FOX ISLAND DIVISION

OPERATION AND MAINTENANCE MANUAL

ENVIRONMENTAL MANAGEMENT PROGRAM
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

CLARK COUNTY, MISSOURI
MISSISSIPPI RIVER
RIVER MILES 353.6 TO 358.5

APPENDIX G

REFERENCE SUBMITTALS

APPENDIX G

REFERENCE SUBMITTALS

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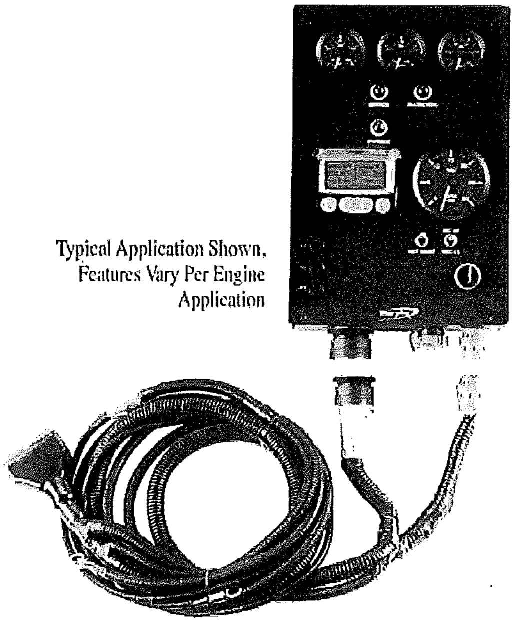
MURPHY

MurphyLink™ Series M310 Panels



Typical Application Shown, Features Vary Per Engine Application

Features

- Standard panel designed for modern electronic engines and equipment applications using SAE J1939 Controller Area Network (CAN)
- PowerView displays over 30 standard SAE J1939 parameters broadcast by major engine and transmission manufacturer's ECU's
- Display active faults and ECU-stored faults with text description on most common faults for diagnosing equipment malfunctions
- Standard harnesses available for most major engine manufacturers ECU's
- Enclosed design or flat panel option
- Deutsch connectors

Description

The M310 Series Panels include the PowerView and the Mlink™ PowerView Analog Gages. They are part of the J1939 MurphyLink™ Family developed to meet the needs for instrumentation and control on electronically controlled engines communicating using the SAE J1939 Controller Area Network (CAN).

The PowerView is a multifunction tool that enables equipment operators to view many different engine or transmission parameters and service codes. The panels provide a window into modern electronic engines. The PowerView includes a graphical backlighted LCD screen. It has excellent contrast and viewing from all angles. The display can show either a single parameter or a quadrant display for viewing four parameters simultaneously. Diagnostic capabilities include fault codes with text translation for the most common fault conditions.

The PowerView has four buttons using touch-sensitive technology, which eliminates the concern for push button wear and failure. In addition operators can navigate the display with ease. Enhanced alarm indication uses ultra bright alarm and shutdown LED's (amber and red). The PowerView has a wide operating temperature range of -40 to +85°C (-40 to185°F), display viewing -29 to +75°C (-20 to 167°F), and environmental sealing to +/- 5 PSI.

Other components in the panels are microprocessor-based M-Link™ PowerView Analog Gages for displaying critical engine data broadcast by an electronic engine: engine RPM, oil pressure, coolant temperature, system voltage, etc. and an optional audible alarm and relay unit for warning and shutdown annunciation.

The M310 Series panels are available in an enclosure or stand-alone flat panel option that can be dropped into a dash or console. This standard panel can be ordered with or without an enclosure, since all of the components are assembled to a stand-a-lone flat panel. Optional mounting kits are offered for the enclosure, which provide packagers and operators numerous mounting solutions to meet multiple applications. Panel designs are offered to meet the needs of specific engine models. In addition, FWMurphy offers standard harnesses for quick Plug and Go operation that interface with all the MurphyLink™ PowerView panels.

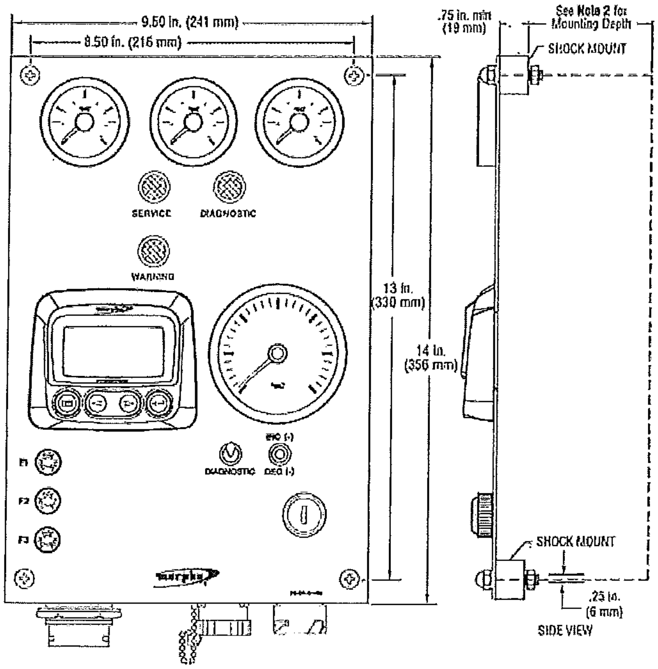
Display Parameters

The following are some of the engine and transmission parameters displayed by the PowerView in English or Metric units (when applicable), consult engine or transmission manufacturer for SAE J1939 supported parameters.

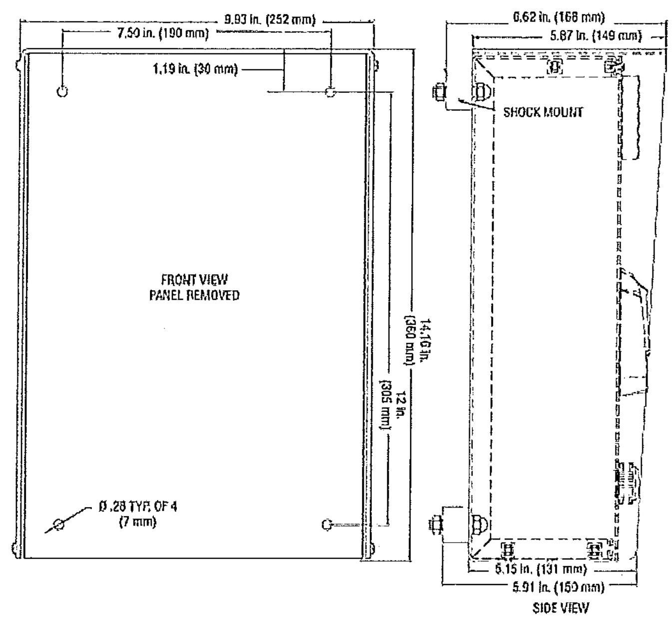
- Engine RPM
- Engine Hours
- Machine Hours
- System Voltage
- % Engine Load at the Current RPM
- Coolant Temperature
- Oil Pressure
- Fuel Economy
- Throttle Position
- Engine Manifold Air Temperature
- Current Fuel Consumption
- Transmission Gear Oil Pressure
- Transmission Gear Oil Temperature
- Transmission Gear Position
- Active Service Codes
- Stored Service Codes from the Engine
- Set Units for Display (English or Metric)
- View Engine Configuration Parameters

Dimensions

Dimensions Flat Panel (only) Includes Shock Mounts

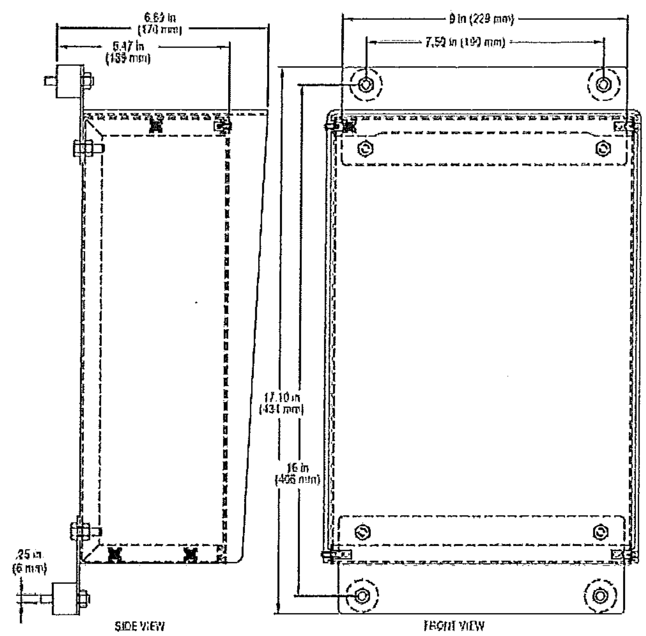


Dimensions in Enclosure Includes Shock Mounts

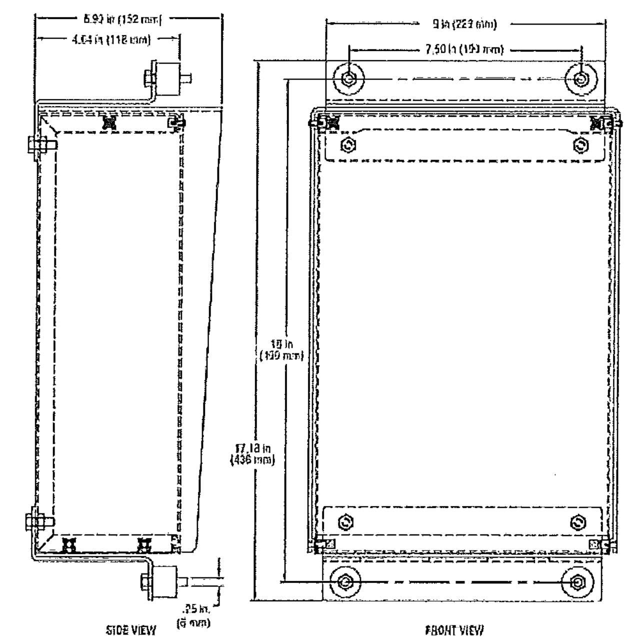


NOTE 1: Flat Panel has approximately 8 inch leads on connectors. Typical application shown, features vary per engine application.
NOTE 2: Allow 4.50 in.(114 mm) minimum mounting depth for versions with Morse throttle. For all other version allow 3.25 in. (83 mm) minimum depth.

Surface Mount Dimension (optional) Kit P/N 32-00-0033



Recessed Mount Dimension (optional) Kit P/N 32-00-0035



NOTE: It is the user's responsibility to verify that the electronic control module (ECM) has been programmed to support these control features, and that the appropriate external wire harness or other interconnecting wiring has been installed from the panel to the ECM.

Warranty - A limited warranty on materials and workmanship is given with this FW Murphy product. A copy of the warranty may be viewed or printed by going to http://www.fwmurphy.com/warranty

How to Order

To order, use the model number designation diagram below.

M-LINK M310 Panel Model Number Configurator for CUMMINS Engines

Example: M31ØCU – AØ1 – 24 – ØØ – B – FP

Base Model No.
M31ØCU

ENGINE/ECM CODE **
AØ1 = Cummins QSB/QSC (QSB5.9, QSC8.3)
A07 = Cummins Tier 3 QSB/QSC engines with CM850 ECM (QSB 4.5, 5.9, QSC 8.3)
BØ1 = Cummins QSK (QSK19, QSK45, QSK60)
CØ1 = Cummins QSM/QSX (QSM, QSX15)

DC Voltage
12
24

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None
Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge
TP = Transmission Oil Pressure Gauge*
TT = Transmission Oil Temperature Gauge*
* = Verify engine model broadcasts this information using auxiliary J1939 parameters from ECU.

*Panels not in Pricing Guide can be quoted, but may have longer lead times.
**Contact FWMurphy sales if your engine is not listed

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Control Codes
Select one:
A = DS,ID
B = DS,ID,RI
C = MT,DS,ID
D = DS,ID, wiring only for MT
*(Please refer to Pricing Guide for available panel-models)

Code Descriptions:
DS = Diagnostic Switch (Mom)
ID = Increment/Decrement (Mom)
RI = Run/Idle Switch
MT = Morse Throttle

Lamp Configurations
Information Only, specified by ECM Code
QSB/QSC = 5 Lamps (Service, Shutdown, Warning Wait to Start, Water in Fuel)
QSK = 3 Lamps (Service, Shutdown, Warning)
QSM/QSX = 4 Lamps (Service, Shutdown, Warning Wait to Start)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for CUMMINS Engines

Example: MEH-MØ1Ø – AØ1 – 6

Base Model No.

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

ENGINE/ECM CODE
AØ1 = Cummins QSB/QSC (QSB5.9, QSC8.3)
A07 = Cummins Tier 3 QSB/QSC engines with CM850 ECM (QSB 4.5, 5.9, QSC 8.3)
BØ1 = Cummins QSK (QSK19, QSK45, QSK60)
CØ1 = Cummins QSM/QSX (QSM11, QSX15)

Contact FWMurphy sales if your engine is not listed

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000045 = 40 ft. (12.1 m) MEH extension

NOTE: All Cummins external harnesses include wiring for Morse Throttle, Diagnostic Switch and Increment/Decrement Switch.

How to Order, continued

To order, use the model number designation diagram below.

M-LINK M310 Panel Model Number Configurator for CATERPILLAR Engines or Perkins 1100D

Example: M31ØCA – AØ4 – 24 – ØØ – C – FP

Base Model
M31ØCA

ENGINE/ECM CODE
AØ4 = Caterpillar - ADEM3
(3176C, 3196, 3406E, 3408E, 3456, 3508EUI, C9, C10, C12, C15, C16, 3126B, 3412E (engines with ADEM3 ECM)
A08 = Caterpiller Tier 3 ACERT
(3128E, 3176C, 3196, 3406E, 3408E, 3456, 3508EUI, 3126B, 3412E, C-9 – C-16
A09 = Catepillar Tier 3 (C4.4, C6.6)
Perkins Tier 3 (1104D, 1106D)

Contact FWMurphy sales if your engine is not listed

DC Voltage
12
24

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None
Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge
TP = Transmission Oil Press. Gauge*
TT = Transmission Oil Temp. Gauge*
* = Verify engine model broadcasts this information.

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Control Codes

Select one:
A = MR, PT
B = MR, wiring only for MT
C = MR, MT, installed

Code Descriptions:
MR = Maintenance Due Reset Switch (Mom)
PT = PTO Ramp Up/Ramp Down With Inc/Dec Switch (Mom)
MT = Morse Throttle (PWM)

Lamp Configurations
Information Only, specified by ECM Code
ADEM 3 = 3 Lamps
(Service, Diagnostic, Warning)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for CATERPILLAR and Perkins 1100 Series Engines

Example: MEH-MØ1Ø – AØ4 – 6

Base Model No.

ENGINE/ECM CODE
AØ4 = Caterpillar - ADEM3
(3176C, 3196, 3406E, 3408E, 3456, 3508EUI, C9, C10, C12, C15, C16, 3126B, 3412E
A08 = Caterpillar Tier 3 ACERT
(3128E, 3176C, 3196, 3406E, 3408E, 3456, 3508EUI, 3126B, 3412E, C-9 – C-16)
A09 = Caterpillar Tier 3 (C4.4, C6.6)

Contact FWMurphy sales if your engine is not listed

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000045 = 40 ft. (12.1 m) MEH extension

NOTE: All CATERPILLAR external harnesses support wiring for Morse Throttle, PTO Control, and Maintenance Reset Switch.

How to Order, continued

To order, use the model number designation diagram below.

M-LINK M310 Panel Model Number Configurator for PERKINS Engines–1100C Series or CATERPILLAR–3000E Series (ADEM4 ECM)

Example: M31ØPK – BØ3 – 24 – ØØ – C – FP

Base Model
M31ØPK

Engine/ECM Code
BØ3 = Perkins-1100 Series (1104C, 1106C)
Caterpillar-3000 Series (3054E, 3056E)
Contact FWMurphy sales if your engine is not listed

DC Voltage
12
24

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None

Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge

Control Codes
Select one:
C = Single speed, no adjust
E = Run/Idle speed select
F = Inc/Dec on speed

Lamp Configurations
Information Only,
Options C-F = 2 Lamps
(Warning, Stop)

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for PERKINS–1100C Series or CATERPILLAR–3000E Series (ADEM4 ECM)

Example: MEH-MØ1Ø – BØ3 – 6

Base Model No.

ENGINE/ECM CODE
BØ3** = Perkins - 1100 Series
(1104C, 1106C)
Caterpillar - 3000 Series
(3054E, 3056E)
****HARNESS REQUIRES RELAY(S) SEE BELOW**
Contact FW Murphy if your engine is not listed

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

NOTE: All PERKINS/CATERPILLAR external harnesses support wiring for Single Speed, Run/Idle and Increment/Decrement

*****HARNESS REQUIRES RELAY(S)***
(BØ3)
00008799 = 12V Relay [1104/3054E (2) Required, 1106/3056E (1) Required]
00008800 = 24V Relay [1104/3054E (2) Required, 1106/3056E (1) Required]
NOTE: Relays sold separately. Relays must have minimum 30 amp contact rating.

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000045 = 40 ft. (12.1 m) MEH extension

How to Order, continued

To order, use the model number designation diagram below.

M-LINK M310 Panel Model Number Configurator for PERKINS Engines–1300 Series and 2000 Series or DETROIT DIESEL–Series 40

Example: M31ØPK – AØ3 – 24 – ØØ – A – FP

Base Model
M31ØPK

Engine/ECM Code
AØ3 = Perkins 1300 Series
Detroit Series 40
(IOPU/IOPU3/IOPU4)
B04 = Perkins Tier 3 (2000 Series)

Contact FWMurphy sales if your engine is not listed

DC Voltage
12
24

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None

Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge

Control Codes

Select one:
A = DS, IOPU2
B = DS, IOPU3/IOPU4

Code Descriptions:
IOPU2= Standard Throttle (Resistive Potentiometer)
IOPU3/IOPU4 = Variable/Preset Includes Variable/Preset Switch and Inc/Dec Switch (Mom)
DS = Diagnostic Switch (Mom)

Included Sensors
Barometric Air Pressure
Ambient Air Temperature
(APS trim pot included with either)

Lamp Configurations
Information Only, specified by ECM Code
1300 Series= 2 Lamps
(Warning, Shutdown)

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for PERKINS 1300 Series or DETROIT DIESEL–Series 40 Engines

Example: MEH-MØ1Ø – AØ3 – 6

Base Model No.

ENGINE/ECM CODE
AØ3* = Perkins - 1300 Series
Detroit Diesel Series 40
(IOPU2/IOPU3/IOPU4)
B04 = Perkins Tier 3 (2000 Series)
***HARNESS REQUIRES RELAY SEE BELOW**

Contact FWMurphy sales if your engine is not listed

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000045 = 40 ft. (12.1 m) MEH extension

****HARNESS REQUIRES RELAY***
(AØ3)
00008799 = 12V Relay
00008800 = 24V Relay
NOTE: Relay sold separately. Relay must have minimum 30 amp contact rating.

NOTE: All PERKINS 1300 Series/DETROIT DIESEL Series 40 external harnesses support wiring for both throttle control and Variable/Preset select with Increment/Decrement.

How to Order, continued

To order, use the model number designation diagram below.

