric/english, set LCD properties.

  2. Maintenance—Includes engine oil, engine air filter, engine fuel filter, transmission oil, generator oil, generator fuel filter, generator use time.

  3. Diagnostics—Includes check gauges, check icons, check inputs, check outputs, engine diagnostics, ABS diagnostics, hardware/software version, and software debug display (this menu is used by the gauge manufacturer only).

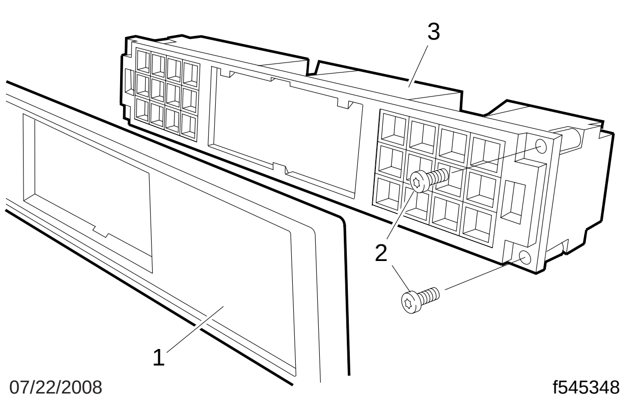
The following steps are used to make changes within the various categories.

1. From the Driver's Favorite Category menu, hold down the right arrow of the toggle switch for five seconds to select the setup/maintenance/diagnostics screen.
2. Press the down arrow on the toggle switch to select either setup, maintenance, or diagnostics.
3. Press the right arrow on the toggle switch to select the sub-category; "Set Time and Date" for example.
4. Use the left/right arrows on the toggle switch to change the information, and the up/down arrows to move within the sub-category.
5. Once all changes have been made, hold down the right arrow on the toggle switch.

NOTE: For menu structure road maps illustrating the screens that are available in the information center and the path to specific screens, see **Chapter 2** of the **Recreational Vehicle Chassis Operator's and Maintenance Manual**.

Replacement

1. Remove the dash panel that covers the LBCU. Remove the four Torx screws, then carefully lift the dash panel to gain access to the LBCU.
2. Disconnect the electrical harness connectors from the back of the LBCU. This includes the 32-pin LBCU connector, the 24-pin LBCU connector, and the 4-pin gauge LIN (Local Interconnect Network) bus connector
3. Remove the LBCU faceplate. Place a small flat blade under each center-end of the LBCU faceplate. Carefully pry the faceplate forward to release the locking end tabs. See **Fig. 1**.



1. LBCU Faceplate
2. Torx Mounting Capscrews
3. LBCU

Fig. 1, LBCU Replacement

4. Remove the LBCU by removing the four Torx mounting capscrews from the front of the LBCU.
5. Install the new LBCU. Place the LBCU into the opening from the back and install the four Torx mounting capscrews in the front of the LBCU.
6. Install the LBCU faceplate. Position the faceplate over the front of the LBCU, then carefully press the faceplate on until the end tabs lock in place.
7. Connect the three electrical harness connectors to the back of the LBCU.
8. Install the dash panel with the four Torx screws.
9. Turn on the ignition and test the operation of the LBCU.

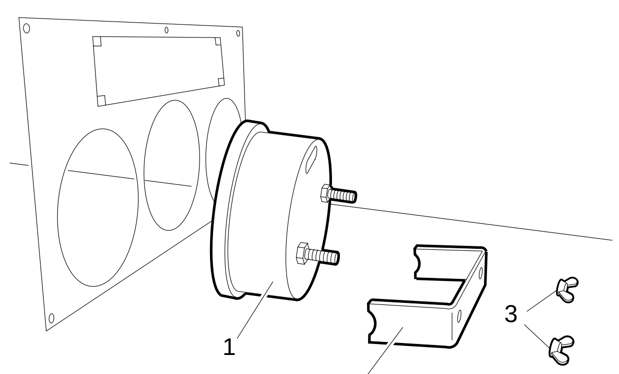
Gauge Replacement

3- and 5-Inch Gauges

1. Remove the dash panel that covers the LBCU. Remove the four Torx screws, then carefully lift the dash panel to gain access to the LBCU.
2. Unplug the wiring harness from the back of the gauge.

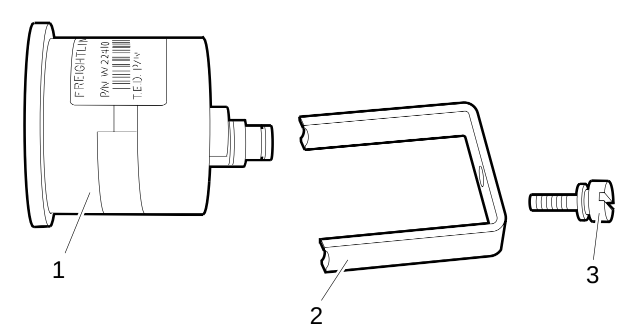
IMPORTANT: If multiple gauges are being replaced, note the location of each gauge before removing them.

3. Remove the two wing nuts or the thumb screw that secure the bracket to the gauge; remove the gauge. See **Fig. 1** and **Fig. 2**.



1. Gauge
2. Mounting Bracket
3. Wing Nuts

Fig. 1, Wing Nut Mounted Gauge



1. Gauge
2. Mounting Bracket
3. Thumb Screw

Fig. 2, Thumb Screw Mounted Gauge

4. Correctly orient the replacement gauge and install it through the opening at the front.
5. Install the mounting bracket on the back of the gauge and use the two wing nuts or the thumb screw to hold it in place.
6. Connect the wiring harness to the back of the gauge.
7. Install the dash panel with the four Torx screws.

Air Gauges

1. Remove the dash panel that covers the LBCU. Remove the four Torx screws, then carefully lift the dash panel to gain access to the LBCU.

IMPORTANT: Bleed off all air before removing the air hoses.

2. Using a paint pen, mark the air hoses for ease of installation. After bleeding all air from the system, disconnect the air gauge hoses.
3. Unplug the wiring harness from the back of the gauge.

IMPORTANT: If multiple gauges are being replaced, note the location of each gauge before removing them.

4. Remove the two wing nuts or the thumb screw that secure the bracket to the gauge; remove the gauge. See **Fig. 1** and **Fig. 2**.
5. Correctly orient the replacement gauge and install it through the opening at the front.
6. Install the mounting bracket on the back of the gauge and use the two wing nuts or the thumb screw to hold it in place.
7. Connect the wiring harness to the back of the gauge.
8. Connect the air gauge hoses.
9. Install the dash panel with the four Torx screws.

Replacement

The term "telltale" refers to the small plastic lens in the top row of the LBCU faceplate (dash message center) with a warning or indicator message printed on it. See **Fig. 1**. These are replaceable.

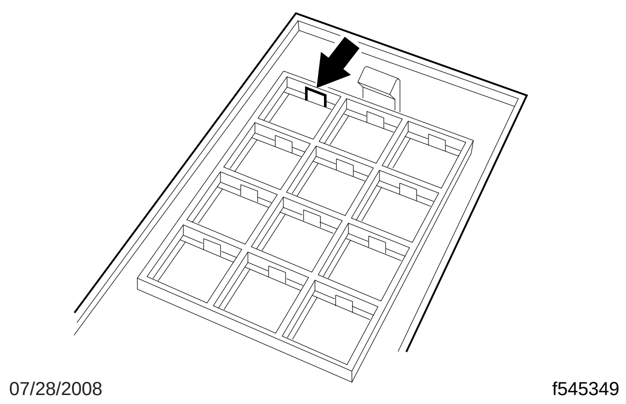


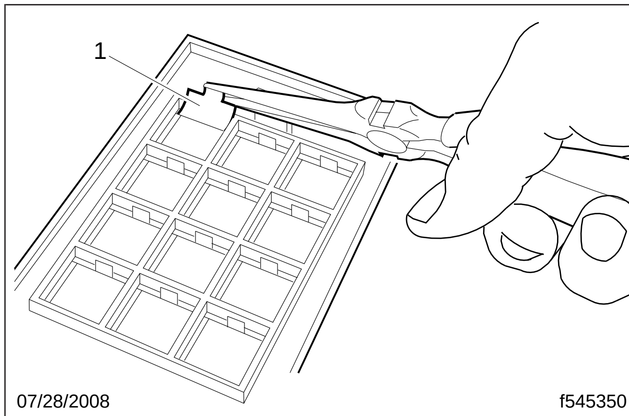
Fig. 1, LBCU Telltales

IMPORTANT: Light-emitting diodes (LEDs) are used in the LBCU to light the individual telltales. If any of the LEDs stop working on the LBCU, the LBCU has to be replaced. It is not possible to replace individual LEDs.

CAUTION

Electronic components of the ICU are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU circuitry.

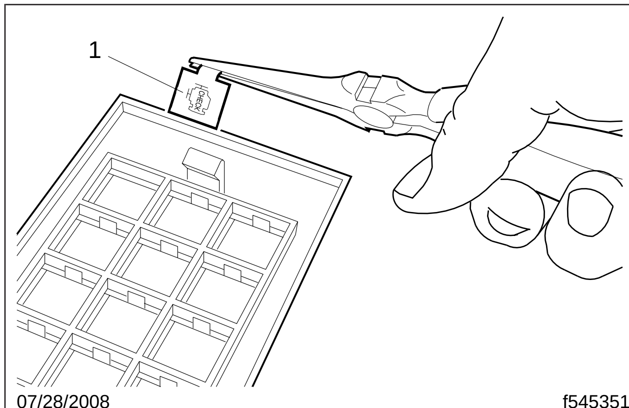
1. Remove the dash panel that covers the LBCU. Remove the four Torx screws, then carefully lift the dash panel to gain access to the LBCU.
2. Place a flat blade under each end of the LBCU faceplate and carefully pry it off the LBCU.
3. Using a pair of needlenose pliers or a similar tool, grab the exposed tab along the side of the telltale slot and carefully slide the telltale out from the slot. See **Fig. 2** for an example of telltale removal.



1. Telltale Lens Removal

Fig. 2, Telltale Removal

4. Place the replacement telltale in its correct slot the same way it was removed. Properly orient the telltale so the text is readable from the front, then slide the telltale into its slot. See **Fig. 3**.



1. Telltale Lens Installation

Fig. 3, Telltale Installation

5. Install the dash panel with the four Torx screws.
6. Turn on the ignition keyswitch. Check all LEDs and telltales for correct operation.

Troubleshooting

J1939 faults consist of the following, in this order:

- Suspect Parameter Number (SPN) – Indicates what function on the ECU has failed.
- Failure Mode Indicator (FMI) – Indicates in what way the function failed.

J1939 Diagnostic Trouble Codes					
Error Description	**SPN**	**SPN J1939 Name**	**FMI**	**FMI Explanation**	**Broadcast Rate: seconds**
LBCU Low Voltage	168	Electrical Potential	4	Voltage Below Normal	1
LBCU Controller Failure	611	System Diagnostic Code	14	Special Instructions	15
LBCU Program Memory Failure	612	System Diagnostic Code	14	Special Instructions	15
Fuel Sensor Fault	96	Fuel Level	5	Current Below Normal/Open Circuit	1
Air Pressure Sensor Fault	117	Brake Primary Pressure	9	Abnormal Update Rate	1

Table 1, J1939 Diagnostic Trouble Codes

Diagnosis for Multiple Gauges Not Working (datalink-driven gauges)			
Step	**Test Procedure**	**Test Result**	**Action**
1	Do the affected gauges sweep using the diagnostic display in the LBCU? Does the gauge sweep when requested? (For instructions on how to access the diagnostic menu in the LBCU and select gauges, see **Chapter 2** of the *Recreational Vehicle Chassis Operator's Manual*.)	Yes	Go to **step 2**.
		No	Go to **step 8**.
2	Are the only affected gauges sensor driven by direct input to the LBCU (fuel sensor and brake air pressure for example)?	Yes	Check the common sensor ground that connects to pin C12. If it is okay and the gauges above are not affected, the LBCU is faulty. Repair as necessary.
		No	Go to **step 3**.
3	Is it only J1939/J1587 driven gauges affected?	Yes	Go to **step 4**.
		No	Replace the LBCU.
4	Cycle the ignition switch ON, and wait 5 seconds. Does the "no CAN" message appear? If the gauge is driven by a J1587 message, wait 40 seconds to see if the "no J1587 data" warning message appears.	Yes	The most likely cause is something taking the entire J1939 datalink down, in which case the LBCU menu will show an error message. Repair as necessary.
		No	Go to **step 5**.
5	In ServiceLink®, does the FCCC LBCU show up in the ECU list (address 23 in J1939)?	Yes	Go to **step 6**.
		No	Check the J1939 datalink to the LBCU. If it is okay, the LBCU is most likely faulty. Repair as necessary.

Troubleshooting

Diagnosis for Multiple Gauges Not Working (datalink-driven gauges)			
Step	**Test Procedure**	**Test Result**	**Action**
6	In ServiceLink®, does the engine ECU show up in the LBCU list (address 0 on J1939)?	Yes	Go to **step 7**.
		No	Check the J1939 datalink to the engine ECU. If it is okay, the engine ECU is faulty. Repair as necessary.
7	In ServiceLink®, open the "LBCU Cluster Datalink Monitor" template. Do the affected gauges work on the template?	Yes	Replace the LBCU.
		No	The engine ECU sensor wiring or the engine ECU itself is faulty. Repair as necessary.
8	Do any of the gauges sweep when the diagnostic menu is used to test the gauges?	Yes	Go to **step 9**.
		No	Check the power and ground to the LBCU. If they are okay, the LBCU is faulty. Repair the LBCU as necessary.
9	Are all of the affected gauges in sequence with one another on the daisy chain?	Yes	Go to **step 10**.
		No	Replace the LBCU.
10	Locate the faulty gauge that is closest to the LBCU in the daisy chain. Replace the jumper wire between this gauge and the next gauge closest to the LBCU that works (or the LBCU itself). Do the gauges work?	Yes	Replace the jumper wire.
		No	Replace the LBCU.

Table 2, Diagnosis for Multiple Gauges Not Working (datalink-driven gauges)

Inaccurate Gauge Diagnostics			
Step	**Test Procedure**	**Test Result**	**Action**
1	Is the gauge controlled by the J1939/J1587 datalink? See *Gauge Overview* in **Subject 400** to determine gauge control strategy.	Yes	Go to **step 2**.
		No	Go to **step 3**.
2	Using the monitor template within ServiceLink®, check whether or not the template gauge reads the same as the cluster gauge.	Yes	The gauge is functioning correctly, however, the sensor connected to the engine ECM may be faulty. See the engine operator’s manual for troubleshooting information.
		No	Try a gauge that is known to be good. If this does not correct the problem, replace the LBCU.
3	For the fuel sensor gauge, use the input menu to determine if the gauge sensor resistance is within 20 to 261Ω. Check SPN 96 diagnostic trouble code. Does this indicate a short circuit?	Yes	Check the connection; if it is good, replace the sensor.
		No	Go to **step 4**.
4	Use the test menu to test the gauge. Does it work as expected? Is the gauge moving?	Yes	Replace the sensor. If that doesn’t work, replace the LBCU.
		No	Try a gauge that is known to be good. If the gauge does not move, replace the LBCU.

Table 3, Inaccurate Gauge Diagnostics

Troubleshooting

Air Pressure Gauge Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Which air pressure gauge is not functioning correctly?	Primary or secondary	Go to **step 2**.
		Application	Go to **step 3**.
		Suspension	Go to **step 4**.
2	Drain the air tanks and connect an accurate pressure gauge to the primary or secondary air tank that corresponds with the problem gauge. Start the engine and build air pressure until the compressor cuts out. Is the air pressure gauge in the cluster within 6 psi (41 kPa) of the test gauge?	Yes	No problem found.
		No	Check for kinked air lines. If the air lines are okay, replace the air pressure gauge.
3	Connect an accurate pressure gauge to a delivery port on the foot valve. Make a 90 psi (620 kPa) brake application while observing the application air pressure gauge in the cluster and the test gauge. Is the air pressure gauge in the cluster within 3 psi (20 kPa) of the test gauge?	Yes	No problem found.
		No	Check for kinked air lines. If the air lines are okay, replace the air pressure gauge.
4	Connect an accurate pressure gauge to the air suspension. Is the air pressure gauge in the cluster within 3 psi (20 kPa) of the test gauge?	Yes	No problem found.
		No	Check for kinked air lines. If the air lines are okay, replace the air pressure gauge.

Table 4, Air Pressure Gauge Troubleshooting

Warning Lamp Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Do the affected warning lamps turn off using the icon diagnostic menu in the LBCU? Does the warning lamp turn on/off when requested? See the *Recreational Vehicle Chassis Operator's Manual* for directions to access the diagnostic menu in the LBCU and select gauges.	Yes	Go to **step 3**.
		No	Replace the LBCU.
2	Do the affected warning lamps turn on using the icon diagnostic menu in the LBCU? Does the warning lamp turn on/off when requested? See the *Recreational Vehicle Chassis Operator's Manual* for directions to access the diagnostic menu in the LBCU and select gauges.	Yes	Go to **step 3**.
		No	Replace the LBCU.
3	Is the warning light driven by a datalink or directly connected to the LBCU?	Yes	Check the sensor and its wiring to the LBCU; repair as needed.
		No	Go to **step 4**.

Troubleshooting

Warning Lamp Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
4	Is there any error message regarding the datalink?	Yes	Repair the datalink as required.
		No	Check the sensor and its wiring to the control module; repair as needed.