M-LINK M310 Panel Model Number Configurator for DETROIT DIESEL Engines–Series 50/60 and Series 2000

Example: M31ØDD – AØ2 – 24 – ØØ – B – FP

Base Model
M31ØDD

Engine/ECM Code
AØ2 = DD50/60 Series
(DDEC III, DDEC IV)
BØ2 = DD 2000 Series
(DDEC III, DDEC IV)
Contact FWMurphy sales if your engine is not listed

DC Voltage
12
24

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None

Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge

Control Codes

Select one:
A = DS, MT
B = ES, DS, MT

Code Descriptions:
MT = Analog Morse Throttle
DS = Diagnostic Switch (Mom)
ES = Emergency Stop Switch

Lamp Configurations
Information Only, specified by ECM Code
DDEC III, IV= 2 Lamps
(Stop Engine, Check Engine)

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for DETROIT DIESEL–Series 50/60 and Series 2000

Example: MEH-MØ1Ø – AØ2 – 6

Base Model No.

ENGINE/ECM CODE
AØ2 = DETROIT DIESEL 50/60, 2000 Series
(DDEC III, DDEC IV)
A06 = DETROIT DIESEL, 50/60, 2000 Series
(DDEC V)
A10 = DETROIT DIESEL
(DDEC III/IV) Electronic Engines with more than 8 cylinders and Dual ECU's
Contact FWMurphy sales if your engine is not listed

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

NOTE: DETROIT DIESEL external harnesses support wiring for Morse throttle control and supports the emergency-stop panel

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000045 = 40 ft. (12.1 m) MEH extension

M-LINK M310 Panel Model Number Configurator for FORD Engines

Example: M31ØFD – DØ5 – 12 – ØØ – C – FP

Base Model
M31ØFD

ENGINE/ECM CODE
DØ5 = FORD - 1.6L, 2.5L, 4.2L)

Contact FWMurphy sales if your engine is not listed

DC Voltage
12

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None
Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge
TP = Transmission Oil Press. Gauge*
TT = Transmission Oil Temp. Gauge*
* = Verify engine model broadcasts this information.

Control Codes

Select one:
A = DS,ID
B = DS,ID,RI
C = DS,IT

Code Descriptions:
DS = Diagnostic Switch (Mom)
ID = Increment/Decrement (Mom)
RI = Run/Idle Switch
MT = Morse Throttle

Lamp Configurations
Information Only, specified by ECM Code
QSB/QSC = 1 Lamp
(MIL= Maintanence indicator light)

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for FORD Engines

Example: MEH-MØ1Ø – DØ5 – 6

Base Model No.

ENGINE/ECM CODE
DØ1 = FORD - 1.6L, 2.5L, 4.2L)

Contact FWMurphy sales if your engine is not listed

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000045 = 40 ft. (12.1 m) MEH extension

How or Order - continued

M-LINK M310 Panel Model Number Configurator for IVECO Engines

Example: M31ØIV – EØ1 – 24 – ØØ – C – FP *(NOTE: Harness required, see below)*

Base Model
M31ØIV

ENGINE/ECM CODE
EØ1 = IVECO Tier 2 (NEF)
E02 = IVECO Tier 3 (NEF, Cursor)

Contact FWMurphy sales if your engine is not listed

DC Voltage
24VDC

Standard M-LINK Instruments Provided:
PowerView, Oil Pressure, Coolant Temperature, Battery Voltage, Tachometer

Additional Indicator Options
(choose up to 2 or none)
ØØ = None
Optional M-LINK Gauges
AA = Audible Alarm
PL = Percent Load Gauge
TP = Transmission Oil Press. Gauge*
TT = Transmission Oil Temp. Gauge*
* = Verify engine model broadcasts this information.

Blank = Enclosure (includes 4 shock mounts)
FP = Flat Panel (includes 4 shock mounts)

Control Codes

Select one:
A = DS, ID, TI (Please refer to Pricing Guide
B = DS, PT for available panel-models)

Code Descriptions:
DS = Diagnostic Switch (Mom)
ID = Increment/Decrement (Mom)
TI = Throttle Enable/Return to Idle
PT = Potentiometer Throttle (Resistive Pot)
Lamp Configurations
Information Only, specified by ECM Code
3 Lamps (Service, Diagnostic, Wait to Start)

Optional Mounting Brackets
To be used with Enclosure
(Not applicable to FP, Flat Panel)
32-00-0033 = Surface Mounting Kit
32-00-0035 = Recessed Mounting Kit
Note: Kits include hardware and brackets.

M-LINK External Harnesses for IVECO Engines

Example: MEH-MØ1Ø – EØ1 – 6

Base Model No.

ENGINE/ECM CODE
EØ1 = IVECO Tier 2 (NEF)
E02 = IVECO Tier 3 (NEF, Cursor)

*(Harness requires Relays-see relays box)

Contact FWMurphy sales if your engine is not listed

Universal Extensions Harness (Optional)
32000048 = 6 ft. (1.8 m) MEH extension
32000044 = 12 ft. (3.6 m) MEH extension
32000049 = 20 ft. (6.1 m) MEH extension
32000050 = 30 ft. (9.1 m) MEH extension
32000046 = 40 ft. (12.1 m) MEH extension

HARNESS LENGTH: ft (m)
6 ft. (1.8)
12 ft. (3.6)

**HARNESS REQUIRES RELAY*
(EØ1)
00008799 = 12V Relay (3 required)
00008800 = 24V Relay (3 required)
NOTE: Relay sold separately. Relay must have minimum 30 amp contact rating.

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Perkins®

RENR9525-01
June 2009

Disassembly and Assembly

1104D Industrial Engine

NH (Engine)
NJ (Engine)

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by "NOTICE" labels on the product and in this publication.

Perkins cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Perkins is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Perkins dealers or Perkins distributors have the most current information available.

⚠ WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

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Disassembly and Assembly Section

i02933646

Fuel Priming Pump - Remove and Install (Electric Fuel Priming Pump)

Removal Procedure

NOTICE
Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

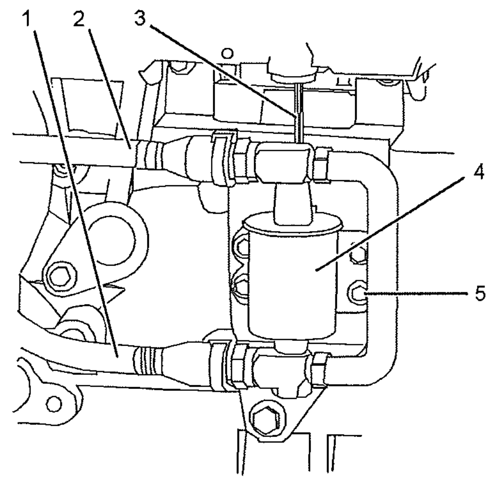

Illustration 1 g01269003
Typical example

3. Disconnect harness assembly (3) from electric priming pump (4).
4. Disconnect plastic tube assembly (1) and plastic tube assembly (2) from electric priming pump (4).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies and the electric priming pump are plugged.

5. Remove bolts (5) from electric priming pump (4).
6. Remove electric priming pump (4) from the mounting bracket.

Installation Procedure

NOTICE
Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that the electric priming pump is clean and free from wear or damage. If necessary, replace the electric priming pump.

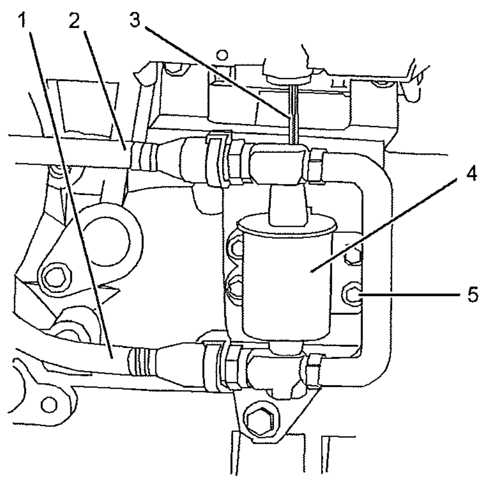

Illustration 2 g01269003

Typical example

2. Position electric priming pump (4) on the mounting bracket. Install bolts (5) to the electric priming pump.

3. Tighten bolts (5) to a torque of 9 N·m (79 lb in).

4. Remove all plugs from plastic tube assembly (1), plastic tube assembly (2) and electric priming pump (4). Connect plastic tube assembly (1) and plastic tube assembly (2) to electric priming pump (4).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are connected.

5. Connect harness assembly (3) to electric priming pump (4).

6. Turn the fuel supply to the ON position.

7. Turn the battery disconnect switch to the ON position.

8. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933647

Fuel Priming Pump - Remove and Install (Manual Priming Pump)

Removal Procedure

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

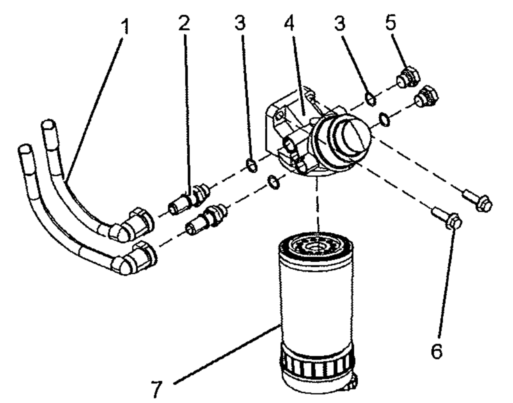

Illustration 3 g01753133

Typical example

1. Turn the fuel supply to the OFF position.

2. Drain primary filter (7). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace".

3. Disconnect plastic tube assemblies (1).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are plugged.

4. Remove primary filter (7) from fuel priming pump (4). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace".

5. Remove bolts (6) from fuel priming pump (4). Remove fuel priming pump (4) from the mounting bracket.

6. If necessary, follow Step 6.a through Step 6.c in order to disassemble the fuel priming pump.

   a. Remove connectors (2) from fuel priming pump (4).

   b. Remove plugs (5) from fuel priming pump (4).

   c. Remove O-ring seals (3) from connectors (2) and plugs (5).

Installation Procedure

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that the fuel priming pump is clean and free from wear or damage. If necessary, replace the fuel priming pump.

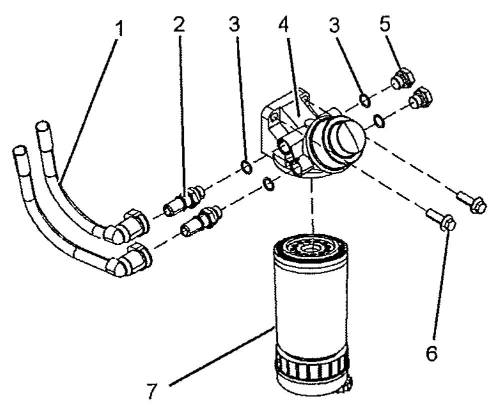

Illustration 4 g01753133

Typical example

2. If necessary, follow Step 2.a through Step 2.d in order to assemble fuel priming pump (4).

   a. Install new O-ring seals (3) to connectors (2) and plugs (5).

   b. Install connectors (2) to fuel priming pump (4).

   c. Install plugs (5) to fuel priming pump (4).

   d. Tighten the plugs and the connectors to a torque of 20 N·m (14 lb ft).

3. Position fuel priming pump (4) on the mounting bracket. Install bolts (6) to the fuel priming pump . Tighten the bolts to a torque of 44 N·m (32 lb ft).

4. Remove plugs from plastic tube assemblies (1). Connect plastic tube assemblies (1) to connectors (2).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are connected.

5. Install a new primary filter (7) to fuel priming pump (4). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace".

6. Turn the fuel supply to the ON position.

7. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933636

Fuel Filter Base - Remove and Install (Secondary Fuel Filter)

Removal Procedure

Table 1

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Strap Wrench	1

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.

2. If necessary, remove the boost pressure sensor. Refer to Disassembly and Assembly, "Boost Pressure Sensor - Remove and Install".

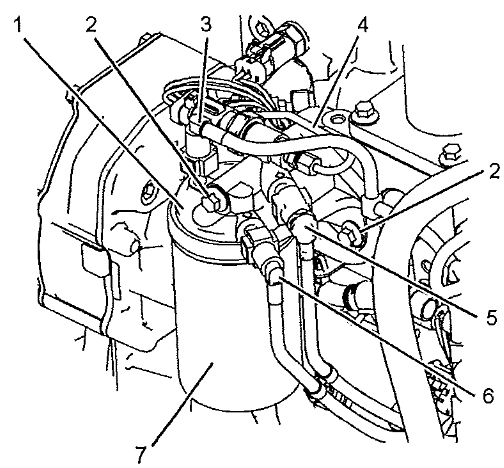

Illustration 5 g01247416

Typical example

3. Disconnect plastic tube assemblies (3), (5) and (6) from fuel filter base (1).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies and the fuel filter base are plugged.

4. Remove tube assembly (4), if equipped.

5. Use Tooling (A) in order to remove fuel filter (7). Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace".

6. Remove bolts (2) from fuel filter base (1). Remove the fuel filter base from the cylinder head.

Note: Do not attempt to disassemble the fuel filter base.

Installation Procedure

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that the fuel filter base is clean and free from damage. If necessary, replace the complete fuel filter base assembly.

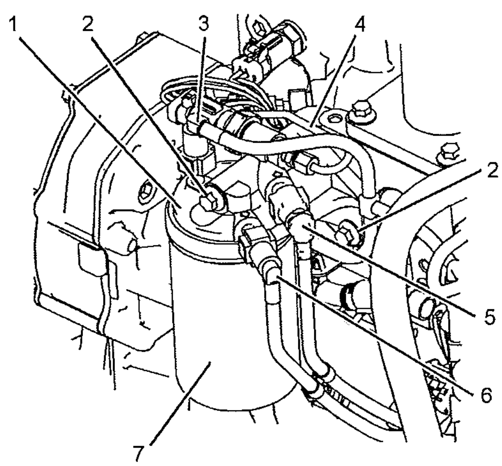

Illustration 6 g01247416

Typical example

2. Position fuel filter base (1) onto the cylinder head. Install bolts (2). Tighten the bolts to a torque of 22 N·m (16 lb ft).

3. Install a new fuel filter (7) to fuel filter base (1). Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.

4. If necessary, install the boost pressure sensor. Refer to Disassembly and Assembly, "Boost Pressure Sensor - Remove and Install".

5. Install tube assembly (4), if equipped. Tighten the nuts to a torque of 9 N·m (80 lb in).

NOTICE

Ensure that the plastic tube assemblies are installed in the original positions. Failure to connect the plastic tube assemblies to the correct ports will allow contamination to enter the fuel system. Contaminated fuel will cause serious damage to the engine.

6. Remove plugs from plastic tube assemblies (3), (5), and (6) and fuel filter base (1). Connect plastic tube assemblies (3), (5) and (6) to fuel filter base (1).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are connected.

7. Turn the fuel supply to the ON position.

8. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933650

Fuel Transfer Pump - Remove

Removal Procedure

Start By:

a. Remove the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, "ECM Mounting Bracket - Remove and Install".

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.

2. If necessary, disconnect the hose for the crankcase breather from the clip that secures the hose to the engine oil pan. Position the hose away from the fuel transfer pump.

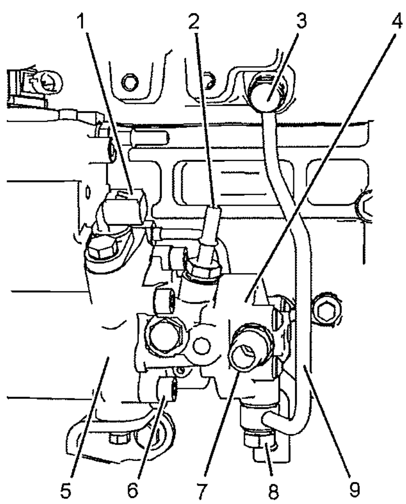

Illustration 7 g01247425

Typical example

3. If necessary, disconnect the harness assembly from position sensor (1). Refer to Disassembly and Assembly, "Position Sensor (Fuel Injection Pump) - Remove and Install". Position the harness assembly away from the fuel transfer pump.

Note: If the tube assembly has quick fit connections, ensure that the connections are clean before the tube assembly is plugged.

4. Disconnect the plastic tube assembly from inlet connection (7) on the fuel transfer pump.

5. Remove the plastic tube assembly from outlet connection (2).

6. Remove outlet connection (2) from fuel transfer pump (4). Plug the open port in the fuel transfer pump immediately with a new plug. Remove the O-ring seal from the connection.

   If necessary, remove inlet connection (7) from fuel transfer pump (4). Plug the open port in the fuel transfer pump immediately with a new plug. Remove the O-ring seal from the connection.

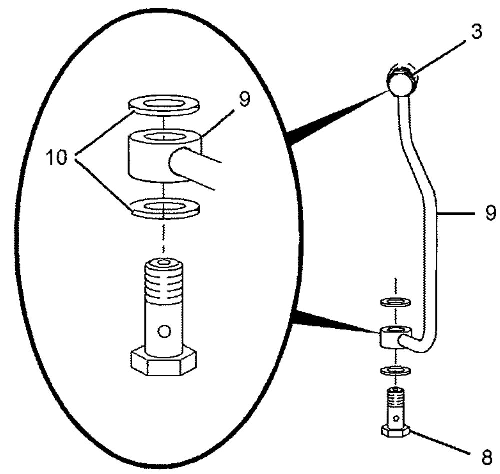

Illustration 8 g01457480

7. Loosen banjo bolt (3) and banjo bolt (8). Remove tube assembly (9) for the fuel return from the cylinder head to the fuel transfer pump.

Note: Disconnect the tube assembly at the fuel transfer pump first in order to drain the fuel from the cylinder head.

8. Remove banjo bolt (3) and sealing washers (10) from tube assembly (9).

9. Remove banjo bolt (8) and sealing washers (10) from tube assembly (9).

10. Use an allen wrench with a ball end in order to remove allen head bolts (6) that secure fuel transfer pump (4) to fuel injection pump (5).

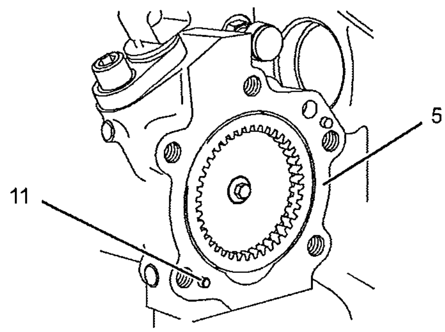

Illustration 9 g01254881

11. Remove the fuel transfer pump from fuel injection pump (5).

Note: Do not remove dowels (11) from the fuel injection pump.

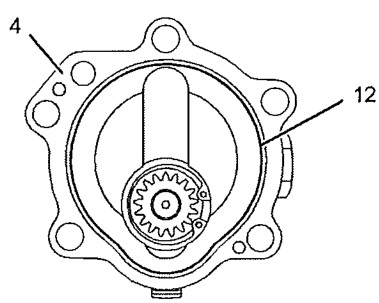

Illustration 10 g01254883

12. Remove O-ring seal (12) from fuel transfer pump (4).

i02933648

Fuel Transfer Pump - Install

Installation Procedure

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that the faces of the fuel injection pump and the fuel transfer pump are clean and free from damage. Replace any components that are damaged.