Table 5, Warning Lamp Troubleshooting

Backlighting Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Does any of the backlighting work?	Yes	Go to **step 2**.
		No	Check the panel light dimmer switch, and the panel lighting circuit. Repair as needed.
2	Is all of the cluster backlighting dead (light bar liquid crystal display [LCD] and all gauges)?	Yes	Go to **step 3**.
		No	Go to **step 5**.
3	Disconnect the LBCU 24-pin connector. Turn the headlights on, and the panel lamp dimmer switch to full bright. Measure the voltage at connector pin A1. It should be approximately +12V. What is the voltage?	12V	Go to **step 4**.
		0V	Check backlighting circuit 29A for open between the LBCU and splice to other dash components. Repair as needed.
4	Disconnect the LBCU 24- and 32-pin connectors. Turn the headlights on and the panel lamp dimmer switch to full bright. Measure the voltage between pin A1 (24-pin connector) and pin D3 (32-pin connector). What is the voltage?	12V	Replace the LBCU.
		0V	Check the panel lamp ground circuit. Repair as needed.
5	Is the LBCU LCD the only thing with dead backlighting?	Yes	Replace the LBCU.
		No	Go to **step 6**.
6	Is only one gauge backlight dead?	Yes	Go to **step 7**.
		No	Go to **step 8**.
7	Is the gauge with dead backlighting the last gauge in the daisy-chain (farthest from the LBCU)?	Yes	Try a known good jumper wire to the gauge. If backlighting now works on this gauge, this solved the problem. If the backlighting still does not work, replace the gauge.
		No	Replace the gauge.

Backlighting Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
8	Are all of the gauges with dead backlighting in sequence with one another in the daisy-chain?	Yes	Try a good known jumper wire between the gauge with dead backlighting that is closest to the light bar and the next good gauge (one closer to the LBCU). If all backlighting now works, the jumper solved the problem. If not, replace all gauges with dead backlighting.
		No	Go to **step 9**.
9	Is one of the dead gauges the last gauge in the daisy-chain?	Yes	Try a known good jumper to the last gauge. If the last gauge now works, the jumper solved the problem to this gauge. Replace all other gauges with dead backlighting. If the jumper did not correct the backlighting to the last gauge in the daisy-chain, replace all gauges with dead backlighting.
		No	Replace all gauges with dead backlighting.

Table 6, Backlighting Troubleshooting

Warning Light Messages in the LBCU		
Displayed As (Actual Text for Display Messages)	**Activation Cause**	**Corrective Action**
No J1939 Data	No CAN messages for 1 second	Troubleshoot the CAN bus connection.
Brakes Worn	Input + data conditions	The brakes are worn. Refer to **Group 42** in this manual.
Tag Dumped	Input + data conditions	Refer to the *Tag-Axle Suspension Dump Switch* section in **Chapter 3** of the *Recreational Vehicle Chassis Operator's Manual*.
Lift Open	Input + data conditions	The lift is open.
Coolant Low Level	Diagnostic trouble code (DTC) on J1939	Check the engine coolant fluid; refer to the engine manufacturer's manual.
Transmission High Temp	DTC on J1939/J1587	Refer to the transmission manufacturer's manual.
Fuel Low Level	Fuel sensor value is 1/8 of scale	Fill up the fuel tank.
Throttle Disabled	Input + data conditions	The throttle is disabled. Consult the engine manufacturer's manual.
Check Brake Fuse	Analog Input	Check the brake fuse.
Battery Low Voltage	J1939 data	The battery is low. Take action to ensure that the battery is charging.
No J1587 Data	No J1587 messages for 20 seconds	Troubleshoot the J1587 datalink connection.
Battery High Voltage	J1939 data	Check chassis power.

Troubleshooting

Warning Light Messages in the LBCU		
Displayed As (Actual Text for Display Messages)	**Activation Cause**	**Corrective Action**
Auto Idle Sys Voltage ~~~~V Threshold 13.4V	Low battery plus other conditions	The LBCU has entered auto idle mode and will attempt to raise battery voltage using cruise control.
Engine Oil Service Due In ~~~~~~	Maintenance menu set warning	Service the oil.
Engine Air Filter Service Due In ~~~~~~	Maintenance menu set warning	Replace the air filter.
Engine Fuel Filter Service Due In ~~~~~~	Maintenance menu set warning	Replace the fuel filter.
Transmission Oil Service Due In ~~~~~~	Maintenance menu set warning	Service the transmission oil.
Generator Oil Service Due In ~~~~~~	Maintenance menu set warning	Service the generator oil.
Generator Fuel Filter Service Due In ~~~~~~	Maintenance menu set warning	Replace the generator filter.
Coolant High Temp	DTC on J1939/J1587	Check the engine cooling system.
Stop Engine	DTC on J1939/J1587	Stop the engine.
Check Engine	DTC on J1939/J1587	Perform engine troubleshooting.
Water In Fuel	Cummins J1939 datalink signal Caterpillar ground on LBCU pin A9	Troubleshoot the fuel system.
Engine Protect	DTC on J1939	Refer to the engine manufacturer’s manual.
Check Transmission	DTC on J1939/J1587	Troubleshoot the transmission.
Self Test Error	Self test error–EE checksum errors	If the battery was removed incorrectly, turn off the ignition and wait 20 seconds. Turn the ignition on. This will load the default value for the affected parameter(s).
J1939 Address Claim Lost	Lost address claim–no J1939 transmission allowed	Do not connect another unit with address 23 on the J1939 datalink.

Warning Light Messages in the LBCU		
Displayed As (Actual Text for Display Messages)	**Activation Cause**	**Corrective Action**
Odometer ~~~~~~ Menu Navigation Switch Failure	Menu toggle switch is missing or faulty	Replace the toggle switch. If this does not help, replace the LBCU.
Shift Inhibit	J1939 datalink	Refer to the transmission manufacturer's manual.
Oil Low Pressure	DTC on J1939	Refer to the engine manufacturer's manual.
ABS Hydraulic	Signal sent by the ABS module	Check pin B11 for signal from the ABS ECU, then refer to the manufacturer's hydraulic brake manual.
ABS Pneumatic	Signal sent by the ABS module	Check pin D12 for signal from the ABS ECU, then refer to the manufacturer's air ABS manual.

Table 7, Warning Light Messages in the LBCU

Using the LBCU to Diagnose Problems

Items shown in **Fig. 1**, **Fig. 2**, **Fig. 3**, **Fig. 4**, **Fig. 5**, **Fig. 6**, **Fig. 7**, and **Fig. 8** can be diagnosed with the built-in warnings and test menus of the LBCU.

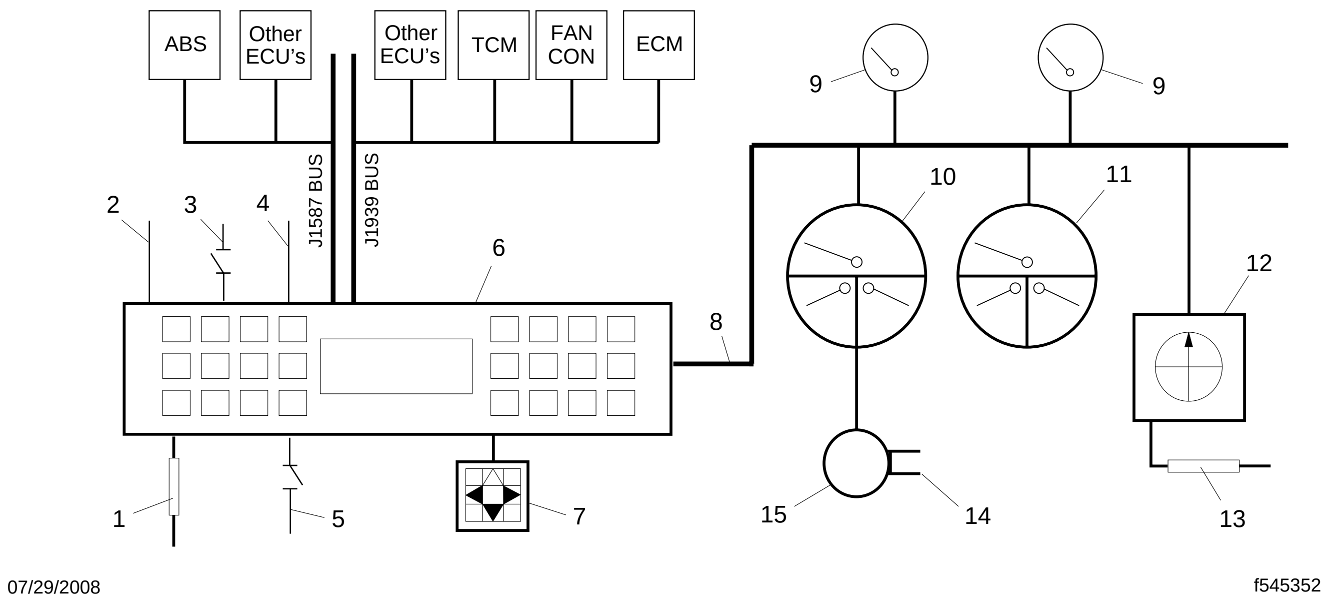
The LBCU can be used to read diagnositc trouble codes on J1939 from the engine ECU, coolant ECU, and the ABS ECU. The following information applies to **Fig. 8**.

- The LBCU can read J1587 diagnostic trouble codes from the ABS ECU; other ECUs are not supported at this time.
- The error menu can hold a maximum of 20 error codes.
- The J1939 error menus show suspect parameter number (SPN), failure mode indicator (FMI), and open circuit (OC).
- The J1587 error menu shows parameter identifier (PID), subsystem identifier (SID), failure mode indicator (FMI), and open circuit (OC).
- When a menu shows zero faults, it continues scanning for errors. You can enter the menu and wait for any errors being sent through the LBCU.

The odometer uses high resolution total vehicle distance from the engine controller. The following information applies to the odometer.

- SPN 917 on J1939 or PID 245 on J1587.
- Information is sent to EE prom memory every mile.
- The odometer has a design life of 2 million miles.
- The LBCU odometer is set to follow the engine total vehicle distance.
- If the new value is within –0 to +2 miles of the currently stored odometer, the LBCU odometer is set to the incoming value. See **Fig. 9** for a graphic illustration. If the new value is outside that range, the LBCU odometer does not change, but the new value is stored and used as an offset to check the next incoming value.

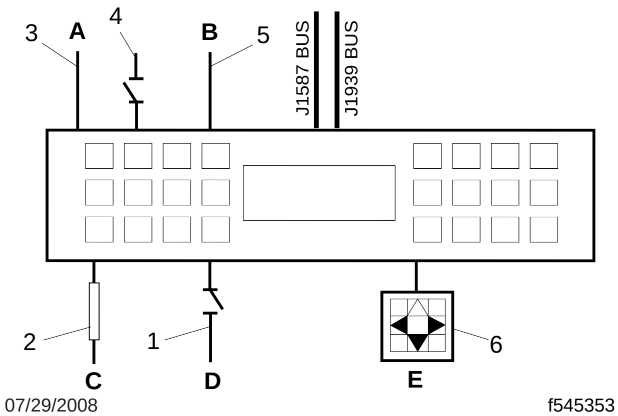
Troubleshooting



1. Fuel Level Sensor
2. Battery Voltage
3. Ignition
4. Digital Outputs
5. Digital Inputs
6. LBCU
7. Toggle Switch
8. LIN Datalink to LIN Gauges
9. Optional Gauges
10. Fuel Gauge/Tachometer/Voltmeter
11. Oil Pressure/Coolant Temperature/Primary/Secondary Air Gauges
12. Compass
13. Outside Temperature Sensor
14. Primary and Secondary Air Lines
15. Air Pressure Transducer

Fig. 1, Problems Diagnosed Through the LBCU

Troubleshooting

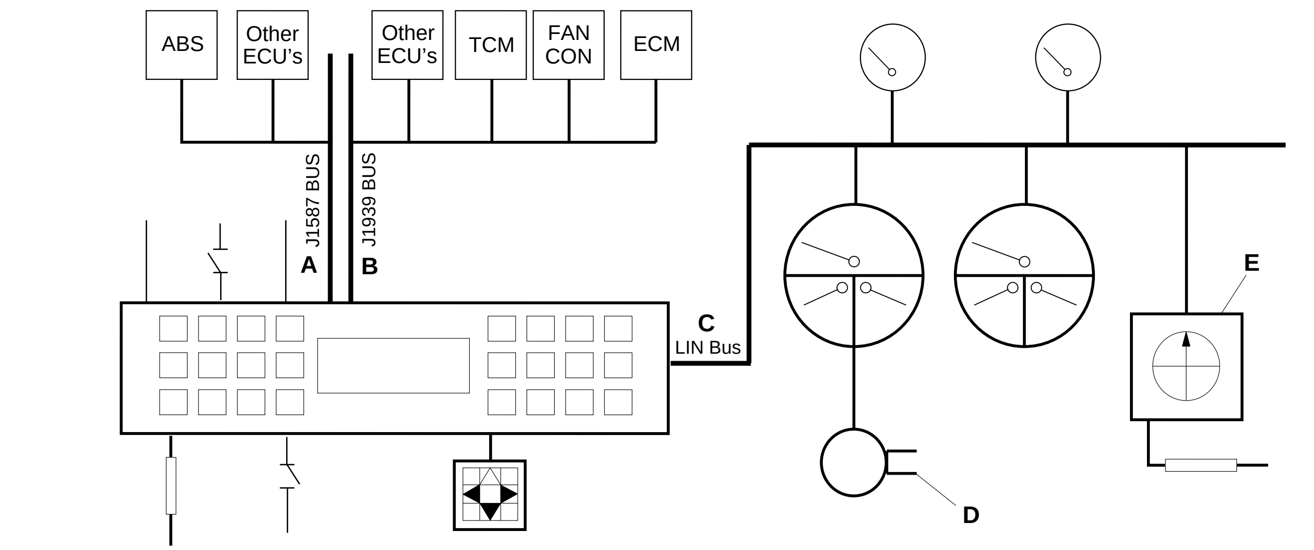


A. Vehicle will shut down if the battery voltage is outside 9V to 18V. The high voltage protection is done in the hardware (H/W), and the low voltage shut down is done in the software (S/W).
B. Digital outputs can be checked in the "Check Internal Data" menu.
C. If the fuel sensor is outside its normal range of 20–260Ω an error code (SPN 96) will be set.
D. Digital inputs can be checked in the "Check Inputs" diagnostic menu.
E. If the toggle switch is faulty, a warning message is displayed, and the menu switches to a special failure mode.

1. Digital Inputs
2. Fuel Sender
3. Battery Voltage
4. Ignition
5. Digital Output
6. Toggle Switch

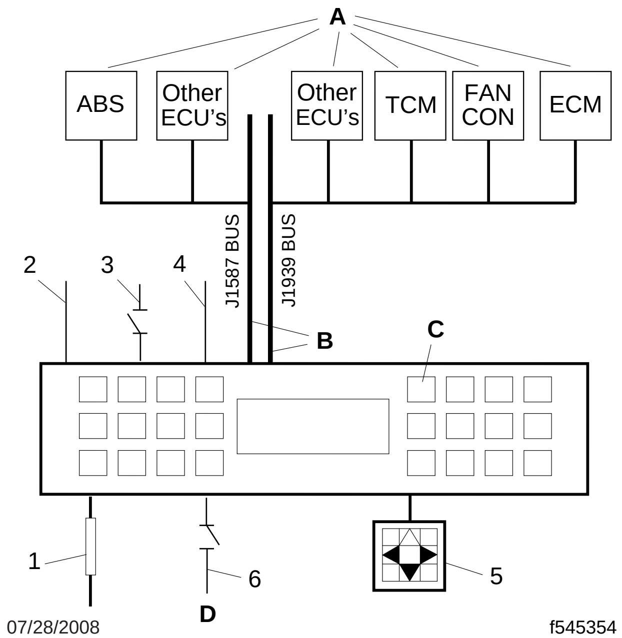
Fig. 2, Possible LBCU Errors

Troubleshooting



A. If no J1587 messages are received by the LBCU within 20 seconds, the J1587 NO DATA alert is shown.
B. If no J1939 messages are received by the LBCU within 1 second, the J1939 NO DATA alert is shown.
C. If you suspect the LIN datalink is faulty, use the "Gauge Test" menu to try to move a gauge. If the LIN datalink appears dead, check the "LIN Power Out ST". This is in the "Check Internal Data" menu, and should read OK.
D. If there is only one gauge that is not working, check that all the cables in the daisy chain are connected and not damaged.
E. If the compass module is not properly connected or it is faulty, it will not show up in the menu. There is a 10 second time out before the compass line disappears due to loss of message on the LIN datalink line. If a message on either datalink is missing and there is no data received, the menu will show dashes for that data item (ROAD SPEED --------). When data driving a gauge is lost, the gauge will be sent to zero position.