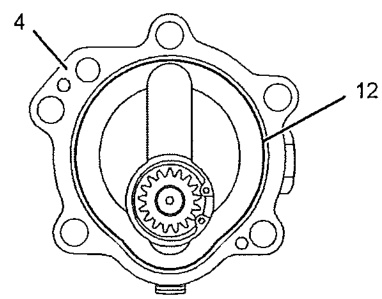

Illustration 11 g01254883

2. Install a new O-ring seal (12) for fuel transfer pump (4).

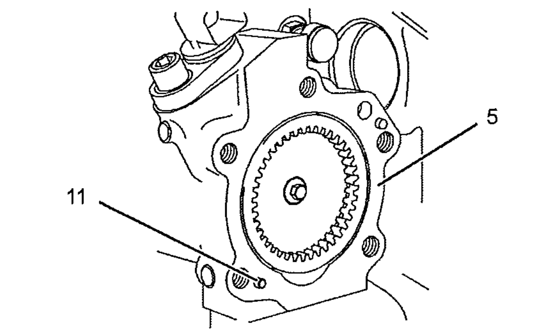

Illustration 12 g01254881

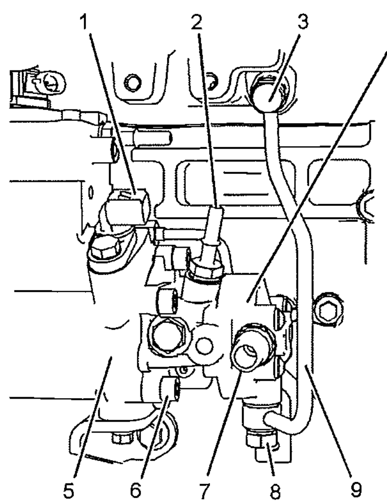

Illustration 13 g01247425

3. Align fuel transfer pump (4) with dowels (11) in fuel injection pump (5). Install the fuel transfer pump to the fuel injection pump.

4. Use an allen wrench with a ball end to install allen head bolts (6). Tighten the allen head bolts to a torque of 30 N·m (22 lb ft).

5. Install a new O-ring seal to outlet connection (2). Install outlet connection (2) to fuel transfer pump (4). Tighten the connection to torque of 15 N·m (11 lb ft).

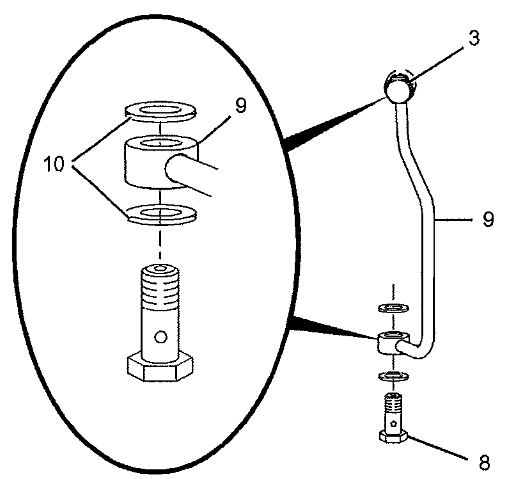

Illustration 14 g01457480

6. Install banjo bolt (8) and new sealing washers (10) to tube assembly (9).

7. Install banjo bolt (3) and new sealing washers (10) to tube assembly (9).

8. Install tube assembly (9) to the fuel return to fuel transfer pump (4) and to the cylinder head. Tighten banjo bolt (3) and banjo bolt (8) to a torque of 22 N·m (16 lb ft).

9. If necessary, install a new O-ring seal to inlet connection (7). Install inlet connection (7) to fuel transfer pump (4). Tighten the connection to torque of 15 N·m (11 lb ft).

Note: If the tube assembly has quick fit connections, ensure that the connections are clean before the tube assembly is connected.

10. Install the plastic tube assembly to outlet connection (2) on the fuel transfer pump.

11. Install the plastic tube assembly to inlet connection (7) on the fuel transfer pump.

12. If necessary, connect the harness assembly to position sensor (1). Slide the locking tab into the locked position.

13. If necessary, connect the hose for the crankcase breather to the clip that secures the hose to the engine oil pan.

14. Install the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, "ECM Mounting Bracket - Remove and Install".

15. Install the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

16. Turn the fuel supply to the ON position.

17. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933644

Fuel Manifold (Rail) - Remove and Install

Removal Procedure

Start By:

a. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

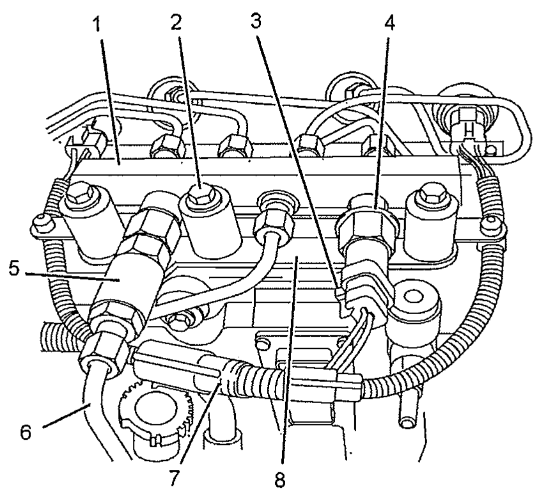

Illustration 15 g01243702

The fuel manifold is shown with fuel injection lines in position.

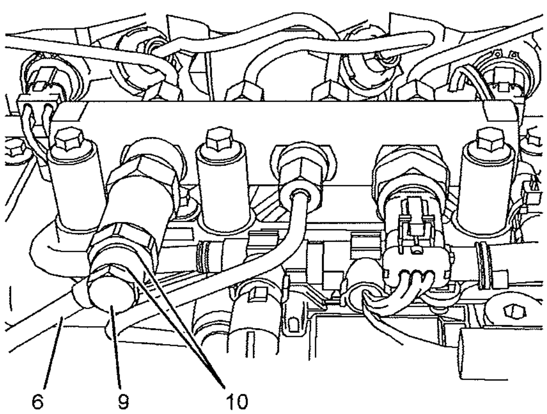

Illustration 16 g01763053

The fuel manifold is shown with fuel injection lines in position.

1. If necessary, remove fuel pressure sensor (4). Refer to Disassembly and Assembly, "Fuel Pressure Sensor - Remove and Install".

2. If fuel pressure sensor (4) does not require removal, slide locking tab (3) into the unlocked position. Disconnect the plug on harness assembly (7) from fuel pressure sensor (4).

3. Disconnect tube assembly (6) from fuel pressure relief valve (5). The tube assembly can be secured with a nut or with a banjo bolt. Immediately cap the open port in the pressure relief valve with a new cap. Immediately plug the open end of the tube assembly with a new plug.

4. If tube assembly (6) is secured with a banjo bolt, remove banjo bolt (9) and sealing washers (10). Refer to Illustration 16.

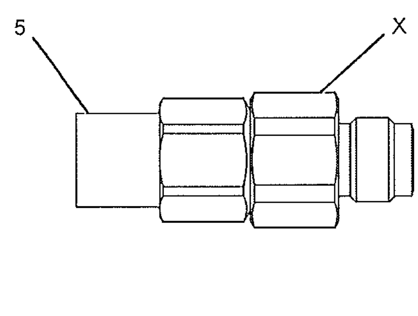

Illustration 17 g01800633

5. If necessary, remove fuel pressure relief valve (5). Use a deep socket in order to remove the fuel pressure relief valve.

Note: The fuel pressure relief valve should only be removed at Position (X). The fuel pressure relief valve is a two-piece assembly which should not be disassembled.

6. Remove bolts (2) from fuel manifold (1). Note the position of any brackets that are secured by the bolts.

7. Remove fuel manifold (1) from mounting bracket (8).

8. If necessary, remove the bolts and remove mounting bracket (8).

Installation Procedure

Table 2

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610294	Injector Pipe Nut Tool	1

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that all ports on the fuel manifold are capped. Ensure that the fuel manifold is externally clean and free from damage.

Note: Do not install a fuel manifold that has not been capped. All caps must be left in place until the fuel injection lines or the fuel pressure sensor are installed.

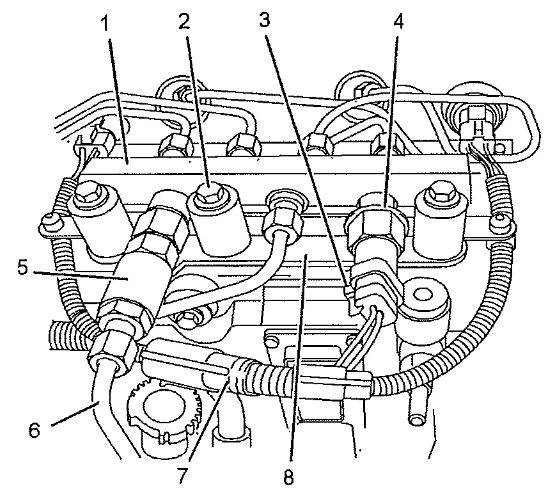

Illustration 18 g01243702

The fuel manifold is shown with fuel injection lines in position.

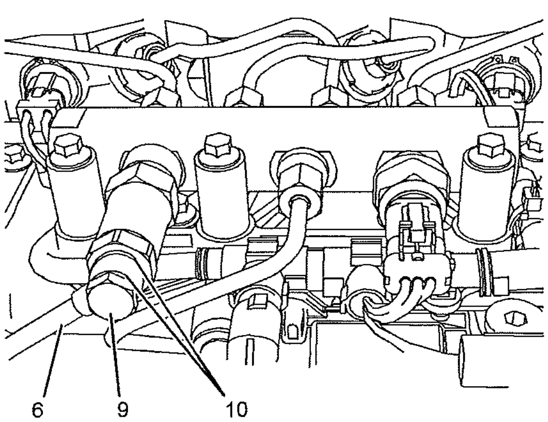

Illustration 19 g01763053

The fuel manifold is shown with fuel injection lines in position.

2. If necessary, install mounting bracket (8) and install the bolts. Tighten the bolts to a torque of 22 N·m (16 lb ft).

3. Position fuel manifold (1) onto mounting bracket (8). Install bolts (2) to the fuel manifold finger tight. Ensure that any brackets that are secured by bolts (2) are installed in the correct position.

4. Loosely install a new set of fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for more information.

5. Tighten bolts (2) to a torque of 22 N·m (16 lb ft).

6. Use Tooling (A) to tighten the nuts on the fuel injection lines to a torque of 30 N·m (22 lb ft). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for more information.

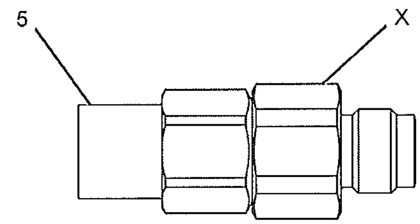

Illustration 20 g01800633

7. If necessary, install a new fuel pressure relief valve (5). Use a deep socket in order to tighten the fuel pressure relief valve. Tighten the fuel pressure relief valve to a torque of 120 N·m (89 lb ft).

Note: Fuel pressure relief valve (5) must only be tightened at Position (X). The fuel pressure relief valve is a two-piece assembly which should not be disassembled.

8. Remove the plug from tube assembly (6). Remove the cap from the appropriate port in fuel manifold (1). Connect tube assembly (6) to fuel pressure relief valve (5). If tube assembly (6) is secured with a nut, tighten the nut to a torque of 26 N·m (19 lb ft). Refer to Illustration 18.

9. If tube assembly (6) is secured with a banjo bolt, install new sealing washers (10) and install banjo bolt (9). Tighten the banjo bolt to a torque of 21 N·m (186 lb in).

10. If fuel pressure sensor (4) was removed from fuel manifold (1), install a new sealing washer and install the fuel pressure sensor. Refer to Disassembly and Assembly, "Fuel Pressure Sensor - Remove and Install" for more information.

    If fuel pressure sensor (4) was not removed from fuel manifold (1), connect the plug on harness assembly (7) to fuel pressure sensor (4). Slide locking tab (3) into the locked position.

11. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

i02933638

Fuel Injection Lines - Remove

Removal Procedure

Table 3

Required Tools			
Tool	Part Number	Part Description	Qty
A	U5MK1124	Cap Kit	1

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

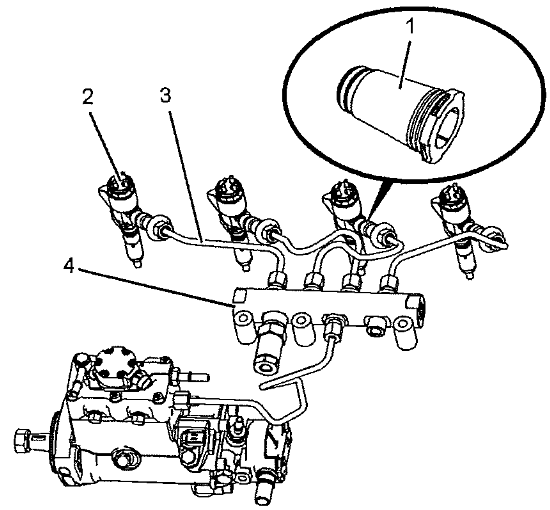

Illustration 21 g01457355

Typical example

3. Disconnect fuel injection line (3) from electronic unit injector (2).
4. Disconnect fuel injection line (3) from fuel manifold (4).
5. Remove fuel injection line (3). Discard the fuel injection line.
6. Plug the open port in fuel manifold (4) immediately. Use Tooling (A) in order to plug the open port.
7. Remove seal (1) from electronic unit injector (2) and from the base of the valve mechanism cover.
8. Use a new plug in order to plug the open port in electronic unit injector (2). Use Tooling (A) in order to plug the open port.
9. Repeat Step 3 through Step 8 in order to remove the remaining fuel injection lines from the electronic unit injectors.
10. If necessary, remove the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".
11. Remove the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

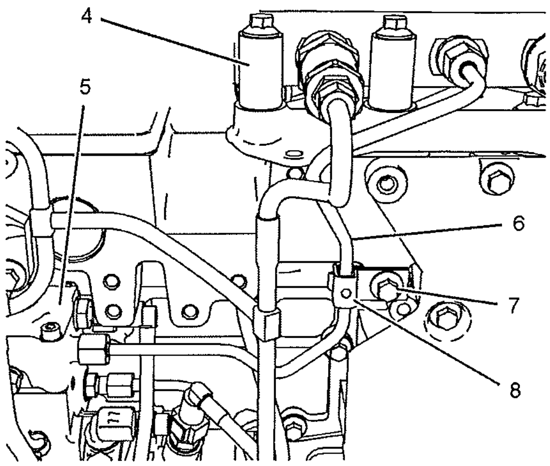

Illustration 22 g01254886

Typical example

12. Remove bolt (7) from clip (8).

13. Disconnect fuel injection line (6) from fuel injection pump (5).

14. Disconnect fuel injection line (6) from fuel manifold (4).

15. Remove fuel injection line (6). Discard the fuel injection line. Plug all open ports immediately. Use Tooling (A) in order to plug the open ports in the fuel manifold and in the fuel injection pump.

i02933637

Fuel Injection Lines - Install

Installation Procedure

Table 4

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610294	Injector Pipe Nut Tool	1

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

Note: The following procedure should be adopted in order to install the fuel injection lines when the electronic unit injectors or the fuel manifold have not been removed. If the electronic unit injectors or the fuel manifold have been removed, refer to Disassembly and Assembly, "Electronic Unit Injector - Install" and Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install" for more information.

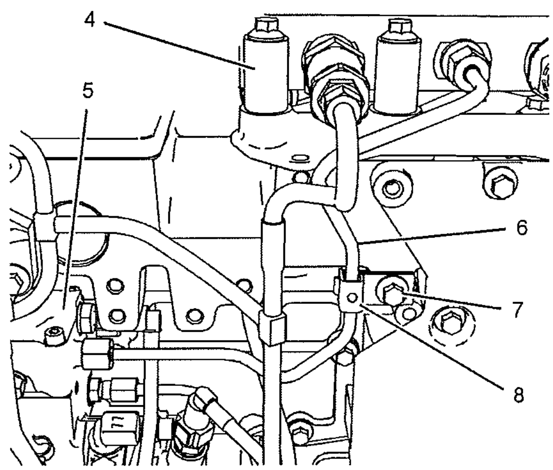

Illustration 23 g01254886

Typical example

1. Remove the caps from the port in fuel injection pump (5) and from the appropriate port in fuel manifold (4). Remove the caps from the new fuel injection line (6).

2. Loosely connect the nuts at both ends of fuel injection line (6), to fuel manifold (4) and to fuel injection pump (5). Ensure that the ends of the fuel injection line are correctly seated in the fuel injection pump and in the fuel manifold.

3. Use Tooling (B) to tighten the nuts on fuel injection line (6) to a torque of 30 N·m (22 lb ft).

4. Install bolt (7) to clip (8). Tighten bolt (7) to a torque of 22 N·m (16 lb ft).

   Ensure that fuel injection line does not contact any other engine component.

5. Install the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

6. If necessary, install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

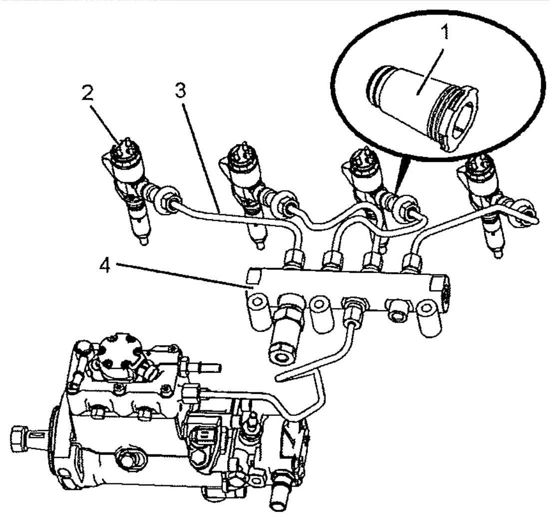

Illustration 24 g01457387

Typical example

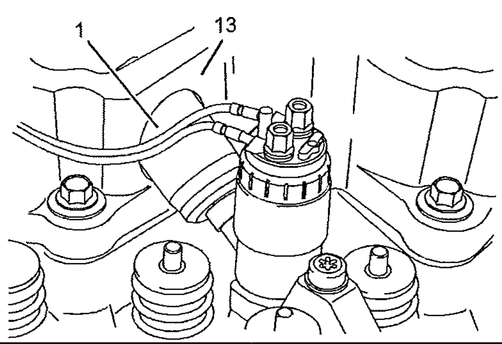

Illustration 25 g01271377

Typical example

The valve mechanism cover is not shown for clarity.

7. Install a new seal (1) to electronic unit injector (2) and to valve mechanism cover base (13).

Note: Ensure that the flange on the seal is flush with the valve mechanism cover base.

8. Remove the caps from the new fuel injection line (3).

Note: Ensure that a dust seal is installed to the fuel injection line. Install the fuel injection line for number one cylinder first. Install the fuel injection lines in numerical order.

9. Remove the caps from electronic unit injector (2) and from the appropriate port in fuel manifold (4).

10. Loosely connect the nuts at both ends of fuel injection line (3), to electronic unit injector (2) and to the appropriate port in fuel manifold (4). Ensure that the ends of the fuel injection line are correctly seated in the electronic unit injector and in the fuel manifold.

11. Use Tooling (B) to tighten the nuts on fuel injection line (3) to a torque of 30 N·m (22 lb ft). Ensure that the dust seal is seated correctly against seal (1).

12. Follow Step 7 through Step 11 in order to install the remaining fuel injection lines.

Note: Ensure that fuel injection lines do not contact any other engine component.

13. Turn the fuel supply to the ON position.

14. Turn the battery disconnect switch to the ON position.

15. Remove the air from the fuel system. Refer to Operations and Maintenance Manual, "Fuel System - Prime".

i03458261

Fuel Injection Pump - Remove

Removal Procedure

Table 5

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1
D	U5MK1124	Cap Kit	1

(1) Install Tooling to the front pulley.
(2) Install Tooling into the aperture for the electric starting motor.

Start By:

a. Remove the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

b. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.

2. Turn the battery disconnect switch to the OFF position.

3. If necessary, remove the fuel filter base. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install".

4. If necessary, remove the fuel priming pump. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

5. If necessary, remove the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

6. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

7. Use Tooling (B) in order to lock the camshaft in the correct position. Use Tooling (C) in order to lock the crankshaft in the correct position. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install" for the correct procedure.

8. Remove the backlash from the fuel pump gear. Lock the fuel injection pump in the correct position and remove the fuel pump gear. Refer to Disassembly and Assembly, "Fuel Pump Gear - Remove" for the correct procedure.

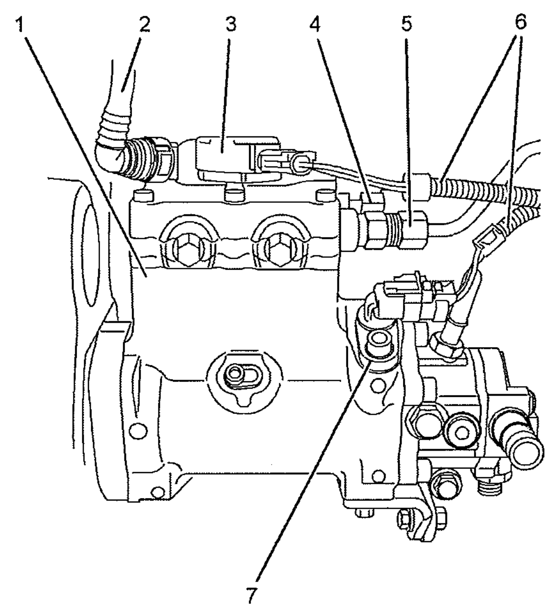

Illustration 26 g01563275

Typical example

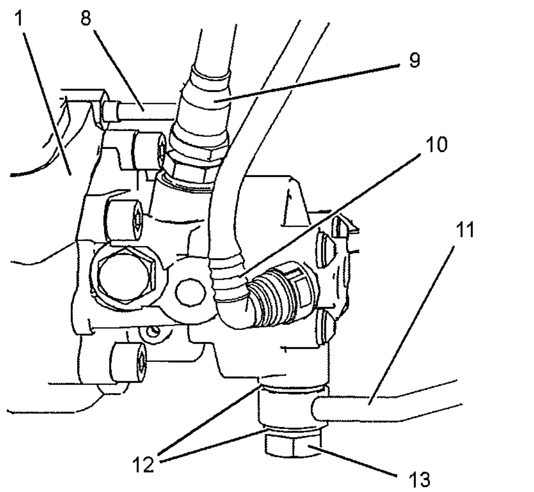

Illustration 27 g01563276

Typical example

9. Disconnect plastic tube assembly (2) from fuel injection pump (1).

10. Disconnect harness assembly (6) from solenoid (3). Slide the locking tab into the unlocked position and disconnect harness assembly (6) from position sensor (7).

Note: The harness assembly should be positioned in order to avoid an obstruction to the fuel injection pump.

11. Disconnect plastic tube assembly (10) from fuel injection pump (1).

12. Disconnect plastic tube assembly (9) from fuel injection pump (1).

13. Disconnect plastic tube assembly (4) from fuel injection pump (1).

14. Remove banjo bolt (13) and remove sealing washers (12).

15. Plug or cap all open ports and tube assemblies immediately with new plugs or caps.

Note: Ensure that quick fit connections are clean before the tube assemblies are plugged.

16. Remove fuel injection line (5). Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove". Use Tooling (D) in order to plug the open ports in the fuel injection pump and in the fuel manifold. Discard the fuel injection line.

17. Remove tube assembly (8) for the engine oil supply to the fuel injection pump. Remove the banjo bolt and the sealing washers from the tube assembly.

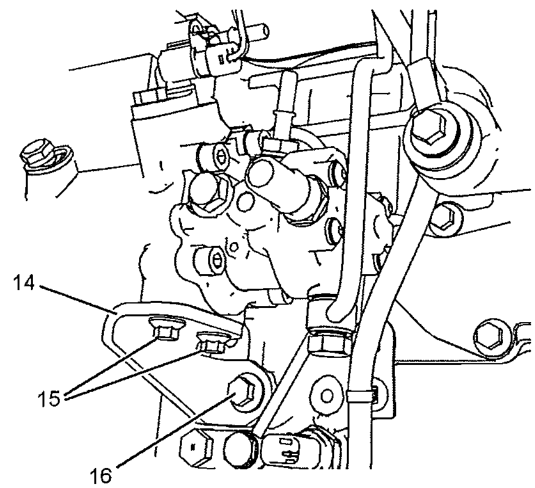

Illustration 28 g01566973

Typical example

18. Remove bolts (15) and remove bolt (16). Remove support bracket (14).

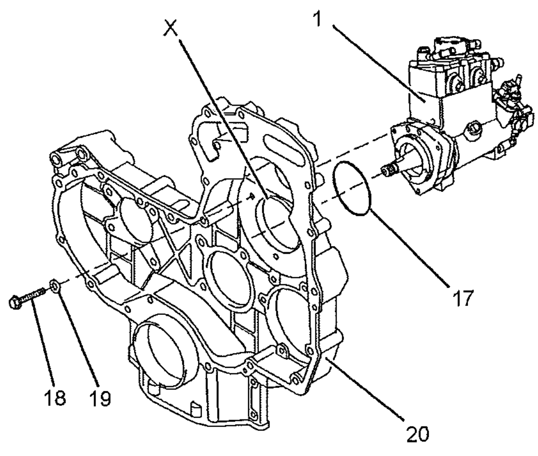

Illustration 29 g01801934

Typical example

19. Remove bolts (18) and remove sealing washers (19).

Note: The fuel injection pump should be supported by hand as the bolts are removed.

20. Carefully remove fuel injection pump (1) from front housing (20). Ensure that bore (X) in the front housing is not damaged as the fuel injection pump is removed.

21. Remove O-ring seal (17) from fuel injection pump (1).

i03401825

Fuel Injection Pump - Install

Installation Procedure

Table 6

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1
E	27610352	Fuel Injection Pump Timing Tool	1
F	21820221	POWERPART Rubber Grease	-

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

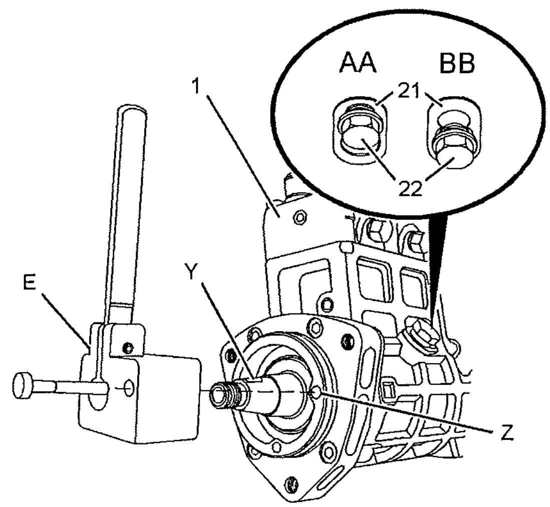

Illustration 30 g01572496

Typical example

Note: A new fuel injection pump is supplied, locked in the correct position. Do not unlock the fuel injection pump before installation.

1. If the fuel injection pump timing has been lost, it is possible to reset the fuel injection pump timing. Follow Step 1.a through Step 1.e in order to reset the fuel injection pump timing.

a. Loosen locking screw (22) and slide spacer (21) to Position (AA). Tighten locking screw (22) to a torque of 9 N·m (80 lb in). This will prevent the locking screw from tightening against the shaft of the fuel injection pump.

The fuel injection pump is now unlocked.

b. Position Tooling (E) onto the shaft of fuel injection pump (1). Align the lever of Tooling (E) with Keyway (Y) and engage the lever into the keyway.

Note: The lever of Tooling (E) should be a close fit in the keyway. If the lever is a loose fit in the keyway, it is not possible to reset the fuel injection pump timing.

c. Rotate the shaft of the fuel injection pump and engage the pin of Tooling (E) into Hole (Z).

The fuel injection pump timing is now set in the correct position.

d. Loosen locking screw (22) and slide spacer (21) to Position (BB). Tighten locking screw (22) to a torque of 9 N·m (80 lb in). The locking screw is now tightened against the shaft of the fuel injection pump.

The fuel injection pump is now locked.

e. Remove Tooling (E).

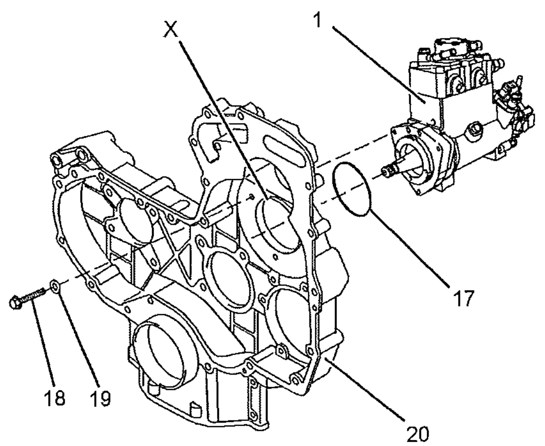

Illustration 31 g01801934

Typical example

2. Inspect Bore (X) in front housing (20) for damage. If the bore is damaged, replace the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove" and Disassembly and Assembly, "Housing (Front) - Install".

3. Use Tooling (F) to lubricate a new O-ring seal (17). Install the O-ring seal onto fuel injection pump (1).

4. Align fuel injection pump (1) with front housing (20). Carefully install the fuel injection pump to the front housing.

Note: The fuel injection pump should be supported by hand until the bolts are installed.

5. Install bolts (18) and new sealing washers (19). Tighten the bolts to a torque of 25 N·m (18 lb ft).

6. If necessary, use Tooling (A) in order to rotate the crankshaft so that number one piston is at top dead center on the compression stroke. Refer to System Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

7. Use Tooling (B) in order to lock the camshaft in the correct position. Use Tooling (C) in order to lock the crankshaft in the correct position. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install" for the correct procedure.

8. Install the fuel injection pump gear to the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install" and refer to Disassembly and Assembly, "Gear Group (Front) - Install".

Note: Ensure that the fuel injection pump is unlocked after the installation of fuel injection pump gear is completed.

9. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

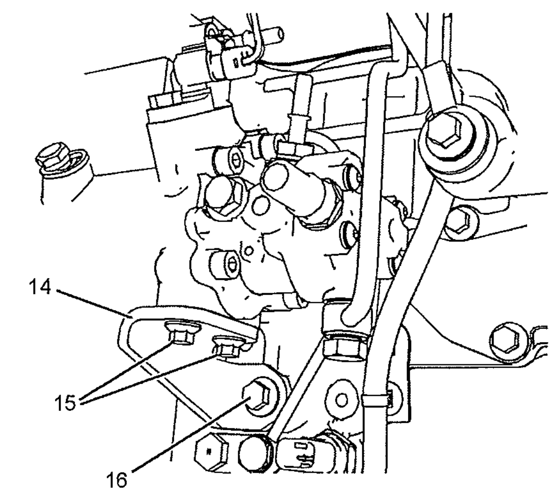

Illustration 32 g01566973

Typical example

10. Position support bracket (14) and install bolts (15) finger tight. Install bolt (16) finger tight.

11. Tighten bolt (16) to a torque of 44 N·m (32 lb ft). Tighten bolts (15) to a torque of 22 N·m (16 lb ft).

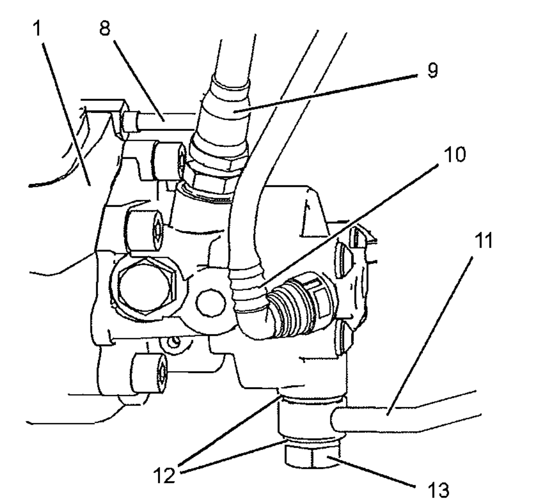

Illustration 33 g01563276

Typical example

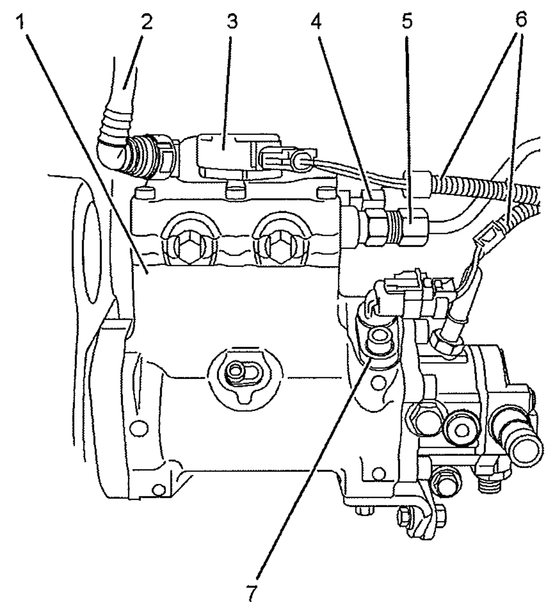

Illustration 34 g01563275

Typical example

12. Install the banjo bolt and new sealing washers to tube assembly (8). Install tube assembly (8) for the oil feed to the fuel injection pump. Tighten the banjo bolt and the nut to a torque of 15 N·m (11 lb ft).

13. Install a new fuel injection line (5). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

14. Install new sealing washers (12) and banjo bolt (13) to tube assembly (11). Tighten the banjo bolt to a torque of 21 N·m (15 lb ft).

15. Connect plastic tube assembly (4) to fuel injection pump (1).

16. Connect plastic tube assembly (9) to fuel injection pump (1).

17. Connect plastic tube assembly (10) to fuel injection pump (1).

18. Connect harness assembly (6) to solenoid (3). Connect harness assembly (6) to position sensor (7). Slide the locking tab into the locked position.

19. Connect plastic tube assembly (2) to fuel injection pump (1).

20. If necessary, install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

21. If necessary, install the fuel priming pump. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

22. If necessary, install the fuel filter base. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install".

23. Turn the battery disconnect switch to the ON position.

24. Turn the fuel supply to the ON position.

25. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

i02933643

Fuel Injection Pump Gear - Remove

Removal Procedure

Table 7

Required Tools			
Tool	Part Number	Part Descriptions	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1
D	-	Puller (Three Leg)	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

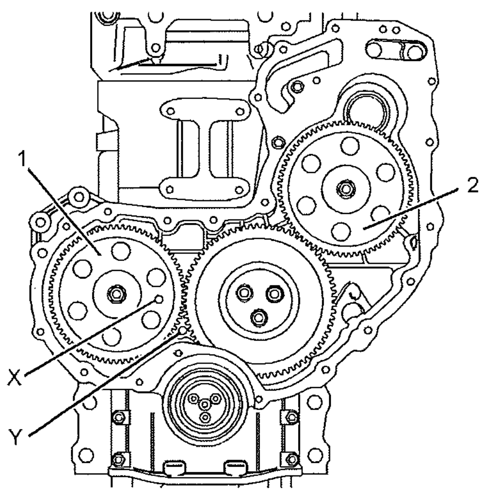

Illustration 35 g01459155

Typical example

2. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position.

3. Install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

Note: Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

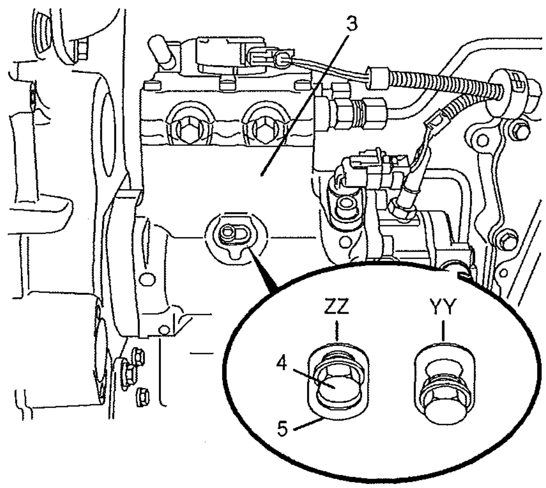

Illustration 36 g01459153

Typical example

4. Apply sufficient pressure to fuel injection pump gear (2) in a counterclockwise direction in order to remove the backlash. Lock fuel injection pump (3) in this position.

   In order to lock fuel injection pump (3), loosen locking screw (4) in the fuel injection pump. Slide spacer (5) into Position (YY). Tighten locking screw (4) against the shaft of the fuel injection pump to a torque of 9 N·m (80 lb in).

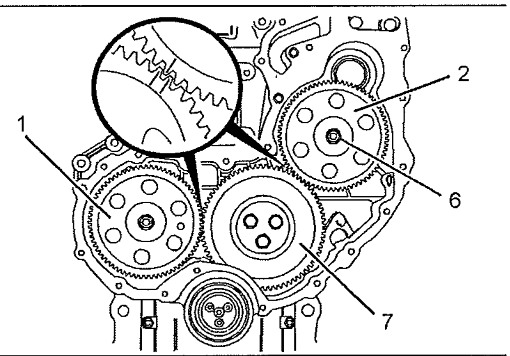

Illustration 37 g01765133

Alignment of timing marks

5. Mark gear (1), gear (2) and gear (7) in order to show alignment. Refer to Illustration 37.

Note: Identification will ensure that the gears can be installed in the original alignment.

6. Loosen nut (6) on fuel pump gear (2).

7. Install Tooling (D) through three holes in fuel pump gear (2). Tighten Tooling (D) until the fuel pump gear is released.

8. Remove Tooling (D) from fuel pump gear (2).

9. Remove nut (6) and the washer from fuel pump gear (2). Remove the fuel pump gear.

i02933642

Fuel Injection Pump Gear - Install

Installation Procedure

Table 8

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1
E	21825617	Dial Indicator Group	1
	-	Finger Clock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The fuel injection pump must remain locked until the procedure instructs you to unlock the fuel injection pump.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

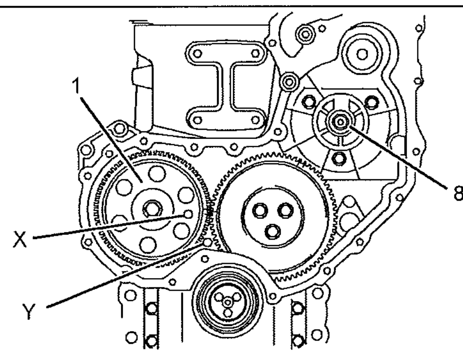

Illustration 38 g01765193

Typical example

2. Ensure that Tooling (C) is installed in Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

3. Ensure that Tooling (B) is installed into Hole (X) in camshaft gear (1).

4. Ensure that shaft (8) on the fuel injection pump is clean, dry and free from damage.

5. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

6. Ensure that the fuel pump gear is clean, dry and free from wear or damage. If necessary, replace the fuel pump gear.

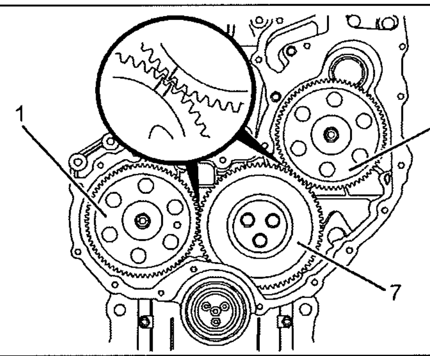

Illustration 39 g01769115

Alignment of timing marks

7. Install fuel pump gear (2) to shaft (8) of the fuel injection pump. Ensure that the timing marks on gears (2) and (7) are in alignment and that the mesh of the gears is correct.