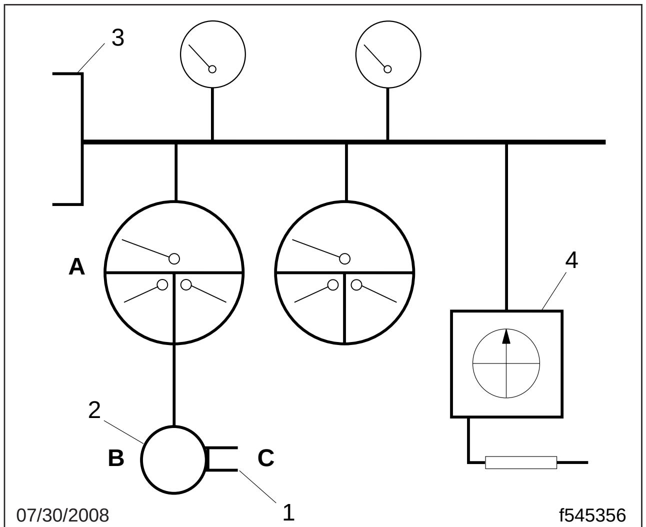
Fig. 3, Datalink Errors



A. If the activation is a diagnostic trouble code associated icon, you can use the "Engine Diagnostic" menu, "ABS Diagnostic" menu, or the "Coolant" menu. Some telltales are activated by messages and not diagnostic trouble codes, such as water in fuel. To check for these types of messages, connect a lap top computer to the diagnostic connector of the chassis. This applies only to vehicles with a Cummins engine; Caterpillar engines are directly wired to the LBCU at pin A9.
B. Turn the ignition off and then turn it back on. Watch the LBCU display screen during the start up to see if the J1587 or J1939 NO DATA warnings appear.
C. If the LED can be turned on and off, use the "Check Icons" menu to test the icon.
D. If it is a direct wired input icon, use the "Check Inputs" menu.

1. Fuel Sender
2. Battery Voltage
3. Ignition
4. Digital Output
5. Toggle Switch
6. Digital Inputs

Fig. 4, Icon Will Not Display

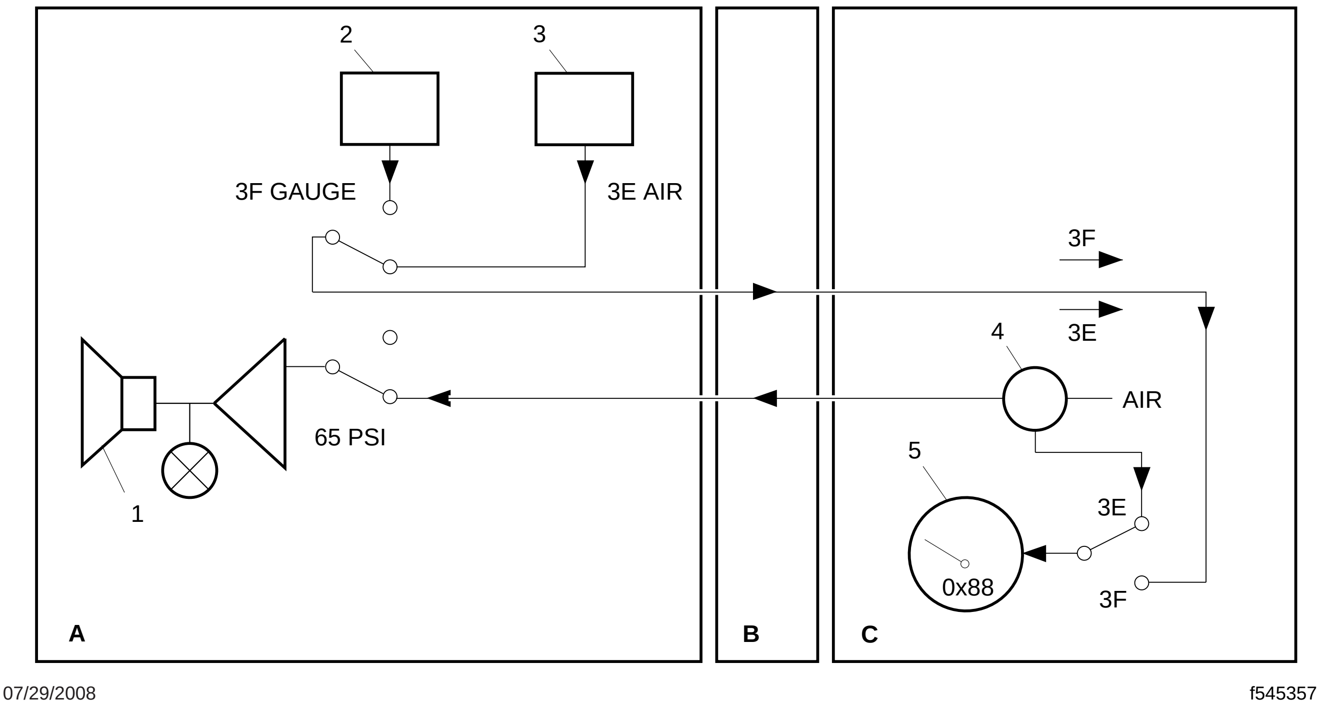


A. Use the "Check Gauges" diagnostic menu to try to move the gauge.
B. Use ServiceLink® to check for the diagnostic trouble code SPN 117.
C. If the reading on the gauge is below 65 psi (448 kPa) check the air circuit.

1. Air Line
2. Air Pressure Transducer
3. LIN Datalink
4. Compass

Fig. 5, Air Pressure Gauge Check

Troubleshooting

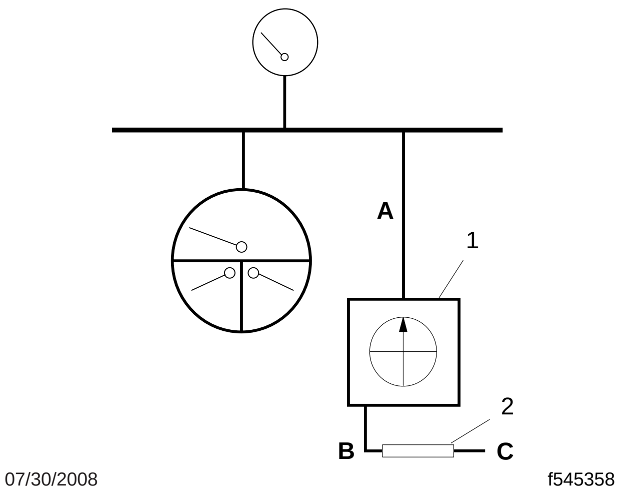


A. LBCU
1. Audible Alarm
2. Test Menu

B. LIN
3. Request Air
4. Sensor

C. Air Gauge
5. Gauge

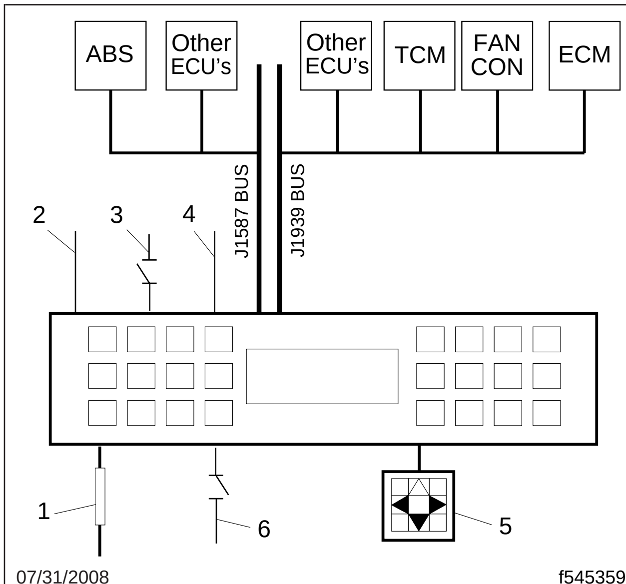
Fig. 6, Air Pressure Message on LIN



A. If the compass module is not properly attached or LIN messages are not received, the compass line will not show up in the menu.
B. If the temperature sensor is not connected, the menu will show sensor loss in the temperature position.
C. If the sensor is shorted or out of range, the temperature field will show dashes (------).

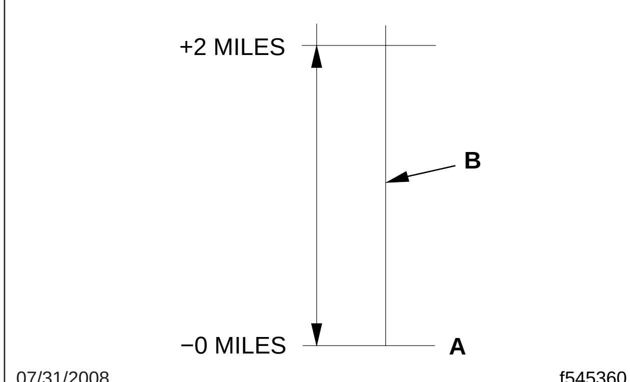
1. Compass
2. Temperature Sensor

Fig. 7, Compass Diagnostics



1. Fuel Sender
2. Battery Voltage
3. Ignition
4. Digital Output
5. Toggle Switch
6. Digital Inputs

Fig. 8, Using the LBCU to Retreive Diagnostic Trouble Codes



A. Current Odometer Mileage
B. New Value

Fig. 9, Odometer Information

Specifications

24-Pin Light Bar Control Unit Pin Descriptions			
Pin	**Description**	**Pin**	**Description**
A1	(+) Panel Backlight Power (PWM)*	B1	Optional Indicator #5—ground activated
A2	Future CAN (not connected to LBCU)	B2	Engine Brake Active Output—12V activated
A3	Engine Brake Level Input—ground activated	B3	J1708/J1587 datalink (–)
A4	Generator Engaged Input—12V activated	B4	Engine Brake Level Input—ground activated
A5	Optional Brake Wear Switch—ground activated	B5	Future CAN (not connected to LBCU)
A6	Optional Indicator #2—ground activated	B6	Future CAN (not connected to LBCU)
A7	Optional Indicator #3—ground activated	B7	Future CAN (not connected to LBCU)
A8	Optional Indicator #4—ground activated	B8	Optional Indicator #6—ground activated
A9	Water in Fuel Input—ground activated	B9	Cruise On/Off Input—ground activated
A10	(+) High Side Resistive Ladder—Display Control Switch Input	B10	J1708/J1587 datalink (+)
A11	(–) Low Side Resistive Ladder—Display Control Switch Input	B11	Hydraulic ABS Indicator—ground activated
A12	High Beam Warning Lamp—12V activated	B12	Optional Buzzer Input—ground activated

* PWM = Pulse Width Modulation

Table 1, 24-Pin Light Bar Control Unit Pin Descriptions

32-Pin Light Bar Control Unit Pin Descriptions			
Pin	**Description**	**Pin**	**Description**
C1	Cruise Set/Decelerate Switch—ground activated	D1	(+) Fuel Level Sensor
C2	Optional Low Current Output (ground)—Starter Lockout	D2	(–) Fuel Level Sensor
C3	Optional Low Current Output (ground)—Vehicle Charging	D3	(–) Panel Backlight Ground
C4	Optional Tag Axle Input—12V activated	D4	Optional Indicator #8—12V activated
C5	Park Brake Warning Lamp—ground activated	D5	J1939 (+)
C6	Optional 12V Input	D6	Optional Low Current Output—ground activated
C7	Optional 12V Input	D7	Optional Input—ground activated
C8	Left Turn Indicator—12V activated	D8	Right Turn Indicator—12V activated
C9	—	D9	J1939 (–)
C10	—	D10	Rain Sensor Input
C11	Optional Indicator #7—ground activated	D11	Service Brake Switch Input
C12	Cruise Resume/Accelerate Switch—ground activated	D12	Pneumatic ABS Indicator—ground deactivated
C13	Brake Fuse—normally >12V	D13	Printed Circuit Board—ground
C14	Optional Indicator #1—ground activated	D14	(+) Battery Power
C15	Future J1850 Input (not connected to LBCU)	D15	(+) Ignition Power

Specifications

32-Pin Light Bar Control Unit Pin Descriptions			
Pin	**Description**	**Pin**	**Description**
C16	Spare Analog Input	D16	(+) Headlamp Power Input 12V—used to control LCD brightness

Table 2, 32-Pin Light Bar Control Unit Pin Descriptions

See **Table 3** and **Fig. 1** for a description and illustration of the daisy chain/local interconnect network (LIN) line and pin connection priority. An example of the daisy chain routing is shown in **Fig. 2**.

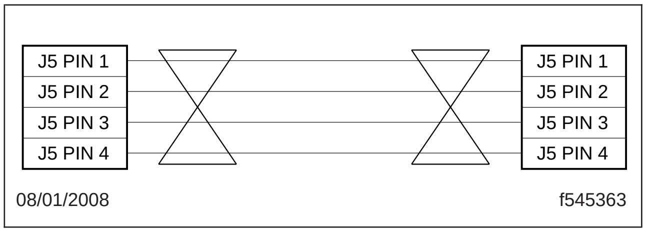
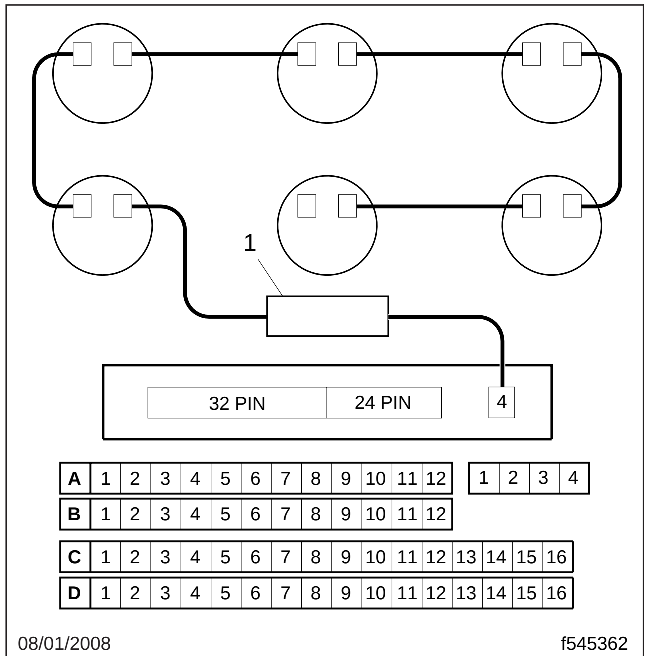


Fig. 1, Daisy Chain/LIN Datalink Connection Priority



1. Ferrot Diode

Fig. 2, Daisy Chain Routing

Daisy Chain/LIN Datalink Pin Description		
Pin	**Designation**	**Description**
J5/1	Gauge Power	5V protected to gauges
J5/2	Ground	Ground for gauges and backlighting
J5/3	LIN Datalink	—
J5/4	Gauges—Dimmed Light	Dimmer output to the gauges

Table 3, Daisy Chain/LIN Datalink Pin Description

Gauge Overview				
Gauge	**Data Source**	**Optional**	**Range/Scale**	**Unit**
Speedometer	SPN84 from Engine	No	0–85	mph
Fuel Level	Stewart Warner Sensor Analog Input	No	E–F	N/A

Specifications

Gauge Overview				
Gauge	**Data Source**	**Optional**	**Range/Scale**	**Unit**
Transmission Oil Temperature	SPN 177 from Transmission	Yes	125–300	Fahrenheit
Primary Air System Pressure	Pressure Transducer over LIN	Yes	0–150	psi
Secondary Air System Pressure	Pressure Transducer over LIN	Yes	0–150	psi
Turbo Boost Air Pressure	SPN 102 from Engine	Yes	0–50	psi
Application Air Pressure	Pressure Transducer over LIN	Yes	0–150	psi
Suspension Air Pressure	Pressure Transducer over LIN	Yes	0–150	psi
Battery Voltage	SPN 158/SPN 168 from Engine	Yes	10–16	Volts
Engine Coolant Temperature	SPN 110 from Engine	Yes	100 (cold)–250 (hot)	Fahrenheit
Engine Oil Pressure	SPN 100 from Engine	Yes	0–100	psi
Tachometer	SPN 190 from Engine	Yes	0–35	rpm x 100

Table 4, Gauge Overview

24-Pin Description, Pins A1 Through A12			
Pin	**Designation**	**Description**	**Cleaning Current**
A1	Panel Backlight Power (+)	Panel Backlight Power From Pulse Width Modulator (PDM) Dimmer Switch	No
A2	TBD CAN 1 (+)	Future CAN (not connected)	N/A
A3	Ground Input	Engine Brake Level Input	Yes
A4	Generator Engaged Input	12V Activated Input	Yes
A5	Optional Ground Input	Ground Activated Input, Brake Wear Switch Input	Yes
A6	Optional Indicator #2	Optional Ground Activated Telltale Indicator	Yes
A7	Optional Indicator #3	Optional Ground Activated Telltale Indicator	Yes
A8	Optional Indicator #4	Optional Ground Activated Telltale Indicator	Yes
A9	Optional Ground Input	Ground Activated Input, Water-In-Fuel Input	Yes
A10	Display Control Switch Input (+)	High Slide Resistive Ladder Input From Switch Bank	N/A
A11	Display Control Switch Input (–)	Low Slide Resistive Ladder Input From Switch Bank	N/A
A12	High Beam Lamp	12V and Micro Activated Telltale Indicator	Yes

Table 5, 24-Pin Description, Pins A1 Through A12

Specifications

24-Pin Description, Pins B1 Through B12

Pin	Designation	Description	Cleaning Current
B1	Optional Indicator #5	Optional Ground Activated Telltale Indicator	Yes
B2	12V Output	Engine Brake Active Output; Sourcing Per Section	N/A
B3	J1708/J1587 Network (–)	Low Side; Tri-State Transceiver Controlled	N/A
B4	Ground Input	Engine Brake Level Input	Yes
B5	TBD CAN 1 (–)	Future CAN (not connected)	N/A
B6	TBD CAN 2 (+)	Future CAN (not connected)	N/A
B7	TBD CAN 2 (–)	Future CAN (not connected)	N/A
B8	Optional Indicator #6	Optional Ground Activated Telltale Indicator	Yes
B9	Ground Input	Cruise Control Switch Input	Yes
B10	J1708/J1587 Network (+)	High Side; Tri-State Transceiver Controlled	N/A
B11	Hydraulic ABS Indicator	Ground and Micro Activated Telltale Indicator	N/A
B12	Optional Ground Buzzer Input	Optional Ground Activated Buzzer	Yes

Table 6, 24-Pin Description, Pins B1 Through B12

General Information

The main purpose of the refrigerant compressor is to draw refrigerant gas from the evaporator and squeeze it into high-pressure gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid so that it can be used for cooling again. A second purpose of the compressor is to move refrigerant through the air conditioning system.