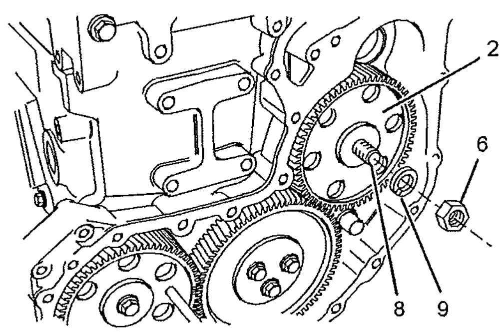

Illustration 40 g01769133

Typical example

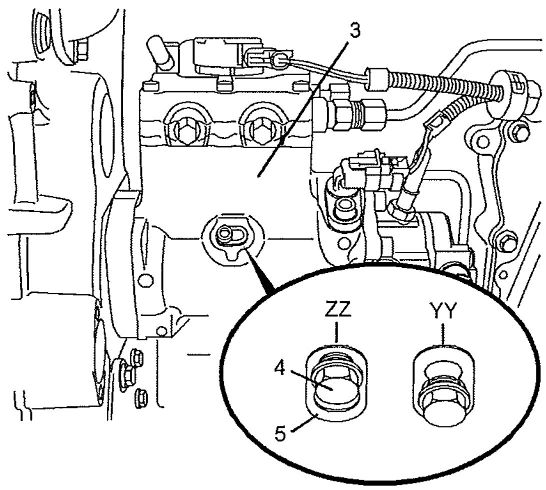

Illustration 41 g01459724

Typical example

8. Install a new spring washer (9) and install nut (6) to shaft (8) of the fuel injection pump. Apply sufficient pressure to fuel injection pump gear (2) in a counterclockwise direction in order to remove the backlash. Tighten nut (6) to a torque of 25 N·m (18 lb ft). Unlock fuel injection pump (3).

   In order to unlock the fuel injection pump, loosen locking screw (4) on the fuel injection pump. Slide spacer (5) into Position (ZZ). Tighten the locking screw against the spacer to a torque of 9 N·m (80 lb in). This will prevent the locking screw from tightening against the shaft of the fuel injection pump.

9. Remove Tooling (B) and Tooling (C).

10. Tighten nut (6) to a torque of 90 N·m (66.4 lb ft).

11. Use Tooling (E) to measure the backlash of gears (2) and (7). Ensure that the backlash for the gears is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

12. Lubricate the teeth of the gears with clean engine oil.

End By:

a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

i02933618

Electronic Unit Injector - Remove

Removal Procedure

Table 9

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610307	T40 Torx Socket	1
C	27610288	Pry Bar	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

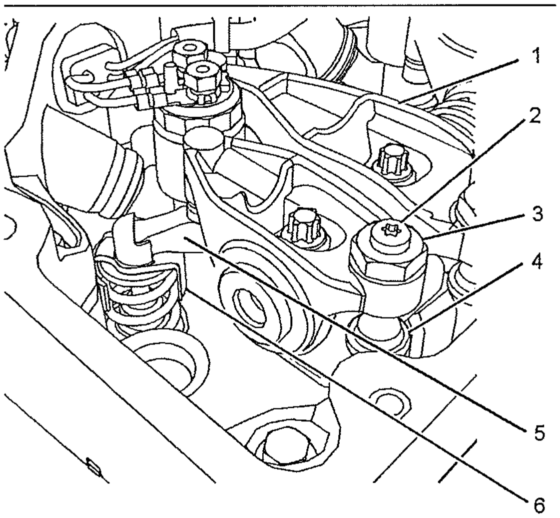

Illustration 42 g01772534

Typical example

3. Use Tooling (A) in order to rotate the crankshaft until rocker arms (1) for the appropriate cylinder are in the correct position in order to adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".
4. Follow Step 4.a through Step 4.d in order to gain access to the electronic unit injector.
   a. Make a temporary mark on valve bridges (5) in order to show the location and orientation.

Note: Identification will ensure that the valve bridges can be reinstalled in the original location and the original orientation.

   b. Loosen nuts (3) for the appropriate cylinder. Unscrew adjusters (2) for the appropriate cylinder until pushrods (4) can be withdrawn from the balls of the adjusters.
   c. Withdraw the cups of pushrods (4) from the balls of adjusters (2).
   d. Remove valve bridges (5) from the cylinder head. If the valve bridges are equipped with shrouds (6), ensure that the shrouds are removed from the cylinder head.

Note: Do not interchange the location or the orientation of used valve bridges.

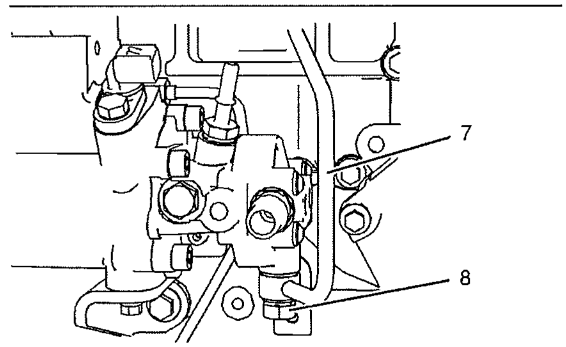

Illustration 43 g01769493

Typical example

5. Loosen banjo bolt (8) on the fuel transfer pump sufficiently in order to allow the fuel to drain from tube assembly (7).

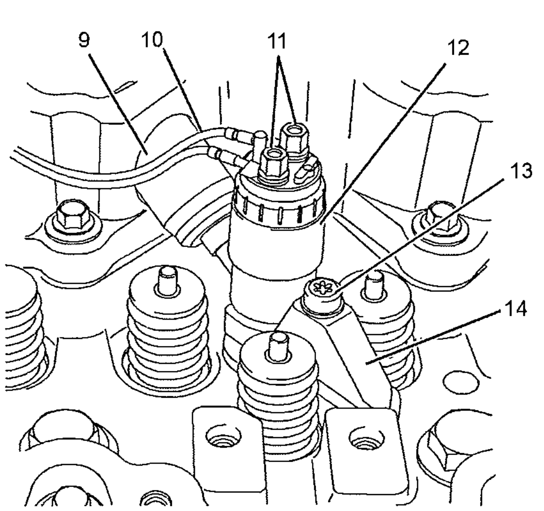

Illustration 44 g01769513

The rocker shaft is not shown for clarity.

6. Remove the fuel injection line and remove seal (9) from the appropriate electronic unit injector (12). Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

Note: Cap all open ports immediately with new caps.

7. Use a deep socket to remove connections (11) from electronic unit injector (12).

8. Slide rocker arms (1) to one side in order to gain access to torx screw (13). Use Tooling (B) in order to remove the torx screw from clamp (14). Discard the torx screw.

Note: Tooling (B) must be used to ensure no damage to the rocker arms.

9. Place a temporary identification mark on the original electronic unit injector. The electronic unit injector must be reinstalled in the original location in the cylinder head.

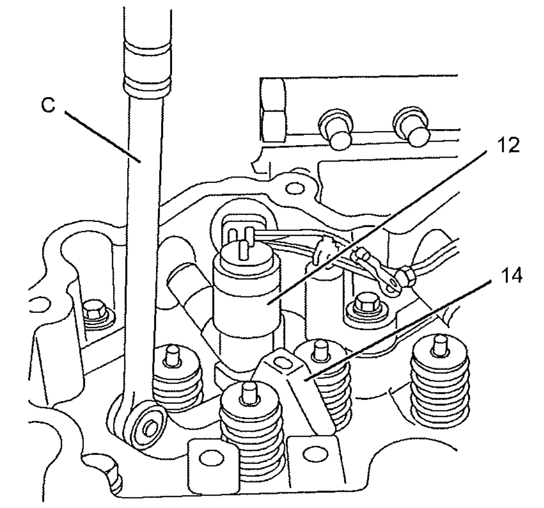

Illustration 45 g01769553

The rocker shaft is not shown for clarity.

10. Use Tooling (C) to pry beneath clamp (14) and free electronic unit injector (12) from the cylinder head.

11. Remove electronic unit injector (12) and clamp (14) from the cylinder head.

Note: Always handle electronic unit injectors with care.

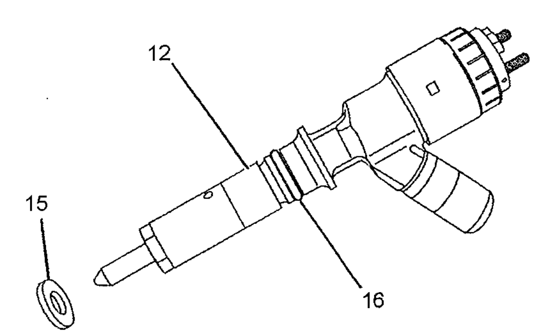

Illustration 46 g01769574

Typical example

12. Remove sealing washer (15). Ensure that the sealing washer is removed from the cylinder head. Remove O-ring seal (16) from the electronic unit injector.

Alternative Removal Procedure

Table 10

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610307	T40 Torx Socket	1
C	27610288	Pry Bar	1

Start By:

a. Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

b. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

Note: This is an optional procedure to remove the electronic unit injectors. The method should ONLY be used when all electronic unit injectors are removed and when the engine is removed from the application.

⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.

2. Turn the battery disconnect switch to the OFF position.

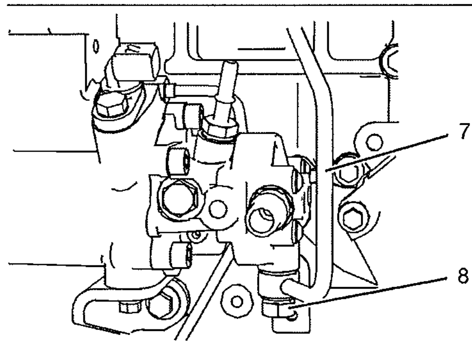

Illustration 47 g01769493

Typical example

3. Loosen banjo bolt (8) on the fuel transfer pump sufficiently in order to allow the fuel to drain from tube assembly (7).

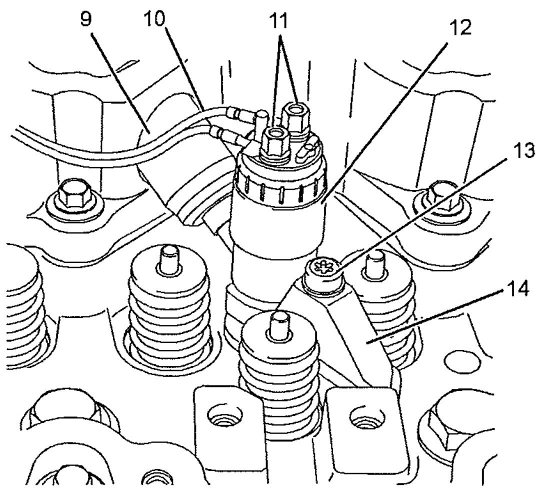

Illustration 48 g01769513

Typical example

4. Place a temporary identification mark on connections (11) for harness assembly (10).

5. Use a deep socket to remove connections (11) from electronic unit injector (12).

6. Use Tooling (B) in order to remove torx screw (13) from clamp (14). Discard the torx screw.

7. Place a temporary identification mark on the original electronic unit injector. The electronic unit injector must be reinstalled in the original location in the cylinder head.

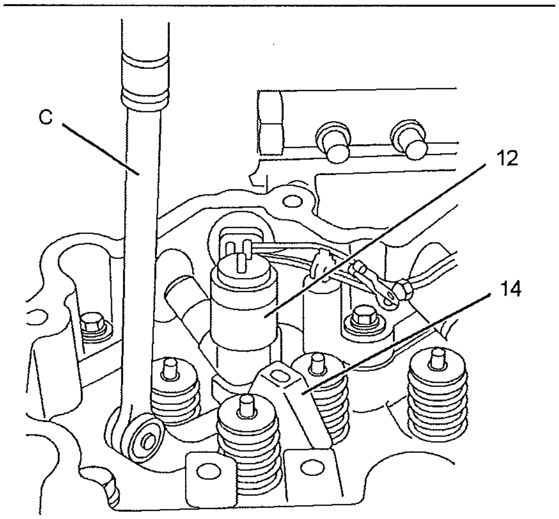

Illustration 49 g01769553

Typical example

8. Use Tooling (C) to pry beneath clamp (14) and free electronic unit injector (12) from the cylinder head.

9. Remove electronic unit injector (12) and clamp (14) from the cylinder head.

Note: Always handle electronic unit injectors with care.

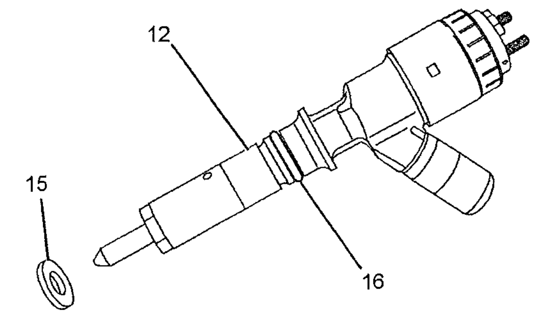

Illustration 50 g01769574

Typical example

10. Remove sealing washer (15). Ensure that the sealing washer is removed from the cylinder head. Remove O-ring seal (16) from the electronic unit injector.

11. Repeat Step 4 through Step 11 in order to remove the remaining electronic unit injectors.

i02933617

Electronic Unit Injector - Install

Installation Procedure

Table 11

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610307	T40 Torx Socket	1
D	GE50028	Vacuum Pump	1
	GE50030	Tube 7.9 mm (0.31 inch) Outside Diameter	1
E	27610294	Injector Pipe Nut Tool	1
F	27610296	Torque Wrench	1

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to install the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

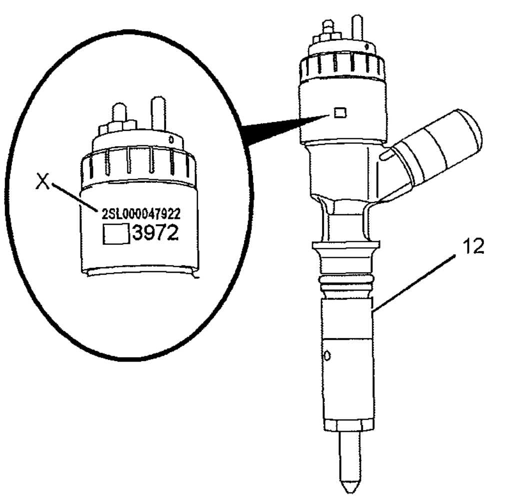

Illustration 51 g01772353

Typical calibration code

1. If a replacement electronic unit injector is installed, the correct trim file for the injector must be programmed into the electronic control module. Refer to Troubleshooting, "Injector Trim File" for more information. The code that is required to obtain the trim file for the injector is located at Position (X).

Note: Record Code (X) before the electronic unit injector is installed.

2. Use Tooling (D) in order to remove any fuel from the cylinder.

Note: Evacuate as much fuel as possible from the cylinder before installing the electronic unit injector.

3. Ensure that the fuel inlet port of the electronic unit injector is capped. Ensure that the electronic unit injector is clean.

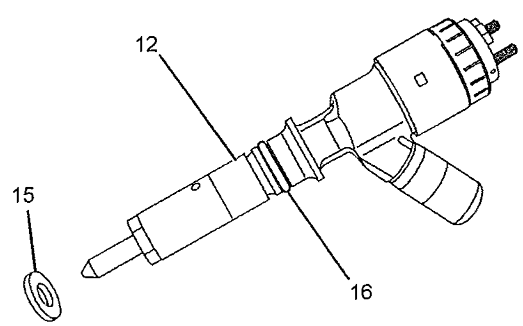

Illustration 52 g01769574

Typical example

4. On installing an original electronic unit injector, install a new O-ring seal (16) and sealing washer (15) to electronic unit injector (12).

   Ensure that O-ring seal (16) and sealing washer (15) on a new electronic unit injector are not damaged and in place.

Note: Do not lubricate the O-ring seal.

5. Ensure that the seat for the electronic unit injector in the cylinder head is clean and free from damage. Ensure that the old sealing washer has been removed from the cylinder head.

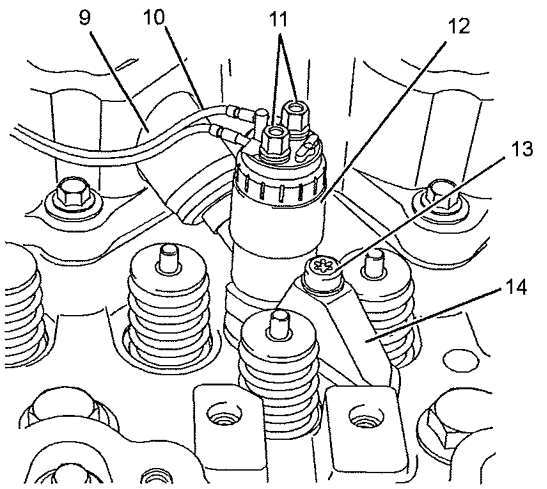

Illustration 53 g01769513

The rocker shaft is not shown for clarity.

6. Position clamp (14) between the rocker arm and the valve springs. Align electronic unit injector (12) to the bore for the electronic unit injector in the cylinder head. Install the clamp to the electronic unit injector. Ensure that the electronic unit injector is pushed firmly against the seat in the cylinder head.

7. Install a new torx screw (13) to clamp (14). Tighten the torx screw finger tight.

8. Remove the cap from electronic unit injector (12). Install a new seal (9) to electronic unit injector (12) and to the valve mechanism cover base. Ensure that the flange on the seal is flush with the valve mechanism cover base.

9. Remove the plugs from the new fuel injection line. Loosely install the fuel injection line. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

Note: Ensure that the ends of the fuel injection line are seated in the electronic unit injector and the fuel manifold. Tighten the nuts finger tight.

10. Use Tooling (B) to tighten torx screw (12) to a torque of 27 N·m (20 lb ft).

Note: Tooling (B) must be used to ensure no damage to the rocker arms.

11. Use Tooling (E) to tighten the fuel injection line to a torque of 30 N·m (22 lb ft). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

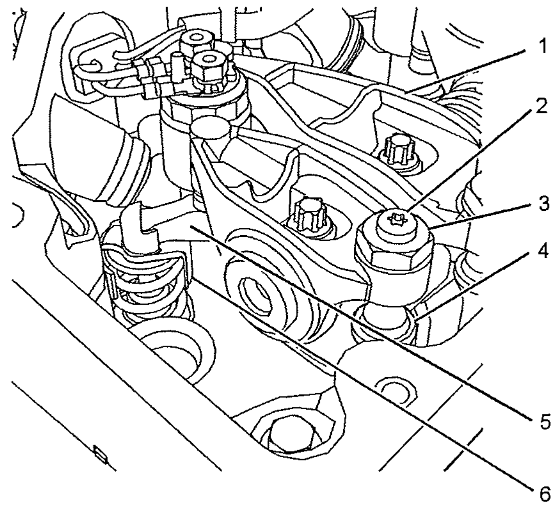

Illustration 54 g01772534

Typical example

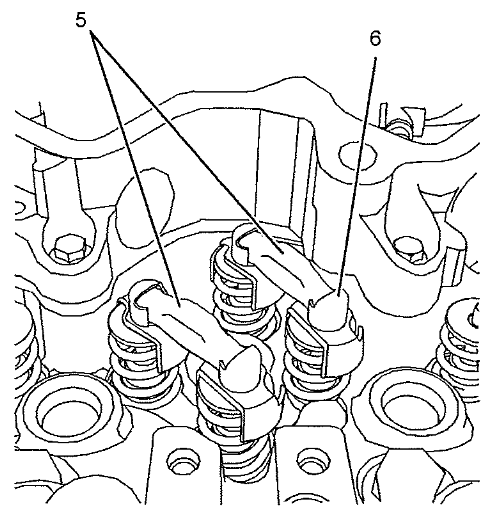

Illustration 55 g01774093

Typical example

The electronic unit injector is not shown for clarity.