The compressor is cycled by a thermostatic switch. When there is enough of a temperature drop in the cab, the switch breaks the circuit to the compressor's clutch. When the clutch is disengaged, its pulley is free-wheeling and the compressor shaft is not turning. When the clutch is engaged, it holds to the pulley, and the turning of the pulley causes the compressor shaft to turn.

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, purge or flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves; when refrigerant gas or liquid contacts leather, the leather will stick to your skin.

WARNING

Use care to prevent refrigerant from touching your skin or eyes, because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come into contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (139 kPa) absolute at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion that could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, charged, and leak tested. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer's instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following:

- keep the oil free of contaminants
- do not expose the a/c system or the PAG oil container to air; PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use.
- use care when handling: painted surfaces, plastic parts, and other components (drive belts) could be damaged if PAG oil is spilled on them
- never mix PAG oil with other types of refrigerant oil

Pre-Service Checks

WARNING

Before doing any work, read the information under Safety Precautions 100. Failure to read the safety precautions, and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

Some special tools are needed for doing repair work on the compressor. Refer to the list of special tool suppliers in **Specifications 400**. Tool kits can be bought from the distributor listed in **Specifications 400**.

NOTE: Compressor problems usually show in one of four ways: abnormal noise; seizure; leakage; or low suction and discharge pressures. Resonant compressor noises are not causes for alarm; irregular noise or rattles are likely to be caused by broken parts. To check for seizure, de-energize the magnetic clutch and see if the drive plate can be turned. If it won't turn, the compressor has seized.

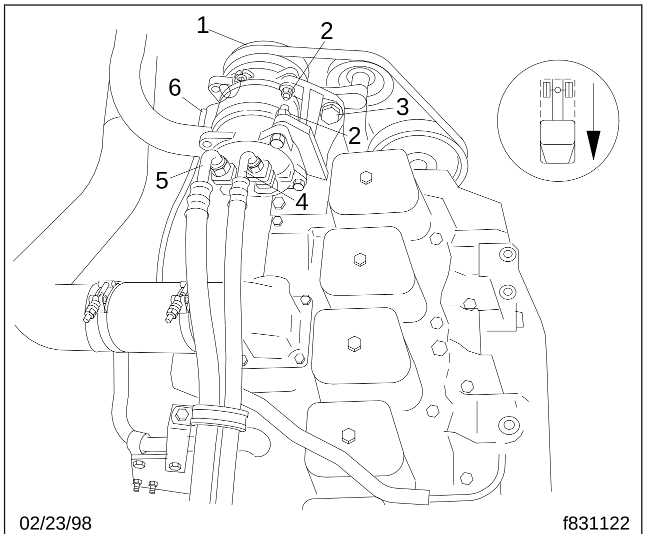
Do the following checks whenever the air conditioner system is not cooling enough and the causes are unknown.

1. Check the drive belt and mounting:
   - 1.1 On the drive belt, look for wear, damage, or oil. If worn, oil-soaked, or damaged, remove it and install a new one. Refer to the drive belt section in **Group 01** of this manual for instructions.
   - 1.2 Check the compressor mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners to the torque value in the torque specifications table under **Specifications 400**. Repair or replace cracked or damaged brackets.
   - 1.3 Check the tension of the compressor drive belt. Refer to the drive belt section in **Group 01** of this manual for instructions.
   - 1.4 Check the compressor oil level. Refer to **Subject 130** for instructions.
2. Check the wiring and connections to the compressor clutch. Replace damaged wiring and tighten loose connections.
3. Check for road debris build-up on the condenser coil fins. Using air pressure and a whiskbroom or a solution of soap and water, carefully clean the condenser; be careful not to bend the fins.
4. Check the refrigerant charge in the air conditioner system; for instructions, refer to the body builder's manual.
5. Check the valve plate and cylinder gasket, and the shaft seal for damage. Replace as needed. See **Subject 160** and **Subject 150**.

Compressor Removal and Installation

Removal

1. Apply the brakes and chock the tires. Open the access panel at the front of the vehicle.
2. Recover the refrigerant from the air conditioning system; for instructions, refer to **Section 83.01, Subject 120**.
3. Clean the compressor around the hose connections. Disconnect the discharge and inlet lines from the compressor. Quickly cap the discharge and inlet ports, and plug the fittings. See **Fig. 1**.



1. Compressor
2. Mounting Bolts
3. Adjusting Bolt
4. Discharge Line
5. Inlet Line
6. Positive Power Lead

Fig. 1, Refrigerant Compressor

IMPORTANT: Under no circumstances should the ports on the compressor remain uncapped or the fittings remain unplugged for longer than five minutes total. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

4. Disconnect the positive power lead to the clutch.
5. Loosen the adjusting bolt on the compressor mounting bracket, turn the adjuster down, and remove the V-belt.
6. Remove the four bolts and nuts that fasten the compressor to the compressor mounting bracket.
7. Remove the compressor.

Installation

IMPORTANT: A new compressor is filled with nitrogen gas and 6.8 fl oz (200 mL) of refrigerant oil. When installing a new compressor on the vehicle, do all of the steps below; if installing a used compressor, skip the following step, and proceed with the installation.

1. Prepare a new compressor.
   1.1 Slowly release the nitrogen from the discharge side of the compressor. Be careful not to let the oil flow out.
   1.2 Turn the compressor shaft several times by hand to distribute oil which has settled in the cylinders.
2. Place the compressor on the compressor mounting bracket and attach the two lower mounting bolts and nuts. Hand tighten the nuts. Attach the upper bolts and nuts to the compressor and bracket, and hand tighten the nuts.
3. Attach the V-belt to the compressor and the adjuster. Adjust the belt tension. For instructions, refer to the applicable section in **Group 01**.
4. Tighten the compressor mounting bolts 33 lbf·ft (45 N·m).
5. Uncap the discharge and inlet ports on the compressor. Unplug the fittings. Check the fittings, and the discharge and inlet ports. They must be clean and free of nicks, gasket residue, and other foreign material.
6. Replace the O-rings in the fittings. Lubricate the O-rings with mineral oil before installing.
7. Attach the discharge and inlet lines to the compressor. Tighten the inlet fitting 29 lbf·ft (39 N·m). Tighten the discharge fitting 27 lbf·ft (37 N·m).
8. Connect the positive power lead to the clutch.
9. Add refrigerant oil to the compressor

IMPORTANT: Whenever the refrigerant system is open, the receiver-drier needs to be replaced. For instructions, refer to **Section 83.01, Subject 110**.

Compressor Removal and Installation

10. Evacuate, charge, and leak test the refrigerant system. For instructions, refer to **Section 83.01, Subject 120**.
11. Close the access panel and remove the chocks.

General Information

IMPORTANT: Add the same amount of oil that is removed when the system is discharged or recovered, or when a system part is replaced. Oil must be from a container that has not been opened, or that has been tightly sealed since its last use. For R–134a systems, order Sanden oil SKI/7803-1997 from your local parts distribution center. Tubing, funnels, or other equipment used to transfer the oil should be very clean and dry.

When installing or replacing a compressor, condenser, receiver-drier, or refrigerant line, a certain amount of refrigerant oil is lost. The list below provides approximate refill amounts for the R–134a air conditioning system.

A. Oil charge—the entire system should have *about* 14 fl oz (414 mL) of refrigerant oil. There should be 10 fl oz (296 mL) in the compressor. Each major component has *about* 2.0 fl oz (59 mL) of oil (this amount has been rounded off for ease of adding oil to the compressor). Therefore, additional oil must be added to the compressor when a major component is replaced.

NOTE: As an example, if the condenser and the receiver-drier are to be replaced, first check the oil level of the compressor. The compressor should have 10 fl oz (296 mL). Add oil if needed. Then, after replacing the condenser and the receiver-drier, add an additional 4.0 fl oz (118 mL) of oil to the compressor. The entire system should then have about 14 fl oz (414 mL).

IMPORTANT: New compressors are factory-charged with about 6.8 oz (200 mL) of refrigerant oil. Some refrigerant oil is circulated through the system with the refrigerant and cannot leave the system except through a leak, when the system is recovered, or when a system part is replaced.

B. Receiver-drier—when the receiver-drier is replaced, *about* 2.0 fl oz (59 mL) must be added to the compressor (in addition to the 10 fl oz [296 mL] that the compressor requires).

IMPORTANT: A new receiver-drier does not contain any refrigerant oil.

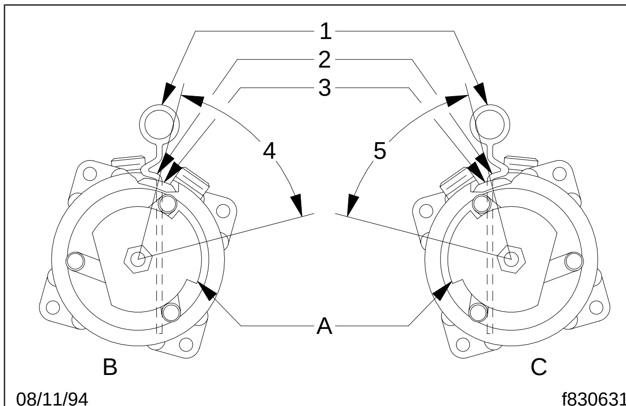
C. Condenser—when the condenser is replaced, *about* 2.0 fl oz (59 mL) must be added to the compressor (in addition to the 10 fl oz [296 mL] that the compressor requires).

D. Refrigerant line—when a refrigerant line is installed or replaced, add 2 fl oz (59 mL) of refrigerant oil to the system.

When handling refrigerant oil:

- The oil should be free of water, dust, metal powder, and other foreign substances.
- Don't mix refrigerant oil with other types or viscosities of oil.
- Refrigerant oil absorbs moisture when exposed to the air for any period. After use, quickly seal the oil container.

IMPORTANT: Check the compressor oil level at the time of installation and whenever a loss of refrigerant oil has occurred.



A. Position of counterweight.
B. Mounting angle right.
C. Mounting angle left.

1. Dipstick
2. Dipstick Stop
3. Oil Fill Hole
4. 2 o'Clock
5. 10 o'Clock

Fig. 1, Checking the Oil Level

⚠ WARNING

Don't remove the oil fill plug without first recovering the system. Failure to recover the system could cause uncontrolled release of high-pressure refrigerant, which can freeze skin and eye tissue causing serious injury or blindness.

Oil Check and Adding Oil to the Compressor

1. Run the compressor for 10 minutes with the engine at idle. Shut down the engine.
2. Recover all of the refrigerant from the system.
3. Determine the mounting angle of the compressor from horizontal (oil fill plug on top).
4. Remove the oil fill plug. Using a socket wrench on the armature retaining nut, turn the shaft clockwise until the counterweight is positioned correctly. See **Fig. 1**.
5. Check the oil level with the dipstick. Make sure the angle of the dipstick stop is pointing in the right direction. See **Fig. 1**.

   Remove the dipstick and count the number of notches covered by the oil (each notch equals 1 fl oz [30 mL]). If the notches read on the dipstick do not match the specifications in **Table 1**, add or subtract oil to the mid-range value. For example, if the mounting angle is zero degrees, add oil in 1fl oz (30 mL) increments until 6 is read on the dipstick.

Oil Quantity at Various Mounting Angles	
Mounting Angle Degrees	**Oil Quantity fl oz (mL)**
0	5 to 7 (148 to 207)
10	6 to 8 (177 to 237)
20	7 to 9 (207 to 266)
30	8 to 10 (237 to 296)
40	9 to 11 (266 to 325)
50	10 to 12 (296 to 355)
60	11 to 13 (325 to 384)
90	16 to 18 (473 to 532)

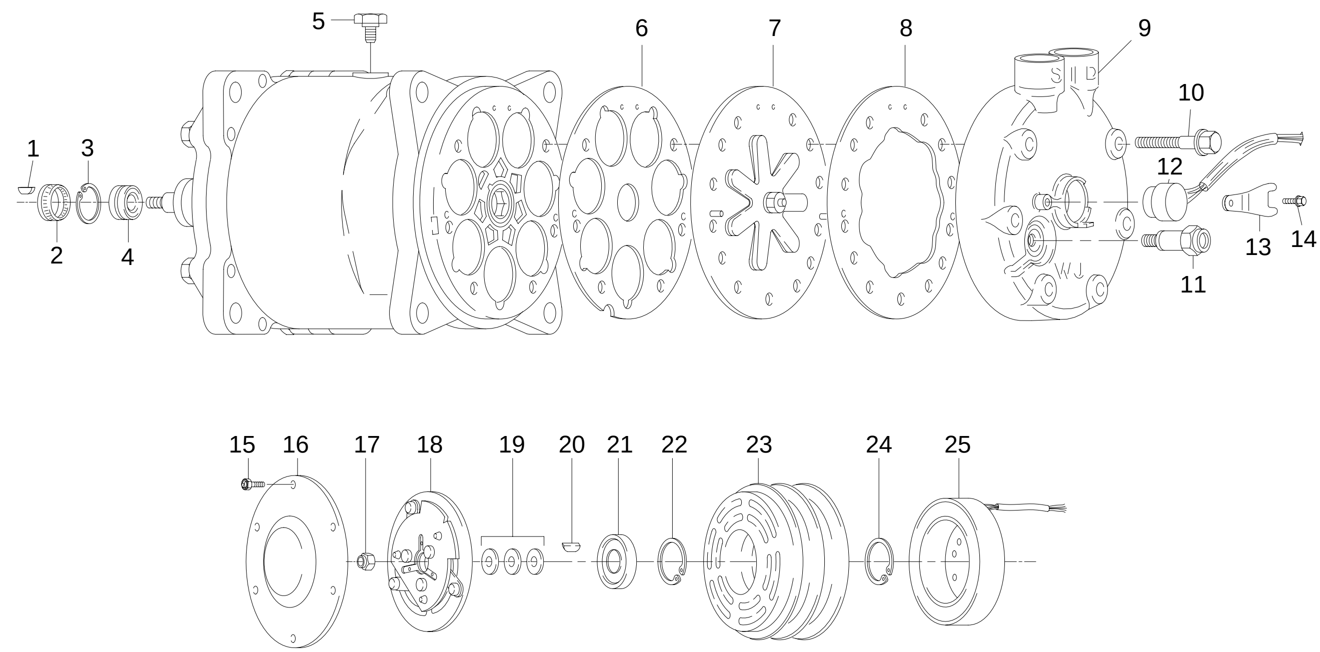
Table 1, Oil Quantity at Various Mounting Angles

NOTE: A dipstick can be made locally or purchased from a special tools supplier. Refer to the list of special tool suppliers in **Specifications 400**.

6. Being careful not to twist the O-ring, insert the plug in the oil fill opening. Tighten the plug 11 to 19 lbf·ft (15 to 25 N·m).
7. Evacuate, charge, and leak test the refrigerant system. For instructions, refer to Section 83.01, **Subject 120**.

Clutch Assembly Removal, Inspection, and Installation

Removal

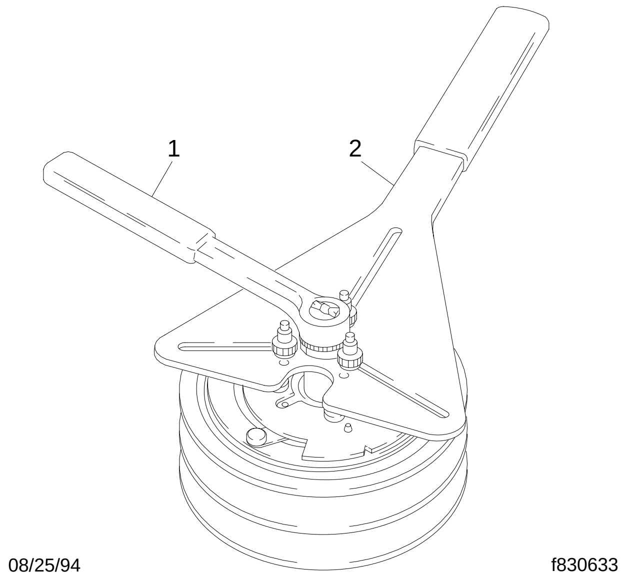


1. Shaft Key
2. Felt Ring
3. Shaft Seal Snap Ring
4. Shaft Seal (with O-ring)
5. Oil Plug
6. Block Gasket
7. Valve Plate Assembly
8. Head Gasket
9. Cylinder Head
10. Cylinder Head Bolt
11. Pressure Relief Valve
12. Thermal Protector Switch, TPS (optional)
13. TPS Clip (optional)
14. TPS Screw (optional)
15. Dust Cover Screw
16. Dust Cover
17. Shaft Nut
18. Drive Plate
19. Clutch Shims
20. Shaft Key
21. Pulley Bearing Dust Cover
22. Pulley Snap Ring
23. Pulley Assembly
24. Field Coil Assembly Snap Ring
25. Field Coil Assembly, Exploded View

Fig. 1, Refrigerant Compressor, Exploded View

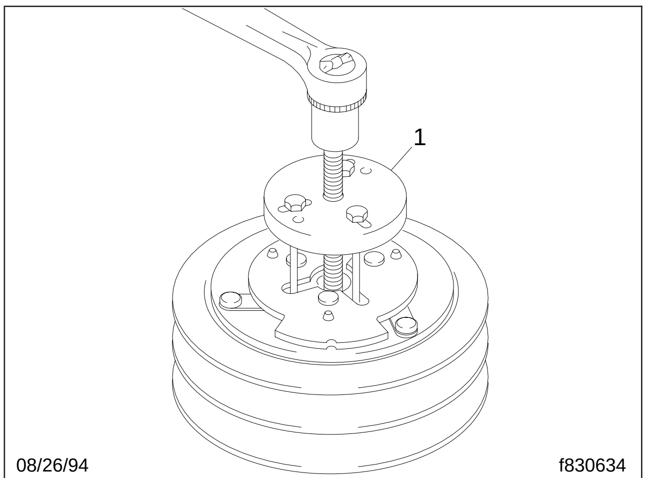
1. Remove the compressor from the vehicle. See **Fig. 1**. For instructions, refer to **Subject 120**.
2. Remove the six bolts that attach the drive plate cover and remove the cover.
3. Insert the pins of the drive plate spanner into the threaded holes of the drive plate. Hold the drive plate securely while removing the retaining nut. See **Fig. 2** .
4. Using the drive-plate puller, thread the three puller bolts into the drive plate. Turn the center screw clockwise to loosen and remove the drive plate. See **Fig. 3**.
5. Remove the pulley bearing dust cover (if equipped), the shaft key, and the clutch shims. Use a slotted screwdriver and hammer to tap the shaft key loose. See **Fig. 4** .
6. Using external snap-ring pliers, remove the pulley assembly snap ring.
7. Remove the pulley assembly.
   - 7.1 Insert the lip of the pulley puller jaws into the snap ring groove. See **Fig. 5**.
   - 7.2 Place the puller shaft protector over the exposed shaft.