NOTICE

Failure to ensure that ALL valve bridges are correctly seated onto the valve stems will cause interference between the pistons and the valves, resulting in damage to the engine.

12. Install valve bridges (5) to the cylinder head. If valve bridges (5) are equipped with shrouds (6), ensure that the shrouds are located correctly.

Note: Ensure that used valve bridges are reinstalled in the original location and the original orientation. Do not interchange the location or the orientation of used valve bridges.

13. Ensure that the bottoms of the pushrods are seated in the cups of the valve lifters. Locate the balls of adjusters (2) into the cups of pushrods (4). Adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

14. Use a deep socket to install harness assembly (10) to electronic unit injector (12). Use Tooling (F) to tighten connections (11) to a torque of 2.4 N·m (21 lb in).

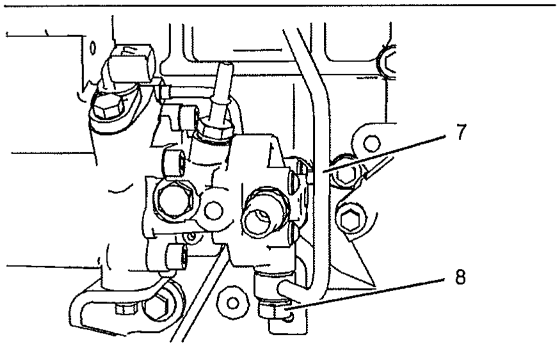

Illustration 56 g01769493

Typical example

15. Tighten banjo bolt (8) on the fuel transfer pump for tube assembly (7). Tighten the banjo bolt to a torque of 21 N·m (15 lb ft).

16. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

17. Turn the fuel supply to the ON position.

18. Turn the battery disconnect switch to the ON position.

19. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

Alternative Installation Procedure

Table 12

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610307	T40 Torx Socket	1
D	GE50028	Vacuum Pump	1
	GE50030	Tube 7.9 mm (0.31 inch) Outside Diameter	1
E	27610294	Injector Pipe Nut Tool	1
F	27610296	Torque Wrench	1

Note: This is an optional procedure to install the electronic unit injectors. The method should ONLY be used when all electronic unit injectors are installed and when the engine is removed from the application.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

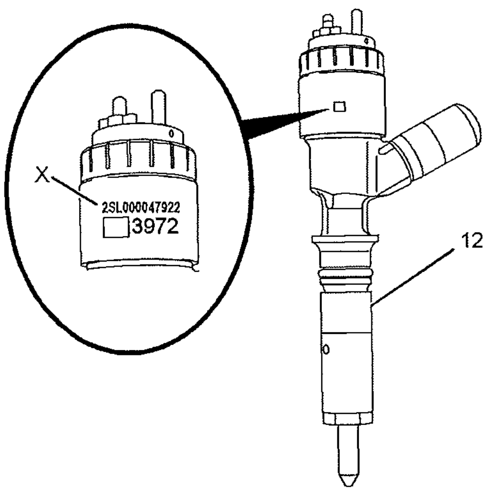

Illustration 57 g01772353

Typical calibration code

1. If a replacement electronic unit injector is installed, the correct trim file for the injector must be programmed into the electronic control module. Refer to Troubleshooting, "Injector Trim File" for more information. The code that is required to obtain the trim file for the injector is located at Position (X).

Note: Record Code (X) before the electronic unit injector is installed.

2. Use Tooling (D) to remove any fuel from the cylinder.

Note: Evacuate as much fuel as possible from the cylinder before installing the electronic unit injector.

3. Ensure that the fuel inlet port of the electronic unit injector is capped. Ensure that the electronic unit injector is clean.

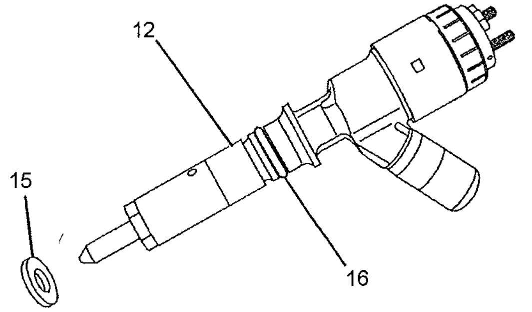

Illustration 58 g01769574

Typical example

4. On installing an original electronic unit injector, install a new O-ring seal (16) and sealing washer (15) to electronic unit injector (12).

   Ensure that O-ring seal (16) and sealing washer (15) on a new electronic unit injector are not damaged and in place.

Note: Do not lubricate the O-ring seal.

5. Ensure that the seat for the electronic unit injector in the cylinder head is clean and free from damage. Ensure that the old sealing washer has been removed from the cylinder head.

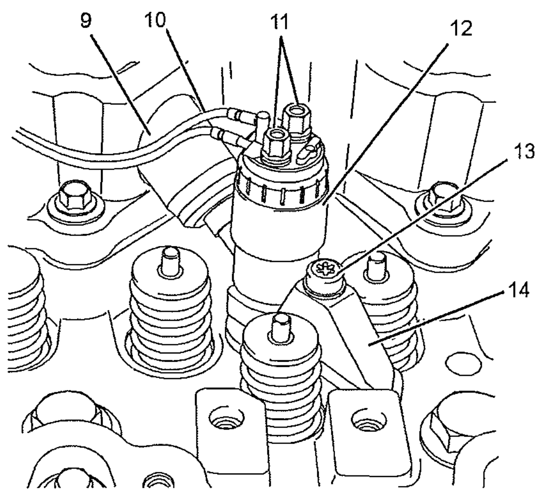

Illustration 59 g01769513

Typical example

6. Install clamp (14) to electronic unit injector (12). Install the electronic unit injector assembly into the original location in the cylinder head.

Note: Ensure that the electronic unit injector is pushed firmly against the seat in the cylinder head. Install the electronic unit injector for number one cylinder first. Install the electronic unit injectors in numerical order.

7. Install a new torx screw (13) to clamp (14). Tighten the torx screw finger tight.

8. Remove the cap from electronic unit injector (12). Install a new seal (9) to electronic unit injector (12) and to the valve mechanism cover base. Ensure that the flange on the seal is flush with the valve mechanism cover base.

9. Remove the plugs from the new fuel injection line. Loosely install the fuel injection line. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

Note: Ensure that the ends of the fuel injection line are seated in the electronic unit injector and the fuel manifold. Tighten the nuts finger tight.

10. Use Tooling (B) to tighten torx screw (12) to a torque of 27 N·m (20 lb ft).

11. Use Tooling (E) to tighten the fuel injection line to a torque of 30 N·m (22 lb ft). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

12. Repeat Step 2 through Step 11 in order to install the remaining electronic unit injectors.

13. Use a deep socket to install harness assemblies (10) to electronic unit injectors (12). Use Tooling (F) to tighten connections (11) to a torque of 2.4 N·m (21 lb in).

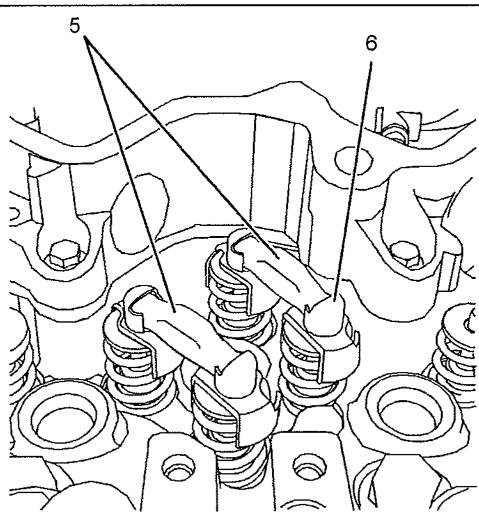

Illustration 60 g01774093

Typical example

The electronic unit injector is not shown for clarity.

NOTICE

Failure to ensure that ALL valve bridges are correctly seated onto the valve stems will cause interference between the pistons and the valves, resulting in damage to the engine.

14. Install valve bridges (5) to the cylinder head. If valve bridges (5) are equipped with shrouds (6), ensure that the shrouds are located correctly.

15. Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods - Install".

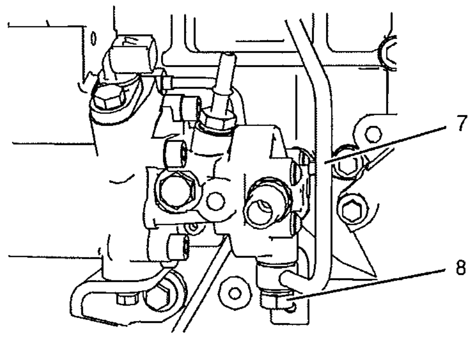

Illustration 61 g01769493

Typical example

16. Tighten banjo bolt (8) on the fuel transfer pump for tube assembly (7). Tighten the banjo bolt to a torque of 21 N·m (15 lb ft).

17. Turn the fuel supply to the ON position.

18. Turn the battery disconnect switch to the ON position.

19. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

i03428965

Turbocharger - Remove (Top Mounted Turbocharger)

Removal Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Plug and cap all open ports and tube assemblies.

1. Disconnect the air hose for the turbocharger inlet and for the turbocharger outlet.

2. If the turbocharger has a remote wastegate solenoid, disconnect the hose from the actuator on the turbocharger. Disconnect the hose assembly for the wastegate solenoid from the tube assembly for the oil feed on the turbocharger. The hose assembly is secured with clips.

3. Disconnect the exhaust pipe.

4. If the turbocharger has an exhaust elbow, remove the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

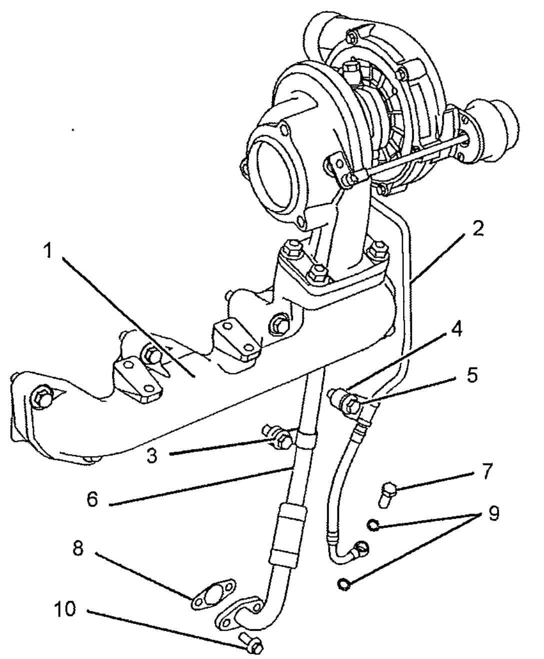

Illustration 62 g01780893

5. Remove bolts (10) in order to disconnect tube assembly (6) from the cylinder block. Remove gasket (8).

6. Remove bolt (7) in order to disconnect tube assembly (2) from the cylinder block. Remove sealing washers (9).

7. Remove bolt (3) for the tube clip.

8. Remove bolt (5) and spacer (4) for the tube clip.

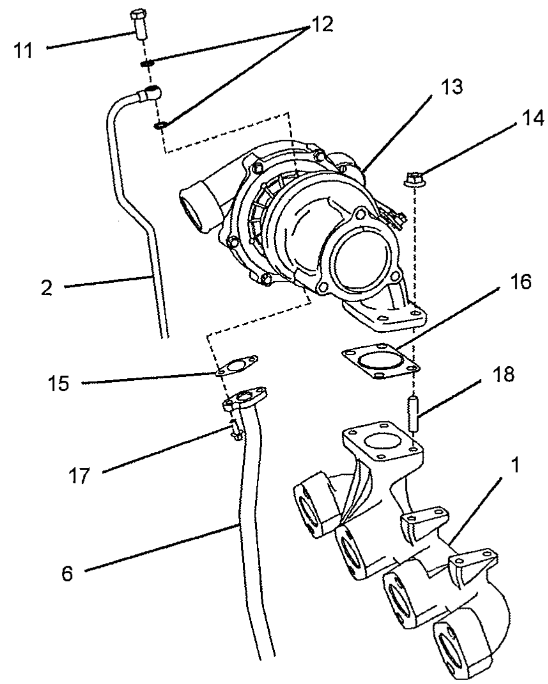

Illustration 63 g01782773

9. Loosen nuts (14).

10. Remove banjo bolt (11) and remove tube assembly (2) for the oil feed from turbocharger (13). Remove sealing washers (12).

11. Remove exhaust manifold (1) and the assembly of the turbocharger from the cylinder head. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install" for the correct procedure.

12. Remove bolts (17) and remove tube assembly (6) for the oil drain from turbocharger (11).

13. Remove gasket (15).

14. Remove nuts (14) and remove turbocharger (13) from exhaust manifold (1).

Note: Ensure that the exhaust manifold and the turbocharger are adequately supported during the removal of the turbocharger.

15. Remove gasket (16) from exhaust manifold (1).

16. If necessary, remove studs (18) from exhaust manifold (1).

i02933674

Turbocharger - Remove (Side Mounted Turbochargers)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Plug and cap all open ports and tube assemblies.

1. Disconnect the air hose for the turbocharger inlet and for the turbocharger outlet (not shown).

2. If the turbocharger is equipped with an exhaust elbow, remove the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

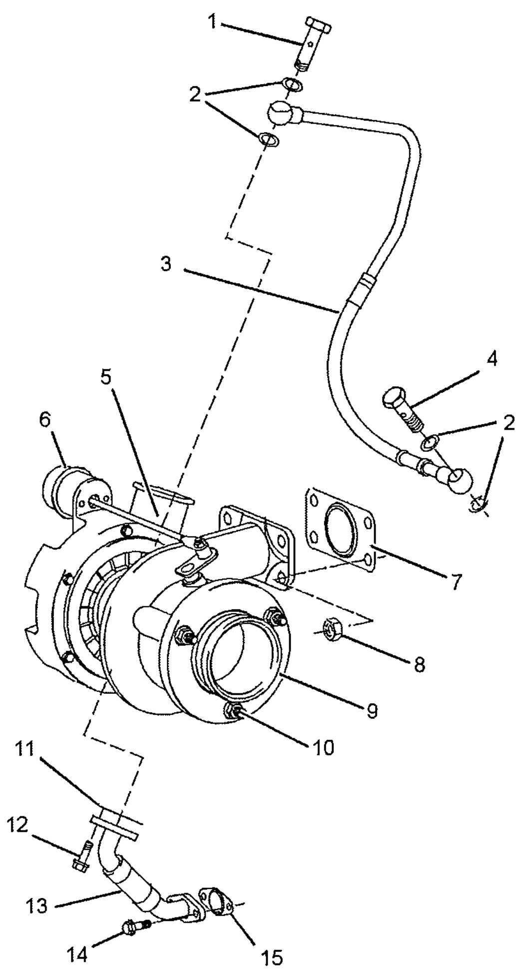

Illustration 64 g01264131

Typical example

3. If the turbocharger is equipped with an adapter (9), Remove nuts (10) and remove adapter (9) from turbocharger (5).

4. Remove banjo bolt (1) and disconnect tube assembly (3) from turbocharger (5). Remove sealing washers (2) from tube assembly (3).

   If necessary, remove tube assembly (3) from the tube assembly for actuator (6). Tube assembly (3) is secured to the tube assembly for the actuator by clips.

5. Disconnect the hose from actuator (6).

6. Remove banjo bolt (4) and remove tube assembly (3) from the cylinder block. Remove sealing washers (2) from tube assembly (3).

7. Remove bolts (12). Disconnect tube assembly (13) from turbocharger (5). Remove gasket (11).

   If necessary, remove bolts (14) and remove tube assembly (13) from the cylinder block. Remove gasket (15).

8. Remove nuts (8) and remove turbocharger (5).

Note: Do not use the actuator rod to lift the turbocharger.

9. Remove gasket (7).

10. If necessary, remove the studs from the exhaust manifold.

i03431780

Turbocharger - Install (Top Mounted Turbocharger)

Installation Procedure

Table 13

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21820117	POWERPART Threadlock and Nutlock	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

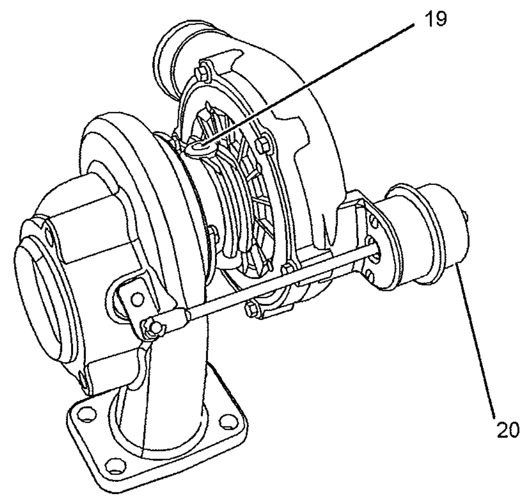

Illustration 65 g01784893

Typical example

1. Ensure that the turbocharger is clean and free from damage. Inspect the turbocharger for wear. Refer to System Operation, Testing and Adjusting, "Turbocharger Inspect" for more information. If the turbocharger is worn, the complete turbocharger must be replaced.

2. Test wastegate actuator (20) for correct operation. Refer to System Operation, Testing and Adjusting, "Turbocharger Inspect". If the wastegate actuator is damaged or the wastegate actuator does not operate within the specified limits, the complete turbocharger must be replaced.

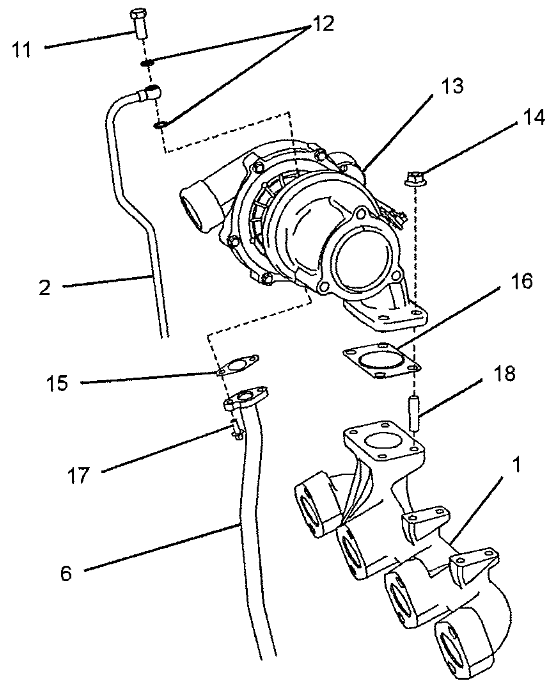

Illustration 66 g01782773

3. Clean the gasket surfaces of the exhaust manifold (1). If necessary, install studs (18) to the exhaust manifold. Tighten the studs to a torque of 18 N·m (13 lb ft).

Note: Support the exhaust manifold during installation of the turbocharger.

4. Install a new gasket (16) to exhaust manifold (1).

5. Position turbocharger (13) on exhaust manifold (1).

6. Install nuts (14). Tighten the nuts to a torque of 44 N·m (32 lb ft).

7. Ensure that tube assembly (6) is clean and free from damage. Replace any damaged components.

8. Position a new gasket (15) and bolts (17) onto tube assembly (6).

9. Install tube assembly (6) to turbocharger (13). Tighten bolts (17) finger tight.

10. Install exhaust manifold (1) and the assembly of the turbocharger to the cylinder head. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install" for the correct procedure.