Clutch Assembly Removal, Inspection, and Installation



1. Socket Wrench 2. Drive Plate Spanner

Fig. 2, Remove the Retaining Nut



1. Puller

Fig. 3, Remove the Drive Plate

7.3 Align the thumb screws to the puller jaws. Tighten the screws finger tight.

7.4 Using a socket wrench, turn the puller center bolt clockwise and remove the pulley.

8. Remove the coil assembly.

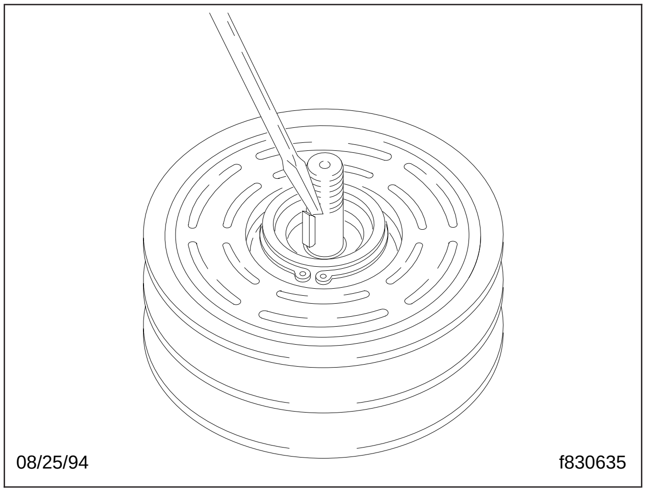
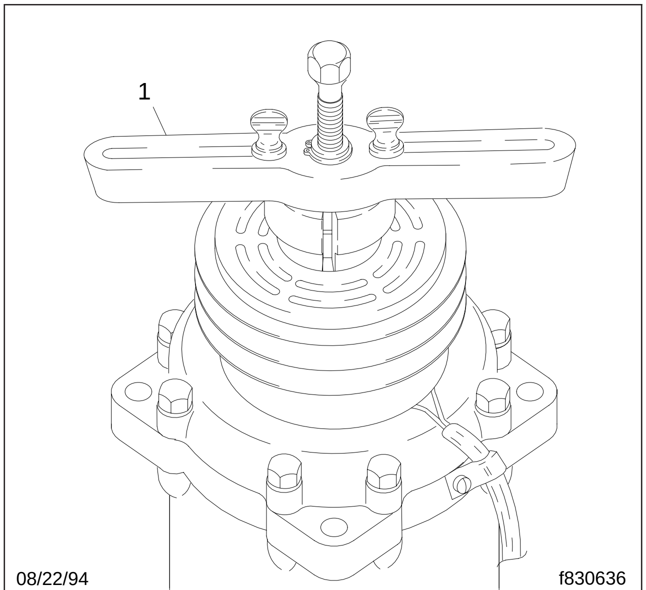


Fig. 4, Remove the Shaft Key



1. Pulley Puller

Fig. 5, Position the Pulley Puller Jaws

8.1 Remove the coil's lead wire from the wire holder on the compressor.

8.2 Disconnect the wiring harness.

8.3 Remove the snap ring; then, remove the coil assembly. See **Fig. 6**.

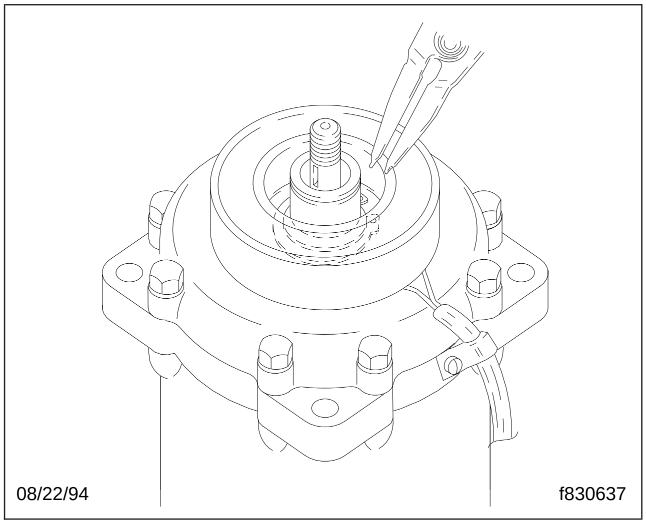


Fig. 6, Remove the Snap Ring

Inspection

1. Inspect the drive plate. If the frictional surface shows signs of damage due to too much heat, replace the drive plate and pulley assembly.
2. Check the appearance of the pulley assembly. If the friction surface of the pulley shows signs of too much grooving due to slippage, replace both the pulley and drive plate. Clean the friction surfaces of the pulley assembly before installing it.
3. Check the coil for a loose connector and for cracked insulation. Replace it if necessary.

Installation

NOTE: When supporting the compressor in a vise, clamp only on the mounting ears, never on the body of the compressor.

1. Install the coil assembly.
   - 1.1 Position the coil assembly on the compressor.
   - 1.2 Install the snap ring.
   - 1.3 Attach the coil's lead wire to the wire holder on the compressor.
   - 1.4 Connect the wiring harness.
2. Install the pulley assembly.
   - 2.1 Position the pulley over the boss of the front housing.
   - 2.2 Place the pulley installer ring into the bearing bore. Make sure that the edge rests only on the inner race of the bearing, not on the seal, pulley, or outer race of the bearing.
   - 2.3 Place the driver into the ring. Using a hammer or arbor press, drive the pulley down against the front housing step. See **Fig. 7**.

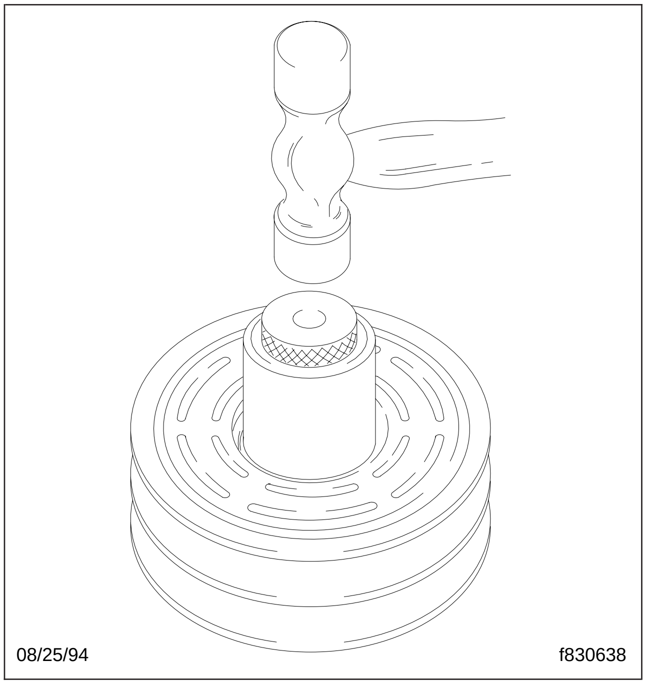


Fig. 7, Drive the Pulley Down Against the Front Housing Step

   - 2.4 Using internal snap ring pliers, install the pulley bearing snap ring.
   - 2.5 Using external snap ring pliers, install the pulley snap ring. If a bevel is present on the snap ring, make sure that it is facing up (away from the body of the compressor).
   - 2.6 Install the pulley bearing dust cover by gently tapping it into place.
3. Install the drive plate assembly.

Clutch Assembly Removal, Inspection, and Installation

3.1 Using pliers, install the shaft key. See **Fig. 8**.

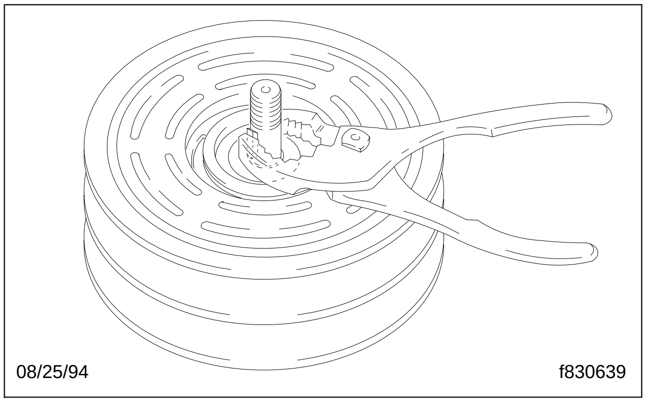


Fig. 8, Install the Shaft Key

3.2 Install the shims.

3.3 Align the keyway in the drive plate assembly with the shaft key. Using a driver, and a hammer or an arbor press, drive the assembly down over the shaft until it bottoms on the shims. See **Fig. 9**.

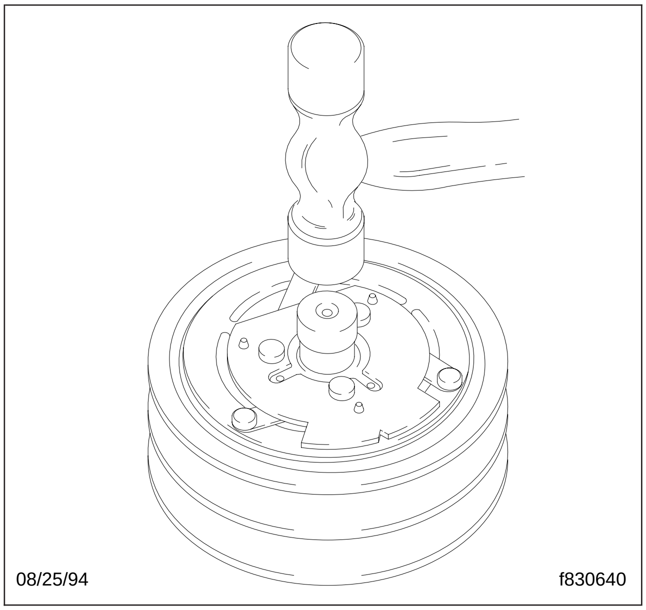


Fig. 9, Install the Drive Plate Assembly

3.4 Install the retaining nut. If the nut is 1/2 inch, tighten it 22 lbf·ft (30 N·m); if the nut is M8, tighten it 13 lbf·ft (18 N·m).

4. Using a feeler gauge, check that the clutch clearance is 0.02 to 0.03 inch (0.4 to 0.8 mm). See **Fig. 10**. Adjust the clearance by gently tapping down on the front plate at the high spots, or gently prying up at the low spots.

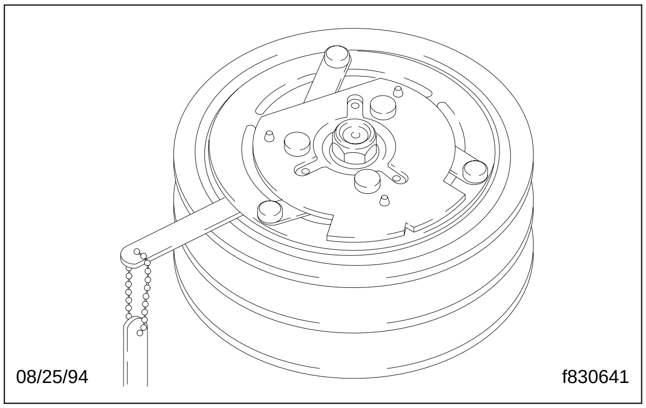


Fig. 10, Check the Clutch Clearance

5. Install the drive plate dust cover. Tighten the dust cover bolts 78 lbf·in (881 N·cm).

6. Install the compressor on the vehicle. For instructions, refer to **Subject 120**.

Replacement

1. Remove the drive plate and pulley assemblies. For instructions, refer to **Subject 140**.
2. Using snap ring pliers, remove the felt ring retainer. See **Fig. 1.** Then remove the felt ring.

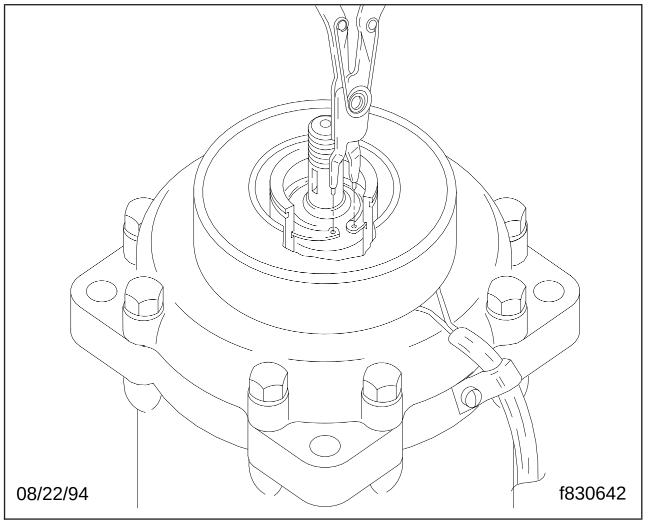
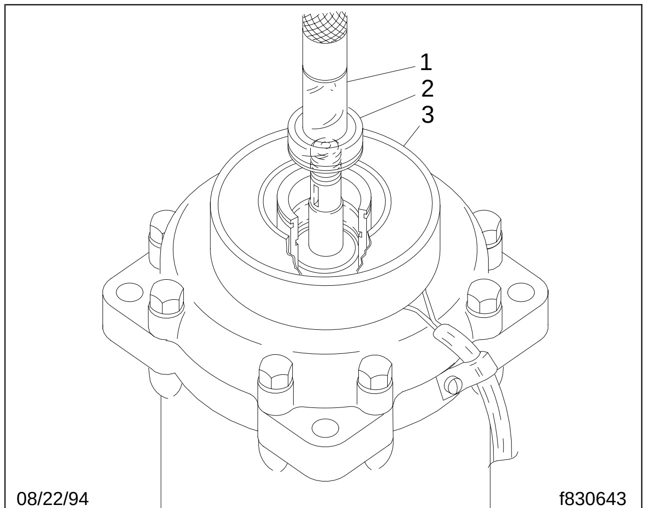


Fig. 1, Remove the Felt Ring Retainer and the Felt Ring

3. Using snap ring pliers, remove the shaft seal snap ring.
4. Position the shaft seal removal and installation tool on the shaft seal. Twist the tool until the hooks on the tool engage the slots in the shaft seal housing, then pull the seal out with a twisting motion. See **Fig. 2**.

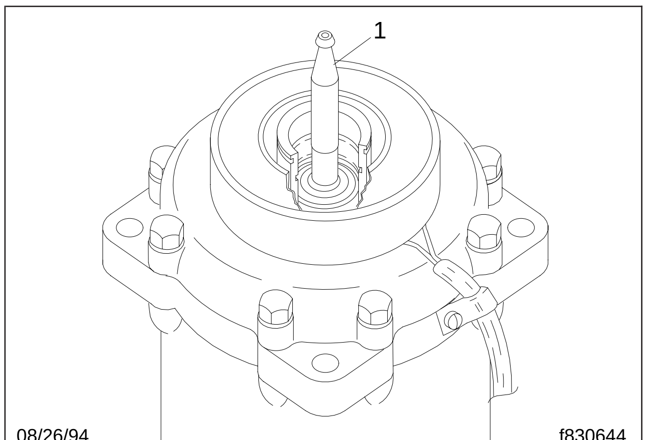
NOTE: The shaft seal and felt ring should not be reused. Always use a new seal kit. Be very careful that the lip of the shaft seal to be installed is not scratched or damaged in any way. Make sure the shaft seal is free of lint and dirt, which could damage the shaft seal surface.

5. Using a non-petroleum based solvent and a lint-free cloth, clean the shaft seal cavity. Then, use dry compressed air to blow out the shaft seal cavity.
6. Position the shaft seal protective sleeve over the compressor shaft. See **Fig. 3** . Make sure that the sleeve has no scratches so that the shaft seal will not be damaged. Also, make sure that there is no gap between the end of the sleeve and the seal surface of the shaft.



1. Shaft Seal Removal and Installation Tool
2. Shaft Seal
3. Coil Assembly

Fig. 2, Remove the Shaft Seal



1. Protective Sleeve

Fig. 3, Position the Shaft Seal Protective Sleeve

7. Position the shaft seal removal and installation tool until the hooks on the tool engage the slots in the new shaft seal housing.
8. Place the entire assembly into clean 5GS refrigerant oil. See **Fig. 4**.
9. Insert the shaft seal over the protective sleeve, then press it down as far as possible. Twist the

Shaft Seal Replacement

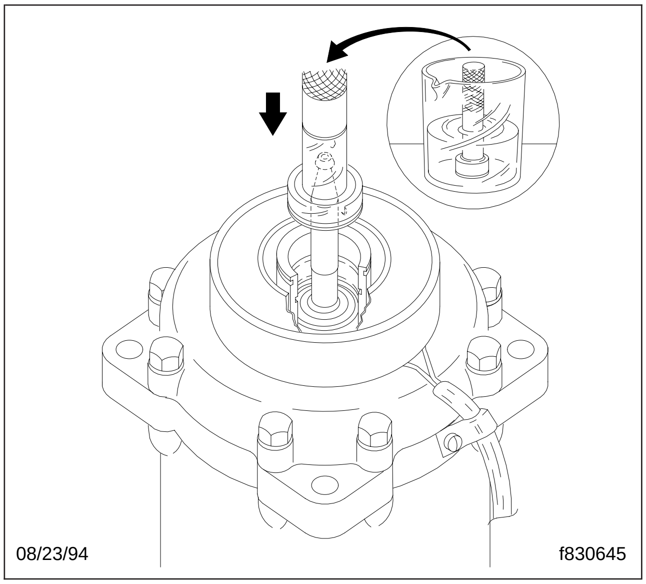


Fig. 4, Place the Shaft Seal Assembly into Clean Refrigerant Oil

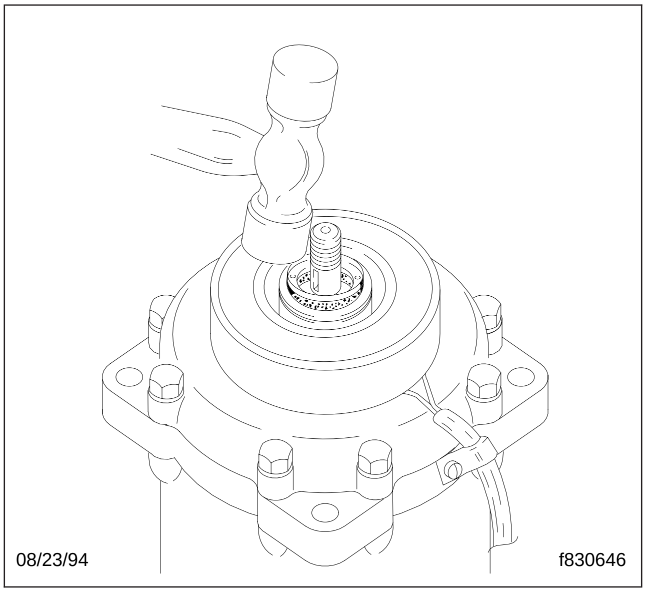


Fig. 5, Tap the New Felt Ring in Place

removal and installation tool to remove it from the seal. Remove the tool and the protective sleeve.

10. Using internal snap-ring pliers, install the snap ring. See **Fig. 1**. If needed, gently tap the snap ring to ensure that it is seated in the groove.

NOTE: When installing the snap ring, the beveled end of the snap ring must face away from the compressor body.

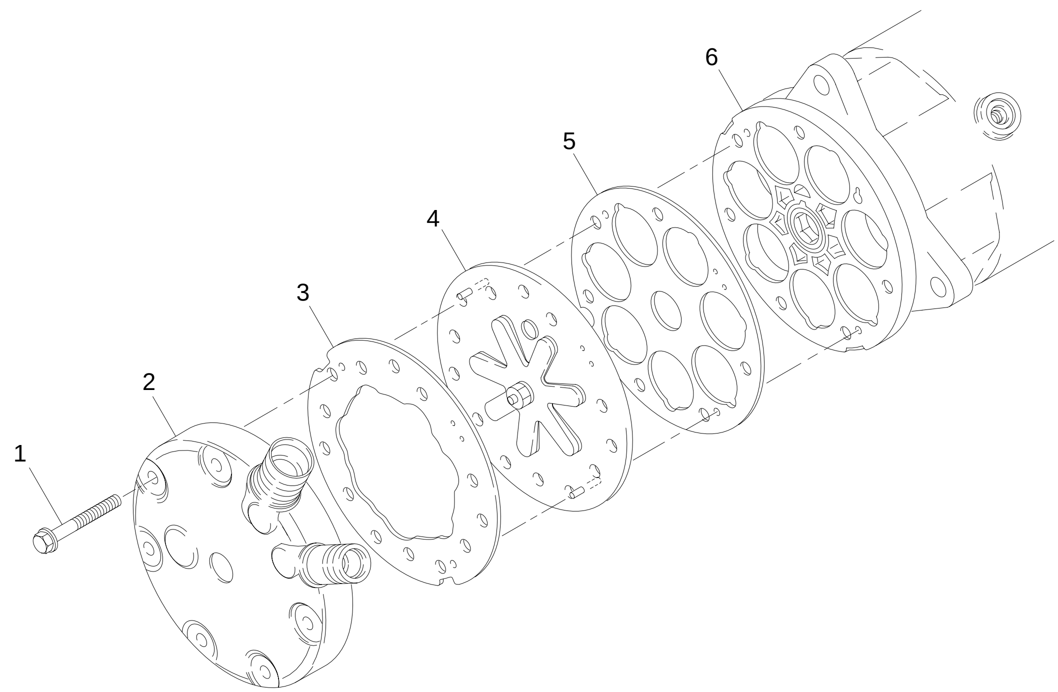
11. Gently tap the new felt ring in place. See **Fig. 5**.
12. Install the drive plate and pulley assemblies. For instructions, refer to **Subject 140**.

Head and Valve Plate Removal and Installation

Removal

NOTE: Before doing any work on the head and valve plate, open both service valves to release any gas pressure in the compressor.

1. Remove the bolts from the cylinder head. See **Fig. 1**.



1. Cylinder Head Bolt
2. Cylinder Head
3. Head Gasket
4. Valve Plate Assembly
5. Block Gasket
6. Compressor Body

Fig. 1, Head and Valve Plate Assembly

2. Remove the valve plate assembly and the cylinder head from the compressor. Use a gasket scraper to separate the cylinder head from the valve plate. See **Fig. 2**. Use care not to scratch the gasket surface of the cylinder head.

CAUTION

Do not hit or tap the head to separate it from the valve plate. Damage to the head may result.

NOTE: It is recommended that the head gasket (located between the cylinder head and the valve plate) and the block gasket (located between the valve plate and the cylinder block) be replaced any time the cylinder head is removed.

3. Being careful not to scratch or nick the machined sealing surfaces, remove all gasket material adhering to the head, valve plate, or compressor block.

Installation

1. Apply a thin film of clean 5GS refrigerant oil to the new block gasket. Place the block gasket in position on the compressor so that the pin holes in the compressor block line up with the pin holes in the block gasket.
2. Place the valve plate assembly in position on the block gasket so that the discharge valve, retainer, and the nut are facing up (away from the cylinder block). Make sure that the locating pins on the valve plate go through the pin holes in the gasket.

Head and Valve Plate Removal and Installation

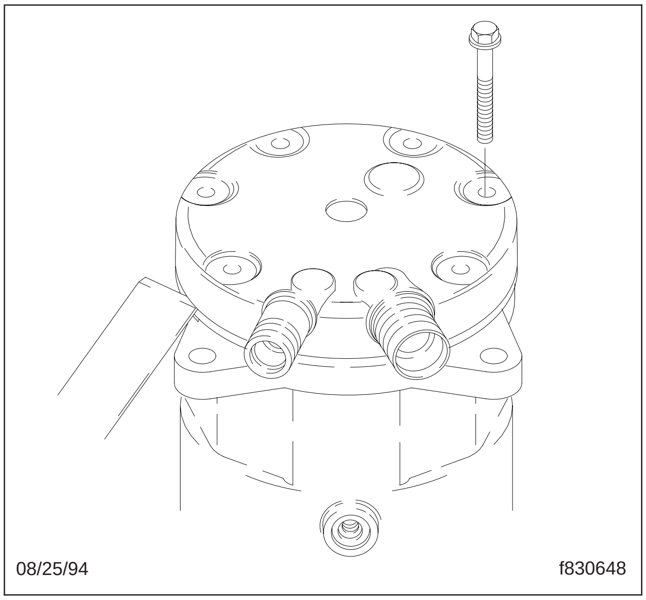


Fig. 2, Separate the Cylinder Head from the Valve Plate

3. Remove all residual oil from each bolt hole on the cylinder block.
4. Apply a thin film of clean 5GS refrigerant oil to the new head gasket. Place the gasket in position over the valve plate locating pins. Make sure that the locating pins on the valve plate go through the pin holes in the gasket.
5. Place the head on the cylinder head gasket so that the dowel pins go into the dowel pin holes in the head.
6. Install the head bolts. If the head bolt is M6, tighten it 10 lbf·ft (14 N·m); if the head bolt is M8, tighten it 25 lbf·ft (34 N·m). See **Fig. 3** for the tightening sequence.

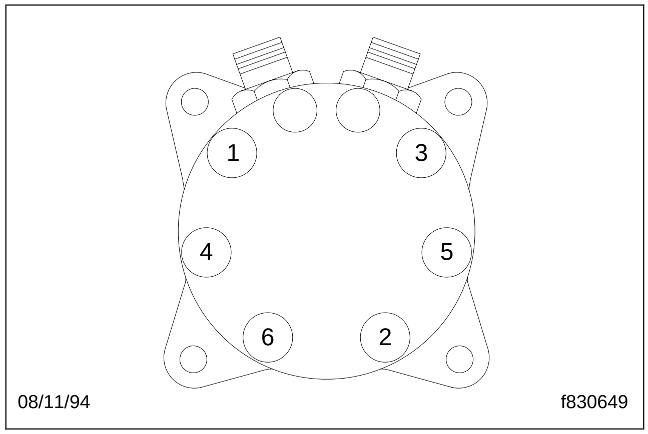


Fig. 3, Tightening Sequence

Specifications

Special tools can be purchased from the following independent suppliers:

Classic Tool Design
31 Walnut St.
New Windsor, NY 12550
(914) 562-8700

Mastercool USA Inc.
216 Route 10, Bldg. 3
Randolph, NJ 07869
(201) 366-1101

Torque Values		
Description	**Torque lbf·ft (N·m)**	**Torque lbf·in (N·cm)**
Compressor Mounting Bolts	33 (45)	—
Compressor, Discharge Fitting	27 (37)	—
Compressor, Inlet Fitting	29 (39)	—
Compressor, Oil Port	11–19 (15–25)	—
Dust Cover Screws, M5	—	78 (881)
Clutch Retaining Nut, 1/2"	22 (30)	—
Clutch Retaining Nut, M8	13 (18)	—
Cylinder Head Bolts, M6	10 (14)	—
Cylinder Head Bolts, M8	25 (34)	—

Table 1, Torque Values

General Information

The components of the air conditioning system that may be supplied by the chassis manufacturer, depending on the vehicle configuration, are the condenser, the condenser fan, and the refrigerant lines. For information on the air conditioning components that are not supplied by the chassis manufacturer, see the body manufacturer's service manual.

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, purge or flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves; when refrigerant gas or liquid contacts leather, the leather will stick to your skin.

WARNING

Use care to prevent refrigerant from touching your skin or eyes, because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come into contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (139 kPa) absolute at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion that could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, charged, and leak tested. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

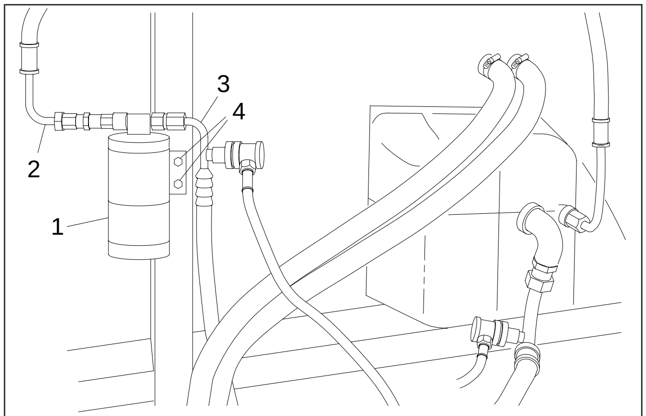
IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer's instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following:

- keep the oil free of contaminants
- do not expose the a/c system or the PAG oil container to air; PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use.
- use care when handling: painted surfaces, plastic parts, and other components (drive belts) could be damaged if PAG oil is spilled on them
- never mix PAG oil with other types of refrigerant oil

Replacement



1. Receiver-Drier
2. Outlet Line
3. Inlet Line
4. Mounting Bolts

Fig. 1, Receiver-Drier

IMPORTANT: The receiver-drier needs to be replaced whenever the refrigerant compressor system is open. See **Fig. 1**.

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions, and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

1. Apply the parking brakes and chock the tires. Open the access panel on the front of the vehicle.
2. Wearing protective goggles and gloves, recover the refrigerant system. For instructions, refer to **Subject 120**.
3. Disconnect the inlet and outlet lines and quickly plug the fittings.

IMPORTANT: Under no circumstances should the fittings remain unplugged for longer than five minutes. Water and dirt, can damage the refrigerant system. Do not blow shop air through the refrigerant hoses since shop air is wet (humid).

4. Remove the bolts that attach the receiver-drier bracket to the firewall, and remove the receiver-drier from the bracket. Remove and discard the receiver-drier.
5. Place a new receiver-drier in the bracket.
6. Place the receiver-drier bracket on the firewall, and install and tighten the bolts.
7. Attach the inlet and outlet lines to the receiver-drier. Tighten the connections 33 lbf·ft (45 N·m).
8. Evacuate and charge the air conditioning system with refrigerant. For instructions, refer to **Subject 120**. Be sure to add refrigerant oil to the compressor to replace that which was lost when the system was discharged. For information, refer to **Section 83.00, Subject 130**.
9. Close the access panel and remove the chocks.

Recovery

⚠ WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant could lead to serious personal injury.

The recovery process removes most of the refrigerant charge in the system.

1. Apply the parking brakes and chock the tires. Open the access panel on the front of the vehicle.
2. Remove the caps from the discharge and inlet service valves.
3. Wearing protective goggles and nonleather gloves, attach the recovery/recycling station hoses to the valves.

   IMPORTANT: Push down firmly on the hose connectors until a clicking sound is heard. This will ensure that the coupler is locked.

   3.1 Make sure that the recovery/recycling station valves are closed.

   3.2 Connect the red high-side hose to the discharge service valve.

   3.3 Connect the blue low-side hose to the inlet service valve.

   3.4 Turn the knob clockwise on each coupler to open the Schrader valves.
4. Follow the recovery/recycling station manufacturer's instructions and recover all of the refrigerant from the system.

IMPORTANT: Always comply with all local regulations regarding refrigerant disposal. You may be subject to substantial penalties for improper disposal.

5. Measure the oil recovered during this procedure. The compressor will have to be refilled with the same quantity of new refrigerant oil.

   If the system is contaminated with moisture, all of the compressor oil must be replaced with clean oil. If the system is heavily contaminated with desiccant or grit, replace the compressor, expansion valve, and receiver-drier.

Evacuating (recycling)

General Information

Moisture in a Refrigerant System

Water forms ice crystals at the thermostatic expansion valve. Ice crystals retard or stop the flow of refrigerant, causing a reduction or complete loss of cooling. As the expansion valve warms due to the lack of refrigerant, the ice melts and passes through the expansion valve. Then refrigerant will flow again until the ice crystals re-form. The result is intermittent cooling.

Refrigerant oil has an extremely high moisture absorption capacity. This reduces the lubricating ability of the oil, which could damage the compressor and other system components.

Effects of Pressure on the Boiling Points of Water

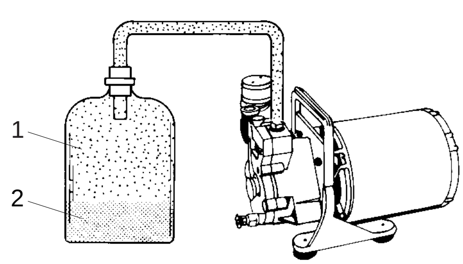
Water boils at 212°F (100°C) at an atmospheric pressure of 14.7 psi (101 kPa) (sea level). At higher elevations the atmospheric pressure is lower which allows water to boil at lower temperatures. See **Table 1** for boiling temperatures of water at converted pressures.