11. Remove the plug from oil inlet port (19). Refer to Illustration 65. Lubricate the turbocharger bearings with clean engine oil through the oil inlet port. Rotate the wheel of the compressor several times in order to lubricate the bearings.

12. Ensure that tube assembly (2) is clean and free from damage. Replace any damaged components.

13. Install banjo bolt (11) and new sealing washers (12) to tube assembly (2).

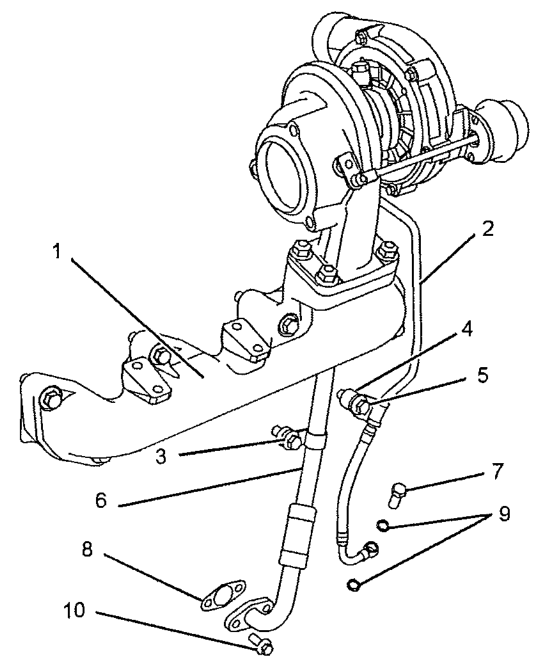

Illustration 67 g01780893

14. Install banjo bolt (7) and new sealing washers (9) to tube assembly (2).

15. Install tube assembly (2) to turbocharger (13). Tighten banjo bolt (11) finger tight. Refer to Illustration 66.

16. Tighten banjo bolt (7) to the cylinder block finger tight.

17. Position a new gasket (8) between the flange of tube assembly (6) and the cylinder block. Install bolts (10) finger tight.

18. Tighten banjo bolt (7) to a torque of 20 N·m (14 lb ft). Tighten bolts (10) to a torque of 22 N·m (16 lb ft).

19. Tighten banjo bolt (11) to a torque of 20 N·m (14 lb ft). Tighten bolts (17) to a torque of 9 N·m (80 lb in). Refer to Illustration 66.

20. Install bolt (3) for the tube clip to the cylinder block. Tighten bolt (3) to a torque of 44 N·m (32 lb ft).

21. Install bolt (5) and spacer (4) for the tube clip to the cylinder block. Tighten bolt (5) to a torque of 44 N·m (32 lb ft).

22. If the turbocharger has an exhaust elbow, install the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

23. Connect the exhaust pipe.

24. If the turbocharger has a remote wastegate solenoid, connect the hose to the actuator on the turbocharger. Connect the hose assembly for the wastegate solenoid to the tube assembly for the oil feed on the turbocharger. The hose assembly is secured with clips.

25. Connect the air outlet hose to turbocharger (13).

If the engine has an air pipe, install the air pipe and install the gasket to the cylinder head. Apply Tooling (A) to the fasteners for the air pipe. Tighten the fasteners to a torque of 22 N·m (16 lb ft).

Tighten the hose clamps to a torque of 5 N·m (44 lb in).

Note: If the air outlet hose has a reflective heat shield, ensure that the reflective heat shield is installed toward the engine.

26. Connect the air inlet hose to turbocharger (13).

i02933673

Turbocharger - Install (Side Mounted Turbochargers)

Installation Procedure

Table 14

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820117	POWERPART Threadlock and Nutlock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the turbocharger is clean and free from damage. Inspect the turbocharger for wear. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for more information. If the turbocharger is worn, the complete turbocharger must be replaced.

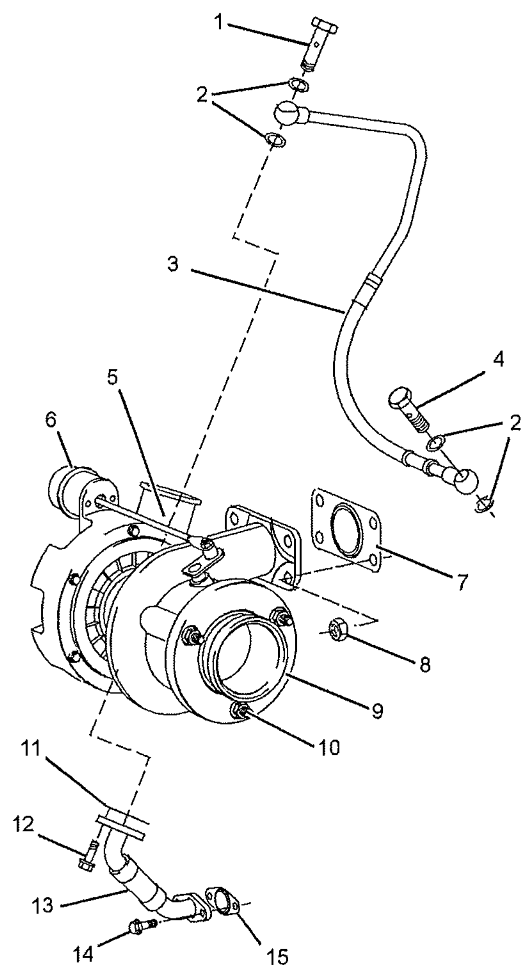

Illustration 68 g01264131

Typical example

2. Test actuator (6) for correct operation. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect". If the actuator is damaged or the actuator does not operate within the specified limits, the complete turbocharger must be replaced.

3. Clean the gasket surfaces of the exhaust manifold. If necessary, install the studs to the exhaust manifold. Tighten the studs to a torque of 18 N·m (13 lb ft).

4. Install a new gasket (7) to the exhaust manifold.

5. Position turbocharger (5) onto the exhaust manifold and install nuts (8). Tighten the nuts to a torque of 44 N·m (32 lb ft).

Note: Do not use the actuator rod to lift the turbocharger.

6. Position a new gasket (11) and tube assembly (13) onto turbocharger (5). Install bolts (12) finger tight.

7. Position a new gasket (15) onto the cylinder block. Install bolts (14) finger tight.

8. Tighten bolts (12) to a torque of 9 N·m (80 lb in). Tighten bolts (14) to a torque of 22 N·m (16 lb ft).

9. Lubricate the bearings of turbocharger (5) with clean engine oil through the oil inlet port. Rotate the shaft of the turbocharger in order to distribute the lubricant.

10. Position tube assembly (3) onto turbocharger (5). Install new washers (2) and banjo bolt (1) to tube assembly (3). Tighten the banjo bolt finger tight.

11. Install new washers (2) and banjo bolt (4) onto tube assembly (3). Connect the tube assembly to the cylinder block. Tighten the banjo bolt finger tight.

12. Tighten banjo bolts (1) and (4) to a torque of 18 N·m (13 lb ft).

Note: Ensure that the tube assembly does not come into contact with any other engine components.

13. Connect the hose to actuator (6). If necessary, secure tube assembly (3) to the tube assembly for actuator (6). Tube assembly (3) is secured to the tube assembly for the actuator by clips.

14. If the turbocharger has an exhaust elbow, install the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

15. If the turbocharger has an adapter (9), position the adapter onto the turbocharger. Tighten three nuts (10) progressively. Tighten the nuts to a torque of 25 N·m (18 lb ft).

Note: Ensure that the adapter is square with the face of the turbocharger.

16. Connect the air outlet hose to turbocharger (5).

    If the engine has an air pipe, install the air pipe and install the gasket to the cylinder head. Apply Tooling (A) to the bolts for the air pipe. Tighten the bolts to a torque of 22 N·m (16 lb ft).

    Tighten the hose clamps to a torque of 5 N·m (44 lb in).

Note: If the air outlet hose has a reflective heat shield, ensure that the reflective heat shield is installed toward the engine.

17. Connect the air inlet hose to turbocharger (5).

i02933679

Wastegate Solenoid - Remove and Install

Removal Procedure

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to keep contaminants from entering the system.

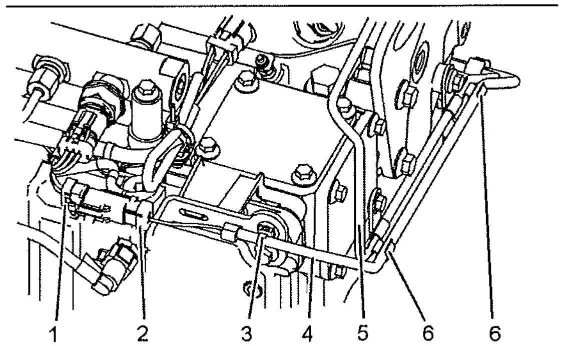

Illustration 69 g01247498

Typical example

1. Follow Step 1.a through Step 1.d in order to disconnect the harness assembly for the wastegate solenoid.

    a. Slide locking tab (1) into the unlocked position.

    b. Disconnect plug (2) from the engine wiring harness.

    c. Cut cable straps (3).

Note: Identify the position of all cable straps for installation purposes.

    d. Remove harness assembly (4) from tube assembly (5). The harness assembly is secured to the tube assembly by plastic clips (6).

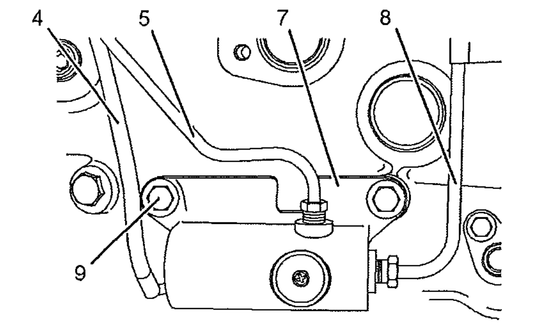

Illustration 70 g01247569

Typical example

2. Disconnect tube assembly (5) from wastegate solenoid (7).

3. Disconnect tube assembly (8) from wastegate solenoid (7). Remove tube assembly (8) from the tube assembly for the oil feed for the turbocharger. Tube assembly (8) is secured to the tube assembly for the oil feed for the turbocharger by spring clips.

Note: Tube assembly (8) must be loose in order to release the tube assembly from the wastegate solenoid.

4. Remove bolts (9) and remove wastegate solenoid (7) from the cylinder block.

Installation Procedure

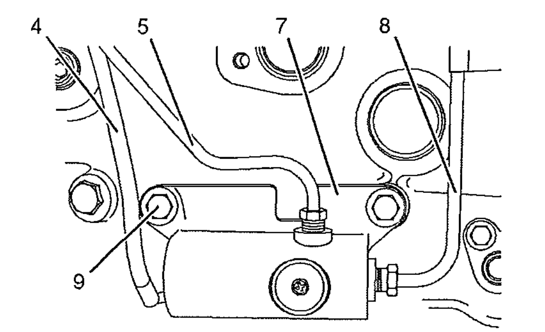

Illustration 71 g01247569

Typical example

1. Loosely install wastegate solenoid (7) to tube assembly (5).

2. Loosely install tube assembly (8) to wastegate solenoid (7).

3. Install bolts (9). Tighten bolts (9) to a torque of 44 N·m (32 lb ft).

4. Tighten tube assembly (5) and tube assembly (8) to a torque of 18 N·m (13 lb ft).

5. Secure tube assembly (8) to the tube assembly for the oil feed for the turbocharger. Tube assembly (8) is secured by spring clips.

Note: Ensure that the tube assemblies do not contact any other engine component.

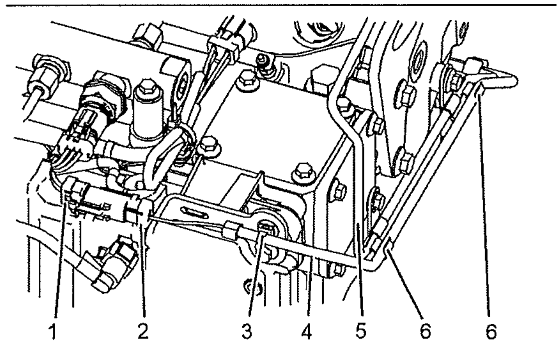

Illustration 72 g01247498

Typical example

6. Follow Step 6 through Step 6.d in order to connect the wire lead for the wastegate solenoid.

    a. Install harness assembly (4) to tube assembly (5). The harness assembly is secured to the tube assembly by plastic clips (6).

    b. Connect plug (2) to the engine harness assembly.

    c. Slide locking tab (1) into the locked position.

    d. Install new cable straps (3) to the previously identified positions.

i02933629

Exhaust Manifold - Remove and Install (Top Mounted Exhaust Manifold)

Removal Procedure

1. Disconnect all hoses, tube assemblies and wire leads from the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" for more information.

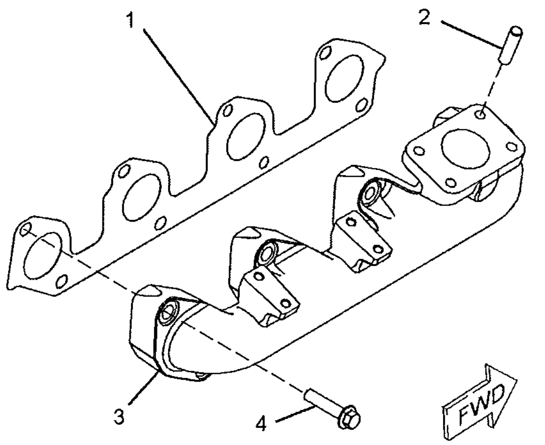

Illustration 73 g01245092
Typical example

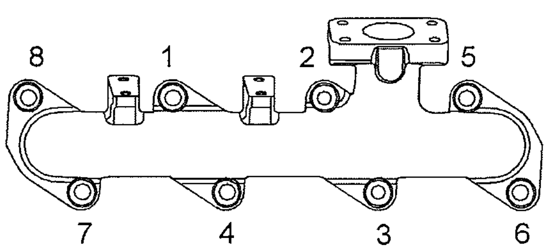

Illustration 74 g01789673
Tightening sequence for the exhaust manifold

2. Loosen bolts (4) in reverse numerical order to the sequence that is shown in Illustration 74.

Note: This will help prevent distortion of the exhaust manifold.

3. Remove bolts (4) from exhaust manifold (3).

Note: Support the manifold as the bolts are removed.

4. Remove the assembly of exhaust manifold (3) and the turbocharger.

5. Remove exhaust manifold gasket (1).

6. Remove the turbocharger from exhaust manifold (3). Refer to Disassembly and Assembly, "Turbocharger - Remove" for more information.

7. If necessary, remove studs (2) from exhaust manifold (3).

Installation Procedure (Top Mounted Exhaust Manifold)

Table 15

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M10 by 100 mm	2

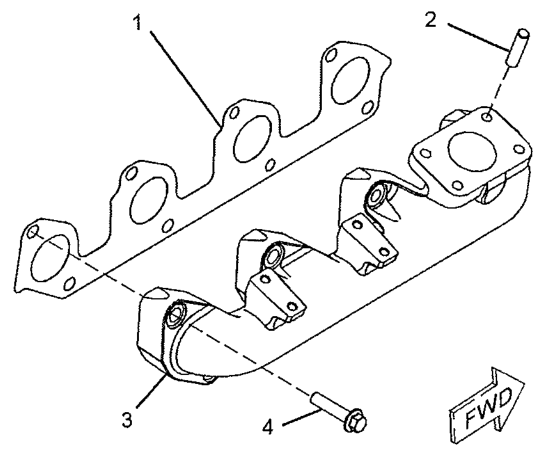

Illustration 75 g01245092
Typical example

1. Ensure that the exhaust manifold is clean and free from damage. If necessary, replace the exhaust manifold. Clean the gasket surface of the cylinder head.

2. If necessary, install studs (2) to exhaust manifold (3). Tighten the studs to a torque of 18 N·m (13 lb ft).

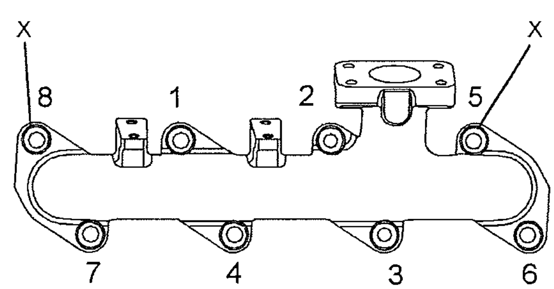

Illustration 76 g01789677
Tightening sequence for the exhaust manifold

3. Install Tooling (A) to the cylinder head in Positions (X). Refer to Illustration 76.

4. Position a new exhaust manifold gasket (1) onto Tooling (A).

Note: Ensure that the exhaust manifold gasket is correctly oriented.

5. Install the tube assembly for the oil drain from the turbocharger to the cylinder block. Refer to Disassembly and Assembly, "Turbocharger - Install" for more information.

6. Align exhaust manifold (3) with Tooling (A). Install the exhaust manifold to the cylinder head.

7. Install new bolts (4) finger tight.

8. Remove Tooling (A). Install remaining bolts (4) finger tight.

9. Tighten bolts (4) to a torque of 40 N·m (30 lb ft) in the sequence that is shown in Illustration 76.

End By:

a. Install the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Install".

i03440266

Exhaust Manifold - Remove and Install (Side Mounted Exhaust Manifold)

Removal Procedure

Start By:

a. Remove the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove".

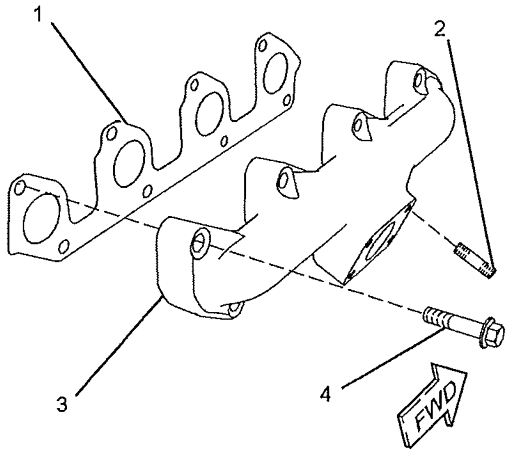

Illustration 77 g01789922

Typical example

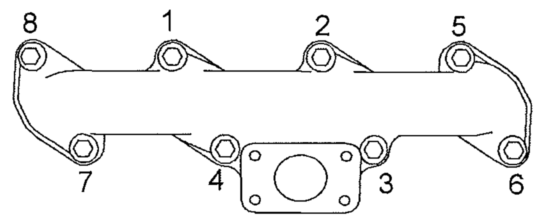

Illustration 78 g01789982

Tightening sequence for the exhaust manifold

1. Loosen bolts (4) in reverse numerical order. Refer to Illustration 78.

Note: This will help prevent distortion of the exhaust manifold.

2. Remove bolts (4) from exhaust manifold (3).

Note: Support the manifold as the bolts are removed.