Water Boiling Temperatures at Converted Pressures		
Boiling Temperature of Water °F (°C)	**Absolute Pressure psi (microns)**	**Vacuum inHg (mmHg)**
212 (100)	14.696 (759993.4)	0 (0)
205 (96)	12.770 (660400.0)	99.6 (3.92)
194 (90)	10.169 (523881.6)	9.22 (234.2)
176 (80)	6.8699 (355269.8)	15.93 (404.6)
158 (70)	4.5207 (233786.7)	20.72 (526.3
140 (60)	2.8900 (14958.7)	24.04 (610.6)
122 (50)	1.7987 (92555.1)	26.28 (667.5)
104 (40)	1.0700 (55336.4)	27.74 (704.6)
89 (32)	0.61540 (31826.2)	28.67 (728.2)
86 (30)	0.57010 (26220.4)	28.89 (733.8)
76 (24)	0.44435 (22979.9)	29.02 (737.1)
72 (22)	0.38856 (20094.7)	29.13 (739.9)
69 (21)	0.35084 (18143.7)	29.21 (741.9)

Water Boiling Temperatures at Converted Pressures		
Boiling Temperature of Water °F (°C)	Absolute Pressure psi (microns)	Vacuum inHg (mmHg)
64 (18)	0.29505 (15258.5)	29.32 (744.7)
59 (15)	0.24720 (12783.8)	29.42 (747.3)
53 (12)	0.19888 (10285.0)	29.52 (749.8)
45 (7)	0.14746 (7625.8)	29.62 (752.3)
32 (0)	0.08858 (4579.6)	29.74 (755.4)
21 (–6)	0.05293 (2738.1)	29.81 (757.2)
6 (–14)	0.02521 (1304.0)	29.87 (758.7)
–24 (–31)	0.004905 (253.7)	29.911 (759.74)
–35 (–37)	0.002544 (131.6)	29.915 (759.84)
–60 (–51)	0.0004972 (25.7)	29.9200 (759.968)
–70 (–57)	0.0002443 (12.6)	29.92050 (759.9807)
–90 (–68)	0.0000526 (2.72)	29.92089 (759.9906)

Table 1, Water Boiling Temperatures at Converted Pressures

Similarly we can boil and remove water from the air conditioning system by lowering the system pressure to a vacuum to cause the moisture to vaporize at normal ambient temperatures. A vacuum pump can reduce the pressure in the system. Since the pressure is the lowest at the pump, water vapor is pulled out of the system. See **Fig. 1**. This process is called evacuation or dehydration. Also, most recovery/recycling stations automatically recycle refrigerant during this process to ensure the system will be charged with the cleanest refrigerant possible.



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1. Vapor
2. Water

Fig. 1, Water to Vapor

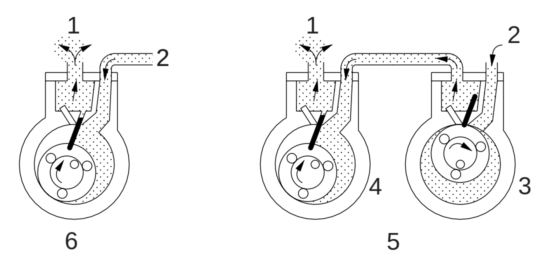
Vacuum Pump Selection

The purpose of a high-vacuum pump is to reduce and hold a vacuum in the air conditioner system so moisture can be boiled at ambient temperature. For example, a vacuum pump capable of pulling a vacuum of 28.89 inHg (734 mmHg), is able to boil water at 80°F (27°C). There are various types of vacuum pumps available. Only some types are recommended for truck air conditioning evacuation.

Air pump-type vacuum pumps are designed to remove large volumes of air but do not develop high vacuum. They cannot pull more than 28 inHg (711 mmHg) which boils water at 100°F (38°C).

Compressor-type vacuum pumps come in two designs: piston-type and rotary-vane type. A piston-type compressor can typically pull a vacuum of 28.2 inHg (727 mmHg) which boils water at 96°F (36°C). A rotary-vane type compressor may pull a vacuum of 29.82 inHg (757 mmHg) which boils water at 21°F (–6°C), but it is limited to pumping 0.4 to 0.8 cfm, which is too slow to handle truck air conditioners.

High-vacuum pumps are available in single-stage and two-stage models. A single-stage model is adequate, but a two-stage model is recommended to save time and ensure complete evacuation. See **Fig. 2**.



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1. Exhaust
2. Intake
3. First
4. Second
5. Two-Stage Pump
6. Single-Stage Pump

Fig. 2, High-Vacuum Pumps

Most single-stage high-vacuum pumps with a gas ballast will pull down to about 29.88 inHg (734 mmHg) which boils water at 4°F (–16°C).

A two-stage high-vacuum pump features a second pump to reach a higher vacuum than a single-stage pump. In a two-stage pump, the exhaust of the first pump discharges into the intake of the second pump.

The second stage pumps at a lower pressure and therefore pulls a higher vacuum on the system than the first pump can by itself.

Two stage high-vacuum pumps are capable of pulling down to 29.9196 inHg (760 mmHg) of vacuum for prolonged periods, which boils water at –60°F (–51°C).

The discharge line restriction is a factor affecting pump-down time. Pump-down time can be significantly reduced by use of larger diameter hoses, as short in length as possible.

Pumping capacity affects pump-down time. It is perfectly acceptable to use a large vacuum pump on a small system. Using too small of a pump on a large system could cause premature pump wear, or require excessive time to pull a vacuum, even though the pump may be able to draw adequate vacuum.

The suggested minimum cfm for pumps on different size air conditioners are listed in **Table 2**.

Suggested Minimum CFM	
System Size	**Suggested High-Vacuum Pump Size**
Panel Trucks Large Window Units	2.2 cfm
Tractor/Trailers, Buses Rooftop A/C systems	3.0 cfm
Refrigeration Van	15.0 cfm

Table 2, Suggested Minimum CFM

Measuring Vacuum

Gauges

Vacuum can be measured with:

- A standard compound gauge;
- A closed-end manometer;
- An electronic thermistor vacuum gauge.

A standard compound gauge reads low pressures in inches of mercury. It is not suitable for measuring high vacuum.

A closed-end U-tube mercury manometer can be read with good accuracy. High vacuum readings can only be read from laboratory-style U-tube manometers, which are not practical for service shops.

An electronic thermistor vacuum gauge is designed for use with high vacuum pumps and can accurately read as low as 100 microns. This gauge can use an analog scale or a digital (LED) display.

Procedure

The location of the vacuum gauge will affect the reading. The closer to the vacuum source, the lower will be the reading.

Isolate the vacuum pump with a good vacuum valve and allow the pressure in the system to stabilize before taking a final reading.

If the pressure will not stabilize, it is an indication of a leak. If it does stabilize at a vacuum which is too high (for example, 1500 microns), it is an indication of moisture and more evacuation is required.

Maintaining the Vacuum Pump

Maintenance is important for high-vacuum pumps. The oil must be changed at regular intervals to prevent moisture build up which will cause eventual pump failure.

Pumping down for extremely wet air conditioning systems can completely saturate the pump oil.

CAUTION

Flush the vacuum pump every fourth time it is used and before storing for long periods of time. Acid will form and corrode the pump if water-laden oil sets in the pump for an extended period.

Vacuum pump oil is water soluble. This aids the pump in reaching a high vacuum by absorbing water and sealing the pump.

Only vacuum pump oil should be used as a lubricant. Do not use any solvent or any other oil. Clean oil should be run through the pump until it runs out clear. Oil should be added to the fill level indicated on the pump. Check the oil level before each use.

Evacuation Procedure

1. The system must have been recovered and the compressor filled with the correct amount of refrigerant oil. Replace the receiver-drier if the system is opened.

Refrigerant Service Operations

2. Wearing protective goggles and nonleather gloves, attach the recovery/recycling station hoses to the valves.

   IMPORTANT: Push down firmly on the hose connectors until a clicking sound is heard. This will ensure that the coupler is locked.

   2.1 Make sure that the recovery/recycling station valves are closed.

   2.2 Connect the red high-side hose to the discharge service valve.

   2.3 Connect the blue low-side hose to the suction service valve.

   2.4 Turn the knob clockwise on each coupler to open the Schrader valves.

3. Follow the recovery/recycling station manufacturer's instructions and evacuate/recycle the refrigerant system.

Flushing

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant could lead to serious personal injury.

Flushing removes moisture-laden oil and some contamination, such as dirty oil and some particles. When a part is flushed, liquid refrigerant is forced through it. The liquid picks up the contaminants and flushes them out.

Whether to flush or replace a part depends on how much contamination there is, as previously described.

Normally, the system always has pressure in it. Some loss of refrigerant from one season to the next is normal, and does not mean that the system is dirty. If refrigerant parts show signs of internal corrosion and grit, the system is contaminated.

If the system is contaminated with moisture, flush all sections of the system. Then change the oil in the compressor, and replace the receiver-drier prior to evacuating and charging the system.

If the system is heavily contaminated or if desiccant has circulated through the system, replace the receiver-drier, expansion valve(s), and inspect the compressor.

Do not flush the receiver-drier or the compressor.

Flush the system in segments to lessen the chance of blowing deposits against a port.

Flush the system in the opposite direction of refrigerant flow.

Flushing parts with refrigerant, requires a refrigerant recovery and charging machine.

Flushing Procedure

Method 1

NOTE: Use this method when the recovery and charging machine is equipped with a flush cycle.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter and follow the instructions from the manufacturer of the recovery and charging machine to perform the flush. When flushing the entire system, use an adaptor that fits where the compressor was located, and backflush.
4. Remove the adaptors and bypass devices and install the expansion device(s), the compressor, and a new receiver-drier.
5. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
6. Charge the system with refrigerant and check the system performance.

Method 2

NOTE: Use this method when two recovery and charging machines are available.

1. Recover the refrigerant from the air conditioning system.

2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter. When flushing the entire system, use an adaptor that fits where the compressor was located, and backflush.
4. Charge the part with 2 pounds (0.9 kg) of refrigerant or the system with 5 pounds (2.3 kg) of refrigerant, then recover the refrigerant with a second machine. It is desirable to start the recovery slightly before the charge cycle is done, since this helps to push fluid through the system. Repeat the process several times until you think that all the oil has been removed.
5. Remove the adaptors and bypass devices and install the expansion device(s), the compressor(s), and a new receiver-drier.
6. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
7. Charge the system with refrigerant and check the system performance.

Charging

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant could lead to serious personal injury.

NOTE: Before charging, the system must be recovered and evacuated with the recovery/recycling station connected to the service and discharge port connections.

1. Determine the amount of refrigerant oil that needs to be replaced by reading the label provided by the body manufacturer.

   Set the tank on a scale and weigh it so that the correct amount of refrigerant enters the system. This prevents overcharging, which could damage the compressor.
2. Charge the refrigerant system.

   NOTE: If equipped with a recovery, recycling, and recharging station, charge the system on the high side following the manufacturer's instructions. If charging from a bulk container, do the following.

   2.1 Turn the tank (bulk container) upside down. With the engine off, open the high-side hand valve. **Do not** open the low-side hand valve

   2.2 Allow refrigerant to enter the system until the correct charge (by weight) has entered. Then, close the high-side hand valve.

   2.3 Start the engine and run it at 1500 rpm. Set the cab air conditioner controls at maximum cooling and fan speed. The refrigerant compressor must engage.

   2.4 If a full charge did not enter the system, place the tank (bulk container) in the upright position, then open the low-side valve to draw vapor into the system. Leave the valve open until the correct weight of refrigerant has entered the system, then close the low-side valve.

   NOTE: If refrigerant is slow to enter the system because of low outside temperatures, vaporization can be quickened by placing the refrigerant tank in a tub of warm water, no warmer than 125 F° (52°C).
3. While the compressor is engaged, check the operating pressures at the suction and discharge ports. The pressures should be acceptable by general air conditioning standards or as stated by the body manufacturer.
4. Disconnect the high-side hose. With the engine running, open the low-side and high-side hose valves to recover the refrigerant from the lines.
5. Shut down the engine.

Refrigerant Service Operations

Leak Testing Methods

General Information

⚠ WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions, and to take precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

Refrigerant is odorless. As a result, all of it may leak away and not be noticed until the system stops cooling. All vehicle refrigerant systems lose some refrigerant, depending on the condition of the system. Higher loss rates signal a need to locate and repair the leaks.

Leaks are most often found at the compressor hose connections and at the various fittings and joints in the system. If unapproved replacement hoses are installed, refrigerant can be lost through hose permeation.

There are two leak testing methods that can be used to detect leaks in the A/C system: UV (ultraviolet) dye leak detection and electronic leak detection. Freightliner recommends using the UV dye leak detection method whenever possible, even though there are some limitations to using this method. A leak on the front seal of the compressor **must** be verified using a heated diode leak detector and the instructions in the workshop manual. Visible dye on the front of the compressor clutch **does not** verify that there is a leak at the front seal. Evaporator leaks may not show up with dye, and must be checked using a heated diode leak detector if dye is not present at the condensate drain.

Determine If the A/C System Contains UV Dye

IMPORTANT: Always wear UV-blocking protective eyewear when using the UV dye leak detection method. Always wear nonleather gloves and protective eyewear when servicing the air conditioning system.

1. Check under the hood for a label indicating that a UV dye has been added to the A/C system. On new Freightliner models, the label on the receiver-drier may be marked with "Contains Tracer Wafer."
2. Remove the low-side service port sealing cap, and direct the UV lamp to the valve stem area.
3. If UV dye is observed in the low-side service port, assume that a UV dye is in the system, and leak test the A/C system using the UV dye leak detection method.
4. If UV dye is not observed, depress the valve stem for an instant to bring some of the lubricant and dye out of the system. This can be safely accomplished using a modified service valve cap. See the instructions in "Modify the Service Valve Cap."

NOTE: Clean the modified valve cap after finding dye to avoid contaminating the next vehicle.

5. If no UV dye is observed in the low-side service port, use an electronic leak detector to leak test the A/C system, or add UV dye to the A/C system using the dye manufacturer's instructions.
6. If UV dye is being added to the A/C system, use the following instructions.
   - 6.1 Inject the amount of dye recommended by the dye manufacturer into the A/C system.
   - 6.2 Place a label under the hood, preferably next to the charge label, that indicates dye has been added to the A/C system.
   - 6.3 Verify that the A/C system has the correct amount of refrigerant.
   - 6.4 Run the air conditioner for at least 15 minutes to find large leaks. It may take as long as two weeks to detect small leaks using the UV dye leak detection method.

UV Dye Leak Detection

IMPORTANT: Always wear UV-blocking protective eyewear when using the UV dye leak detection method. Always wear nonleather gloves and protective eyewear when servicing the air conditioning system.

1. Inspect the A/C system for leaks using a UV lamp.
   - 1.1 Shut down the engine, apply the parking brakes, chock the tires, and open the hood.

1.2 Inspect the entire A/C system under low lighting using a UV lamp. Low lighting will increase the apparent brightness of the UV dye at leak sights.

1.3 Move the UV lamp along the entire refrigerant system, looking for signs of damage or corrosion on the fittings, hose-to-line crimps, switch ports, service ports with caps installed (dye inside the port is not an indication of a leak), brazed or welded areas, and around all connections. Check for evaporator leaks by illuminating the condensate drain tube or hole using the UV lamp.

1.4 Move the UV lamp along the refrigerant system following a continuous path so that no potential leak sites are missed. If a leak is found, continue to check the remainder of the system since other leaks may be present.

2. After repairing a leak, remove all UV dye residue remaining on the outside of the A/C system using the cleaner provided by the dye manufacturer, or a comparable cleaner. Use a spray bottle of cleaner, a toothbrush, and a spray bottle of clean water for hard-to-reach areas.

NOTE: Minor UV dye residue, or residue that is impossible to reach, will lose its fluorescence.

3. See **Table 3** for a list of products that have been tested and approved for use by Freightliner dealers.

4. Close the hood and remove the chocks from the tires.

<table>
<tr><th colspan="5">Approved Products for UV Dye Leak Detection</th></tr>
<tr><th>Type of Refrigerant Oil</th><th>Product Description</th><th>Vendor Part Number</th><th>Freightliner Part Number</th><th>Website Address</th></tr>
<tr><td rowspan="3">PAG</td><td>Tracerline BigEZ Kit—Can be injected without discharging the system.
• Each kit includes one 4-oz (118-mL) cartridge and an injection tool.</td><td>TP-9741CS</td><td>ABP N83 327911</td><td rowspan="3">www.tracerline.com</td></tr>
<tr><td>• A 4-oz (118-mL) replacement cartridge services 16 vehicles.</td><td>TP-9760-0004CS</td><td>ABP N83 327961</td></tr>
<tr><td>• An 8-oz (237-mL) replacement cartridge services 32 vehicles.</td><td>TP-9760-0108</td><td>ABP N83 327951</td></tr>
<tr><td rowspan="3">POE/ universal</td><td>Tracerline BigEZ Kit—Can be injected without discharging the system.
• Each kit includes one 4-oz (118-mL) cartridge and an injection tool.</td><td>TP-9742CS</td><td>ABP N83 327910</td><td rowspan="3">www.tracerline.com</td></tr>
<tr><td>• A 4-oz (118-mL) replacement cartridge services 16 vehicles.</td><td>TP-9770-0004CS</td><td>ABP N83 327950</td></tr>
<tr><td>• An 8-oz (237-mL) replacement cartridge services 32 vehicles.</td><td>TP-9770-108</td><td>ABP N83 327960</td></tr>
<tr><td>—</td><td>Tracerline Optimax UV Lamp</td><td>TP-8680</td><td>ABP N83 327985</td><td>www.tracerline.com</td></tr>
<tr><td>—</td><td>Bright Solutions UV Lamp</td><td>BSL760</td><td>ABP N83 327967</td><td>www.brightsol.com</td></tr>
<tr><td>—</td><td>Service Valve Cap</td><td>—</td><td>PH 660412</td><td>—</td></tr>
</table>

Table 3, Approved Products for UV Dye Leak Detection

Modify the Service Valve Cap

Use the following instructions to modify a service valve cap that will depress a Schrader valve.

1. Purchase a low-side service valve cap, part number PH 660412.
2. Locate the small, 0.145-inch diameter (3.7-mm) barrel inside the cap.
3. Fill the barrel to within 0.25 inch (6 mm) of its rim with epoxy, felt material, or wadded paper.
4. Mark the cap with the words "Do Not Use."

Electronic Leak Detection

When checking for leaks, move the probe all the way around the fitting or suspected leak.

NOTE: Do not try to use a leak tester right after connecting or disconnecting service hoses. Traces of refrigerant at the fittings can falsely signal a leak. Always verify a leak by blowing shop air in to the area of the suspected leak and checking the area again.

Freightliner recommends using only the heated diode type of electronic leak detector. This type of detector can be identified by its construction and power supply. It has a heated element which requires periodic replacement and uses either a 12V DC or 120V AC power supply or has a rechargeable battery. The heated diode type detector is sensitive only to gases containing halogen, such as R–134a and R–12 refrigerants. It will not detect other substances and is more likely to detect all of the leaks in a system. This type has both visual and audio indicators and self-tests to confirm operation.

Recommended electronic heated diode type leak detectors are available from their manufacturers. See **Table 4**.

Another type of detector, the corona discharge type, is the kind most commonly found in service and repair shops. This detector requires very little power and can operate on as few as four AA alkaline batteries. The corona discharge detector is not sufficiently sensitive and will create false alarms by detecting moisture and antifreeze or solvent vapors. This type of detector is specifically **not recommended**.

Electronic Leak Detectors		
Designation	**Manufacturer**	**Comments**
D-TEK	Leybold Inficon 2 Technology Place East Syracuse NY 13057 (315) 434–1144	• Rechargeable battery • Hand-held design • Simple to operate
H–10 Professional	Bacharach Inc. c/o Yokogawa Corp. of America 2 Dart Road Newnan GA 30265 (800) 850–0044	• Rechargeable battery • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Most sensitive available
J 39400	SPX Kent-Moore 28635 Mound Road Warren MI 48092–3499 (800) 328–6657	• 12V DC or 120V AC • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Manual balance control

Table 4, Electronic Leak Detectors

Refrigerant Service Operations

Use the following procedures to locate A/C system refrigerant gas leaks using a heated diode type electronic leak detector.

1. Operate the electronic leak detector in accordance with the manufacturer’s instructions.
2. Leak test with the engine turned off.
3. Charge the air conditioning system with sufficient refrigerant to indicate a gauge pressure of at least 50 psi (345 kPa) with the system not operating. It may not be possible to produce this amount of pressure and measure leakage if the ambient temperature is less than 59°F (15°C).
4. Be careful not to contaminate the detector probe tip if the part being tested is not clean. Wipe the part off with a dry shop towel or blow it off with shop air. Do not use cleaners or solvents as many detectors are sensitive to their chemical ingredients.
5. Visually inspect the entire refrigerant system. Look for air conditioning lubricant leakage and corrosion or damage to lines, hoses, and all other components. Inspect each questionable location carefully with the detector probe. Check all fittings, couplings, refrigerant controls, service ports (with caps installed), brazed or welded areas, and areas around attachment points and hold-downs.
6. Follow the path of the refrigerant system methodically so that no leaks are missed. If a leak is found, continue to test the rest of the system.
7. Inspect an area of possible leakage slowly and close to the part, moving completely around the part. Move the probe no faster than one to two inches (25 to 50 mm) per second and no farther away than 1/4 inch (6.4 mm) from the part.
8. If a large leak is present in either the system being serviced or the service equipment, the surrounding air will be saturated with refrigerant gas. In this situation the leak detector operates erratically and will indicate leakage without being near a possible leak source. Place a large fan so that a light breeze blows through the work area. Verify a leak by blowing shop air into the area and repeating the inspection. Pinpoint a large leak by blowing out the area often.
9. You may test the evaporator core while it is in its housing. Turn on the blower motor for a minimum of 15 seconds. Shut off the blower and wait for refrigerant gas to accumulate in the housing. Follow the detector instructions for the specific length of time to wait for the gas to accumulate. Insert the detector probe into the blower resistor block, or condensate drain tube if no water is present. If this is not possible insert the probe into the closest opening to the evaporator, such as a heater or vent duct.

NOTE: The presence of water in the condensate drain tube can be determined by inserting the eraser end of a pencil in the drain tube. Inserting the pencil will break the surface tension of any water near the opening of the drain tube and allow the water to drain out before inserting the probe tip. It is only necessary to break the plane of the drain tube with the probe tip. It doesn’t need to be inserted far into the tube.

10. Leak test the front seal area of the compressor. Blow shop air into the cavities in and around the clutch for at least 15 seconds. Let the compressor stand for one minute and then test for leakage. Inspect axial-type compressors (Sanden or Sel-Tec) by placing the probe near the holes at the front of the clutch. See **Fig. 3**. Inspect two-cylinder reciprocating type compressors (Climate Control) by placing the probe between the clutch coil and the compressor. See **Fig. 4**.

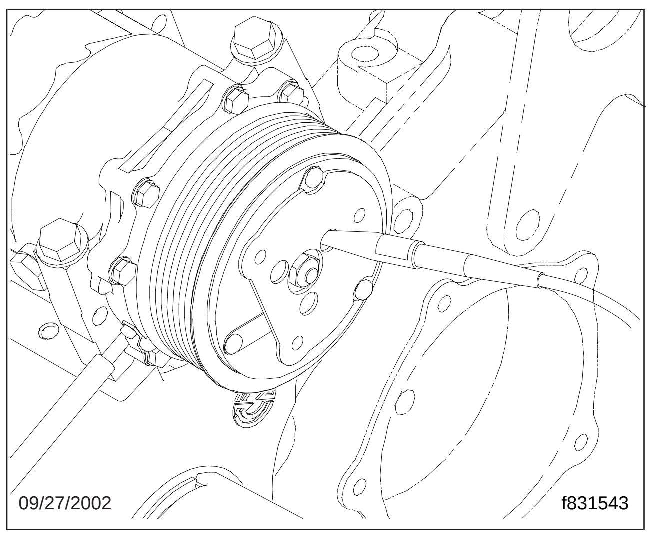


Fig. 3, Axial Type Compressor

IMPORTANT: Be careful not to damage the clutch bearing seal with high pressure shop air.

Refrigerant Service Operations

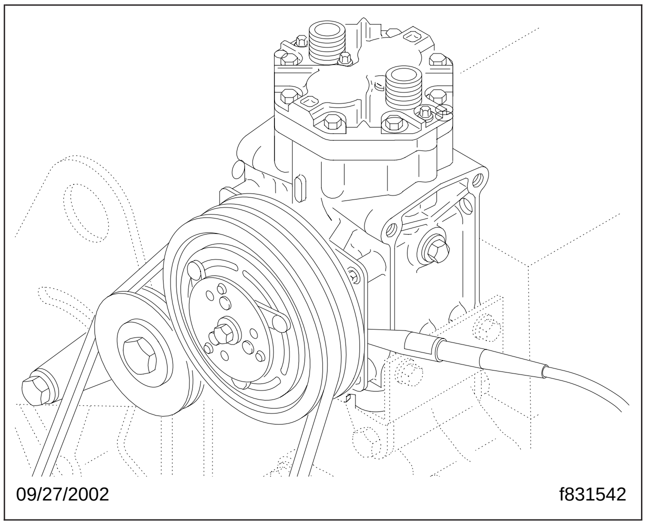


Fig. 4, Two-Cylinder Reciprocating Compressor

11. Leak test repaired areas of the system after repairs have been performed. Leak test the service ports (with caps installed) after any service which disturbs the refrigerant system.

Replacement

⚠ WARNING

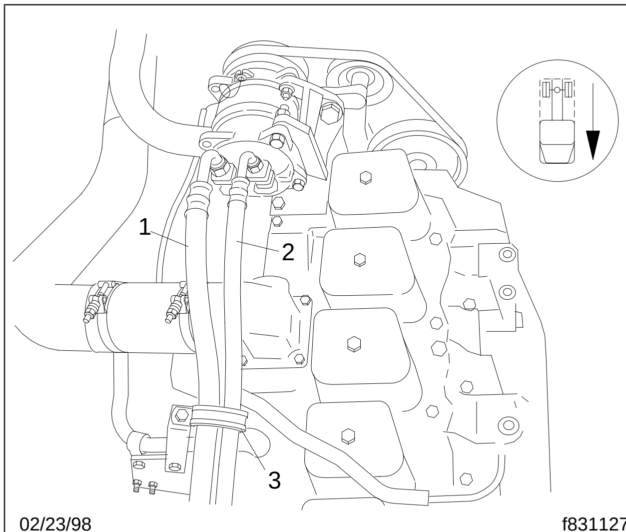
Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions, and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

1. Apply the brakes and chock the tires. Open the access panel on the front of the vehicle.
2. Recover the refrigerant from the air conditioning system; for instructions, refer to **Subject 120**.
3. Clean the refrigerant compressor around the hose connections. Disconnect the discharge and inlet lines from the refrigerant compressor. See **Fig. 1**. Quickly cap the discharge and inlet ports, and plug the hoses.

IMPORTANT: Under no circumstances should the ports on the compressor remain uncapped or the fittings remain unplugged for longer than five minutes total. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

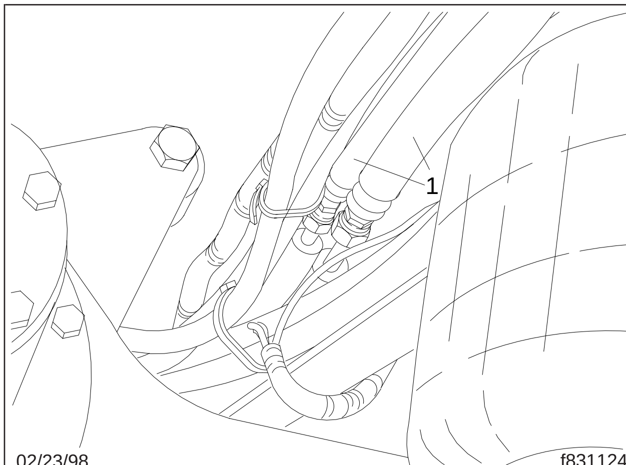
4. Remove the bolts and nuts on the two cushion clamps around the discharge and inlet lines.
5. Remove all the tie straps that hold the refrigerant lines to the bundle of hoses inside the right frame rail.
6. Disconnect the fittings on the discharge and inlet lines where they connect to the copper refrigerant lines. See **Fig. 2**. Remove the discharge and inlet lines and plug the fittings.
7. Disconnect the fittings on the opposite end of the copper refrigerant lines where they connect to the flexible tubing. See **Fig. 3**. Remove the copper refrigerant lines and plug the fittings.
8. Disconnect the fittings that connect the copper refrigerant lines to the flexible refrigerant lines at the front of the vehicle. See **Fig. 4**. Pull the copper and flexible refrigerant lines out towards the front of the vehicle and plug the fittings.

NOTE: Before installing the flexible or copper refrigerant lines or the discharge and inlet lines, check the O-rings in the fittings for nicks and cuts. If an O-ring needs to be replaced, lubricate it with mineral oil before installing.



1. Inlet Line
2. Discharge Line
3. Cushion Clamp

Fig. 1, Refrigerant Compressor

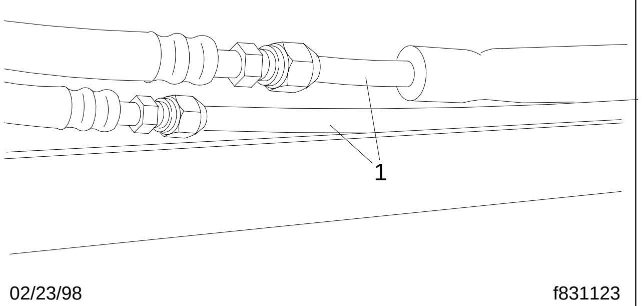


1. Discharge and Inlet Lines

Fig. 2, Discharge and Inlet Lines

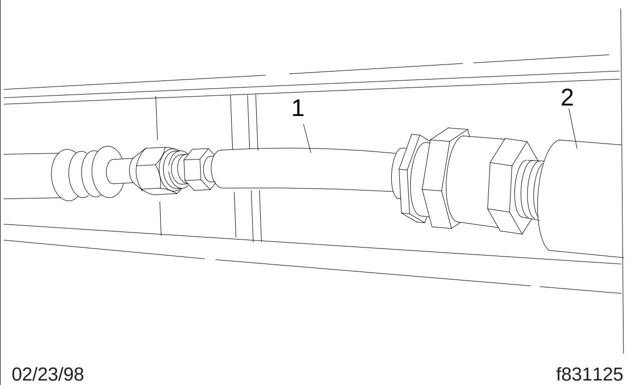
9. Place the flexible refrigerant lines, with the short piece of copper tubing, inside the right frame rail at the front of the vehicle.
   9.1 Connect the copper tubing attached to the smaller diameter line to the condenser.

Refrigerant Lines Replacement



1. Copper Refrigerant Lines

Fig. 3, Refrigerant Line Connections



1. Copper Refrigerant Line
2. Flexible Refrigerant Line

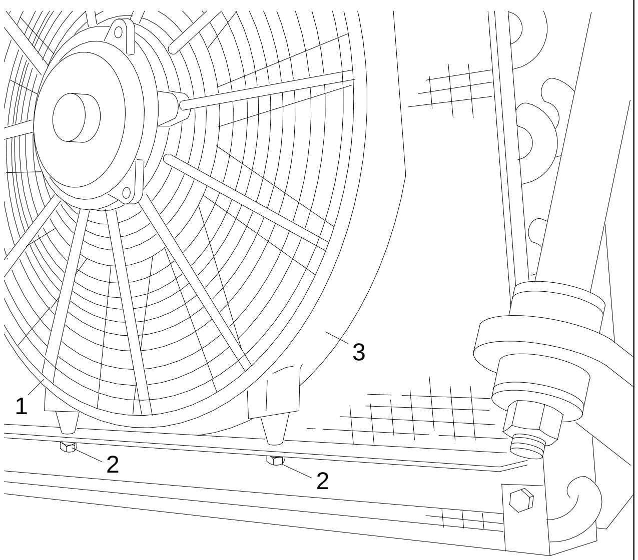
Fig. 4, Refrigerant Line Connection at Front of Vehicle

9.2 Connect the copper tubing attached to the larger diameter line to the evaporator.

10. Place the copper refrigerant lines inside the right frame rail. Connect the copper lines to the flexible refrigerant lines.
11. Uncap the discharge and inlet ports on the compressor. Unplug the fittings. Check the fittings and the discharge and inlet ports. They must be clean and free of nicks, gasket residue, and other foreign material.
12. Attach the discharge and inlet lines to the ports. Tighten the discharge fitting 27 lbf·ft (37 N·m). Tighten the inlet fitting 29 lbf·ft (39 N·m).
13. Place the cushion clamps around the discharge and inlet lines, and attach the clamps to the clamp brackets using the bolts and nuts.
14. Place the discharge and inlet lines inside the right frame rail and through the crossmember. Attach the discharge and inlet lines to the copper refrigerant lines.
15. Use tie straps to attach the refrigerant lines to the bundle of hoses inside the right frame rail.
16. Remove the chocks.

Condenser Fan Replacement

Replacement



1. Condenser
2. Mounting Screws
3. Fan

Fig. 1, Condenser Fan

1. Apply the parking brakes and chock the tires.
2. Unplug the fan motor.
3. Remove the four screws that attach the fan to the condenser. See **Fig. 1**.
4. Place a new fan on the condenser. Install the four screws and tighten 48 lbf·in (542 N·cm).
5. Plug the fan motor in to the receptacle.
6. Remove the chocks.

Condenser Removal and Installation

Removal

1. Apply the parking brakes and chock the tires. Open the access panel on the front of the vehicle.

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions, and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

2. Wearing protective goggles and gloves, recover the refrigerant system. For instructions, refer to **Subject 120**.
3. After the system is recovered, disconnect the refrigerant lines at the condenser. Install plugs in the refrigerant lines and cap the condenser fittings.

IMPORTANT: Under no circumstances should the fittings on the condenser remain uncapped or the refrigerant lines remain unplugged for longer than five minutes total. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

4. Remove the bolts that fasten the condenser to the condenser bracket.
5. Loosen or remove the bolts that attach the right condenser bracket to the frame rail. Turn the right bracket until the condenser can be removed.

Installation

1. Place the new condenser on the condenser bracket.
2. Put the right condenser bracket in place, and install and tighten the bolts.
3. Install the bolts that attach the condenser to the condenser bracket, and tighten 72 lbf·in (813 N·cm).
4. Remove the caps and plugs from the condenser and the refrigerant lines. Check the O-rings for nicks and cuts. If an O-ring needs to be replaced, lubricate it with mineral oil before installing.
5. Attach the refrigerant lines to the condenser. Tighten the fittings to the values in **Table 1**.

IMPORTANT: Whenever the refrigerant system is open, the receiver-drier needs to be replaced. For instructions, refer to **Subject 110**.

6. Evacuate, charge, and leak test the refrigerant system. For instructions, refer to **Subject 120**.
7. Add refrigerant oil to the condenser to replace that which was lost in the old condenser. For instructions, refer to Section 83.00, **Subject 130**.

Refrigerant Line Torque Specifications		
Outside Diameter for Metal Tube	**Torque for Steel Tubes * lbf·ft (N·m)**	**Torque for Aluminum or Copper Tubes lbf·ft (N·m)**
1/4	10–15 (14–20)	5–7 (7–9)
3/8	30–35 (41–47)	11–13 (15–18)
1/2	30–35 (41–47)	15–20 (20–27)
5/8	30–35 (41–47)	21–27 (28–37)
3/4	30–35 (41–47)	28–33 (38–45)

* When tightening fittings, always use the torque reading for the softer metal when unlike metals are used.

Table 1, Refrigerant Line Torque Specifications

8. Close the access panel and remove the chocks.