3. Remove exhaust manifold (3).

4. Remove exhaust manifold gasket (1).

5. If necessary, remove studs (2) from exhaust manifold (3).

Installation Procedure (Side Mounted Exhaust Manifold)

Table 16

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M10 by 100 mm	4

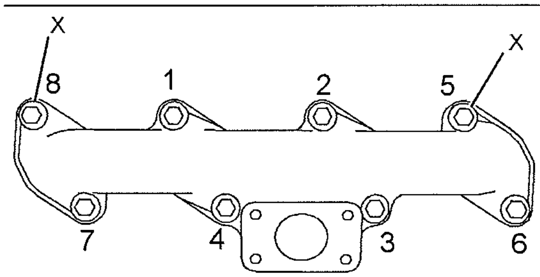

Illustration 79 g01790878

Tightening sequence for the exhaust manifold

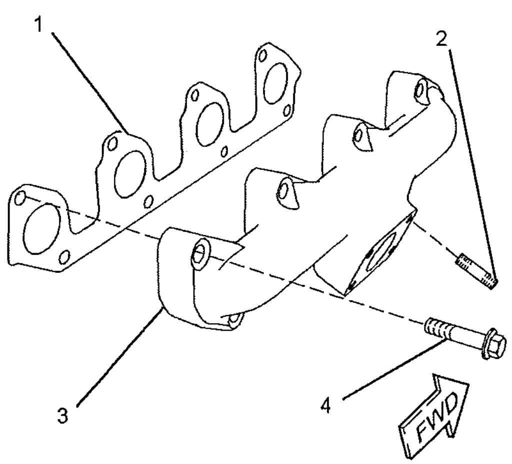

Illustration 80 g01789922

Typical example

1. Ensure that the exhaust manifold is clean and free from damage. If necessary, replace the exhaust manifold. Clean the gasket surface of the cylinder head.
2. If necessary, install studs (2) to exhaust manifold (3). Tighten the studs to a torque of 18 N·m (13 lb ft).
3. Install Tooling (A) to the cylinder head in Positions (X). Refer to Illustration 79.
4. Position a new exhaust manifold gasket (1) onto Tooling (A).

Note: Ensure that the exhaust manifold gasket is correctly oriented.

5. Align exhaust manifold (3) with Tooling (A). Install the exhaust manifold to the cylinder head.
6. Install new bolts (4) finger tight.
7. Remove Tooling (A). Install remaining bolts (4) finger tight.
8. Tighten bolts (4) to a torque of 40 N·m (30 lb ft). Tighten the bolts in the sequence that is shown in Illustration 79.

End By:

a. Install the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Install".

i02933628

Exhaust Elbow - Remove and Install

Removal Procedure

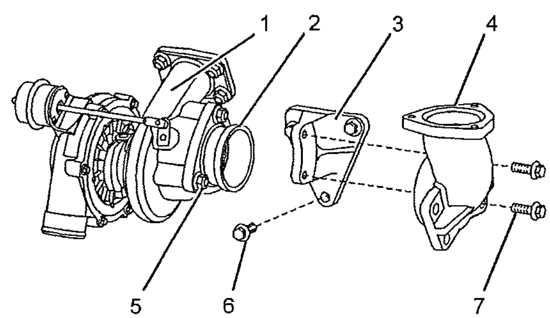

Illustration 81 g01798993

Typical example

1. Remove bolts (7) and remove exhaust elbow (4) from turbocharger (1). Note the orientation of the exhaust elbow.
2. Remove nuts (5) and remove adapter (2).
3. If necessary, remove bolts (6) and remove support bracket (3) from the cylinder block.

Installation Procedure

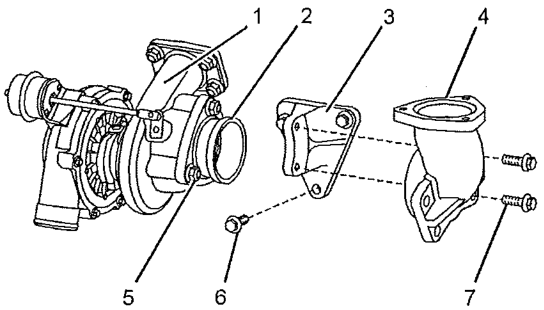

Illustration 82 g01798993

Typical example

1. Ensure that the exhaust elbow, the adapter and the outlet of the turbocharger are free from damage. Replace any components that are damaged.
2. Install adapter (2) to turbocharger (1).
3. Install nuts (5). Tighten the nuts progressively. Tighten nuts (5) to a torque of 25 N·m (18 lb ft).
4. If necessary, install support bracket (3) to the cylinder block and install bolts (6). Tighten the bolts to a torque of 44 N·m (32 lb ft).
5. Install bolts (7) finger tight.
6. Ensure that the gap between the turbocharger and the exhaust elbow is evenly spaced.
7. Tighten bolts (7) to a torque of 44 N·m (32 lb ft).

i02933660

Inlet and Exhaust Valve Springs - Remove and Install

Removal Procedure

Table 17

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Circlip Pliers	1
B	21825739	Valve Spring Compressor	1
	27610235	Adapter	1
	27610295	Head	1
C(1)	21825576	Crankshaft Turning Tool	1
C(2)	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

Note: Either Tooling (C) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The following procedure should be adopted in order to remove the valve springs when the cylinder head is installed to the engine. Refer to Disassembly and Assembly, "Inlet and Exhaust Valves - Remove and Install" for the procedure to remove the valve springs from a cylinder head that has been removed from the engine.

Note: Ensure that the appropriate piston is at the top center position before the valve spring is removed. Failure to ensure that the piston is at the top center position may allow the valve to drop into the cylinder bore.

NOTICE
Plug the apertures for the push rods in the cylinder head in order to prevent the entry of loose parts into the engine.

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

1. Turn the battery disconnect switch to the OFF position.

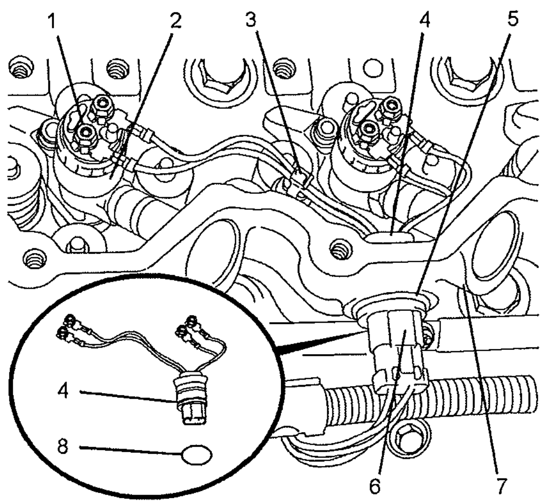

Illustration 83 g01469791

Typical example

2. Follow Step 2.a through Step 2.h in order to remove the harness assemblies for the electronic unit injectors.

   a. Place a temporary identification mark on connections (1).

   b. Use a deep socket to remove connections (1) from electronic unit injectors (2).

   c. Cut cable strap (3).

   d. Disconnect plug (6) from harness assembly (4).

   e. Use Tooling (A) to remove circlip (5).

   f. From the outside of valve mechanism cover base (7), push harness assembly (4) inward. Withdraw the harness assembly from the valve mechanism cover base.

   g. Remove O-ring seal (8) from harness assembly (4).

   h. Repeat Step 2.a through Step 2.g in order to remove the remaining harness assembly.

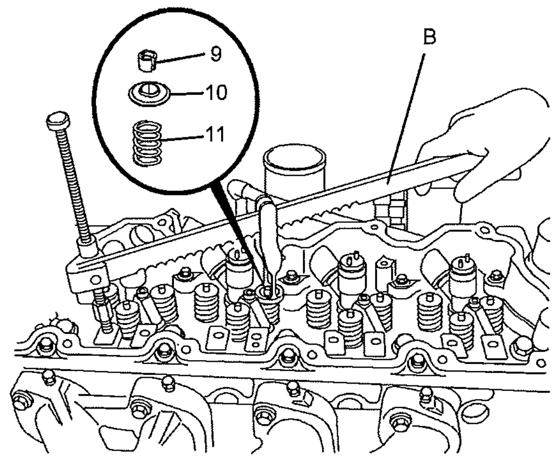

Illustration 84 g01469792

Typical example

WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

NOTICE
Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

3. Follow Step 3.a through Step 3.d in order to position the appropriate piston at top dead center.

   a. Install Tooling (B) in position on the cylinder head in order to compress a valve spring for the appropriate piston.

   b. Use Tooling (B) in order to compress valve spring (11) and open the valve slightly.

Note: Do not compress the spring so that valve spring retainer (10) touches the valve stem seal.

   c. Use Tooling (C) in order to rotate the crankshaft carefully, until the piston touches the valve.

Note: Do not use excessive force to turn the crankshaft. The use of force can result in bent valve stems.

d. Continue to rotate the crankshaft and gradually release the pressure on Tooling (B) until the piston is at the top center position. The valve is now held in a position that allows the valve spring to be safely removed.

Note: Valve springs must be replaced in pairs for the inlet valve or the exhaust valve of each cylinder. If all valve springs require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. Ensure that all of the valve springs are installed before changing from one pair of cylinders to another pair of cylinders.

NOTICE
Do not turn the crankshaft while the valve springs are removed.

4. Apply sufficient pressure to Tooling (B) in order to allow removal of valve keepers (9).

Note: Do not compress the spring so that valve spring retainer (10) touches the valve stem seal .

Remove valve keepers (9).

5. Slowly release the pressure on Tooling (B).
6. Remove valve spring retainer (10) and remove valve spring (11).
7. If necessary, remove the valve stem seals.
8. Repeat Step 4 through Step 7 in order to remove the remaining valve springs from the appropriate cylinder.
9. Remove Tooling (B).

Installation Procedure

Table 18

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Circlip Pliers	1
B	21825739	Valve Spring Compressor	1
	27610235	Adapter	1
	27610295	Head	1
C[1]	21825576	Crankshaft Turning Tool	1
C[2]	27610291	Barring Device Housing	1
	27610289	Gear	1
D	21820221	POWERPART Rubber Grease	1
E	27610296	Torque Wrench	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Note: Either Tooling (C) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Do not turn the crankshaft while the valve springs are removed.

NOTICE
Plug the apertures for the push rods in the cylinder head in order to prevent the entry of loose parts into the engine.

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

1. Inspect the valve springs for the correct length. Refer to Specifications, "Cylinder Head Valves ".
2. If necessary, install a new valve stem seal onto the valve guide.

Note: The outer face of the valve guide must be clean and dry before installing the valve stem seal.

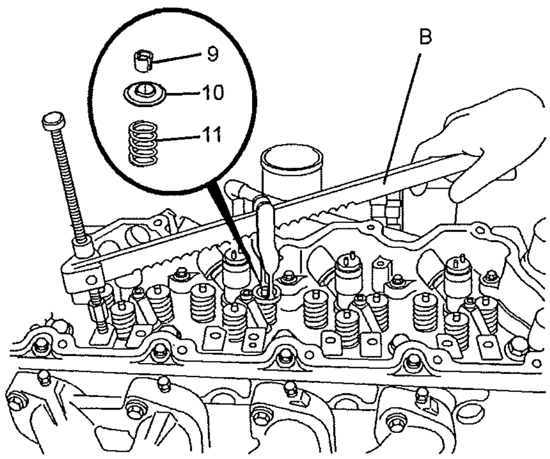

Illustration 85 g01469792

Typical example

3. Install valve spring (11) onto the cylinder head. Position valve spring retainer (10) onto valve spring (11).

WARNING

Improper assembly of parts that are spring loaded can cause bodily injury.

To prevent possible injury, follow the established assembly procedure and wear protective equipment.

NOTICE

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

4. Install Tooling (B) in the appropriate position on the cylinder head in order to compress the valve spring.

5. Apply sufficient pressure to Tooling (B) in order to install valve keepers (9).

Note: Do not compress the spring so that valve spring retainer (10) touches the valve stem seal .

Install the valve spring keepers.

6. Carefully release the pressure on Tooling (B).

Note: Ensure that the valve keepers are correctly seated.

7. Repeat Step 2 through Step 6 for the remaining valves.

WARNING

The valve spring keepers can be thrown from the valve when the valve spring compressor is released. Ensure that the valve spring keepers are properly installed on the valve stem. To help prevent personal injury, keep away from the front of the valve spring keepers and valve springs during the installation of the valves.

8. Remove Tooling (B).

Note: Valve springs must be replaced in pairs for the inlet valve or the exhaust valve of each cylinder. If all valve springs require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. Ensure that all of the valve springs are installed before changing from one pair of cylinders to another pair of cylinders.

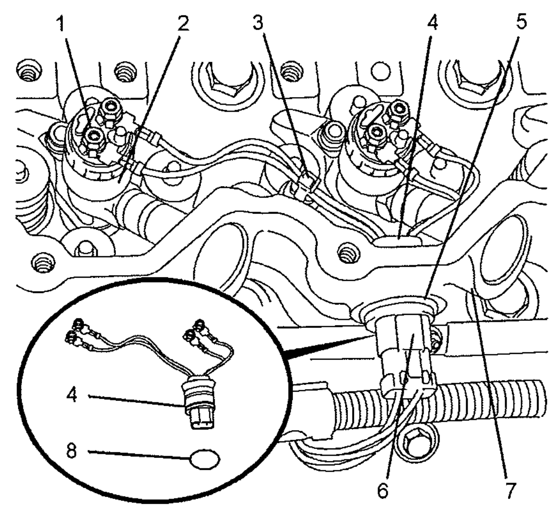

Illustration 86 g01469791

Typical example

9. Follow Step 9.a through Step 9.g in order to install the harness assemblies for the electronic unit injectors.

   a. Ensure that harness assembly (4) and the bore in the valve mechanism cover base (7) are clean and free from damage.

   b. Use Tooling (D) to lubricate a new O-ring seal. Install new O-ring seal (8) onto harness assembly (4).

   c. From the inside of valve mechanism cover base (7), push harness assembly (4) into the valve mechanism cover base.

   d. Use Tooling (A) to install circlip (5).

e. Connect plug (6) to harness assembly (4).

f. Use a deep socket to install connections (1) to electronic unit injectors (2). Use Tooling (E) to tighten the connections to a torque of 2.5 N·m (22 lb in).

g. Install a new cable strap (3).

Note: Ensure that the cable straps conform to the Perkins specification.

h. Repeat Step 9.a through Step 9.g in order to install the remaining harness assembly.

10. Turn the battery disconnect switch to the ON position.

End By:

a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods - Install".

i02933661

Inlet and Exhaust Valves - Remove and Install

Removal Procedure

Table 19

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825666	Valve Spring Compressor	1
	27610235	Adapter	1
	27610295	Head	1

Start By:

a. Remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the bottom face of the cylinder head. Check the depth of the valves below the face of the cylinder head before the valve springs are removed. Refer to Specifications, "Cylinder Head Valves" for the correct dimensions.

2. Place a temporary identification mark on the heads of the valves in order to identify the correct position. Inlet valves have a recess in the center of the head.

Note: Do not stamp the heads of the valve. Stamping or punching the heads of the valves could cause the valves to fracture.

3. Use a suitable lifting device to position the cylinder head with the valve springs upward. The weight of the cylinder head is approximately 56 kg (125 lb).

Note: Ensure that the cylinder head is kept on a clean, soft surface in order to prevent damage to the machined face.

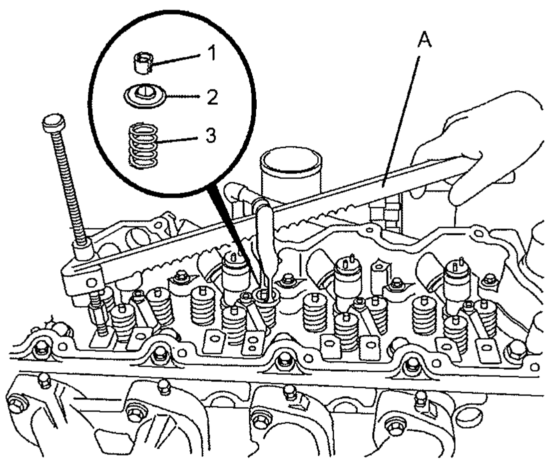

Illustration 87 g01469809

Typical example

⚠ WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

4. Install Tooling (A) in position on the cylinder head in order to compress the appropriate valve spring.

NOTICE

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

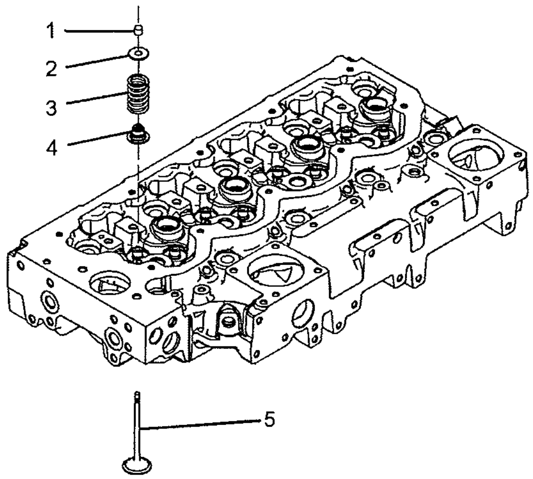

Illustration 88 g01245105

5. Apply sufficient pressure to Tooling (A) in order to remove valve keepers (1).

Note: Do not compress the spring so that valve spring retainer (2) touches valve stem seal (4).

6. Slowly release the pressure on Tooling (A).

7. Remove valve spring retainer (2). Remove valve spring (3).

8. Repeat Step 4 through Step 7 for the remaining valves.

9. Remove Tooling (A).

10. Remove valve stem seals (4).

11. Use a suitable lifting device to carefully turn over the cylinder head.

12. Remove valves (5).

Installation Procedure

Table 20

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21825666	Valve Spring Compressor	1
	27610235	Adapter	1
	27610295	Head	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean all components of the cylinder head assembly. Ensure that all ports, all coolant passages and all lubrication passages in the cylinder head are free from debris. Follow Step 1.a through Step 1.e in order to inspect the components of the cylinder head assembly. Replace any components that are worn or damaged.

   a. Inspect the cylinder head for wear and for damage. Refer to Systems Operation, Testing and Adjusting, "Cylinder Head Inspect".

   b. Inspect the valve seats for wear and for damage. Refer to Specifications, "Cylinder Head Valves" for further information.

   c. Inspect the valve guides for wear and for damage. Refer to Specifications, "Cylinder Head Valves" and Systems Operation, Testing and Adjusting, "Valve Guide - Inspect" for further information.

   d. Inspect the valves for wear and for damage. Refer to Specifications, "Cylinder Head Valves".

   e. Inspect the valve springs for damage and for the correct length. Refer to Specifications, "Cylinder Head Valves".

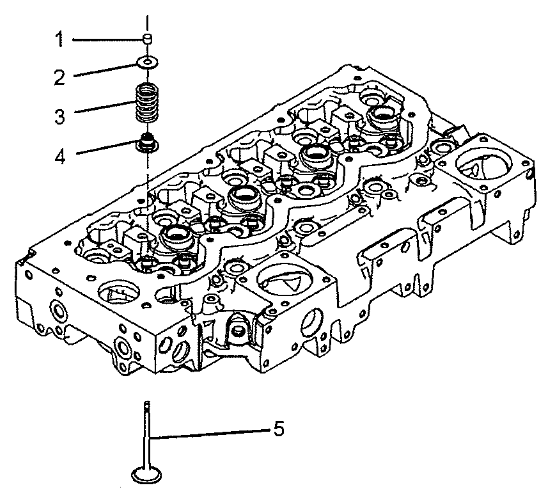

Illustration 89 g01245105

2. Lubricate the stems of valves (5) with clean engine oil. Install valves (5) in the appropriate positions in the cylinder head. Check the depth of the valves below the face of the cylinder head. Refer to Systems Operation, Testing and Adjusting, "Valve Depth - Inspect" for more information.

3. Use a suitable lifting device to carefully turn over the cylinder head. The weight of the cylinder head is approximately 56 kg (125 lb).

Note: Ensure that all of the valves remain in place.

4. Install new valve stem seals (4) onto each of the valve guides.

Note: The outer face of the valve guides must be clean and dry before installing the valve stem seals.

5. Install valve spring (3) onto the cylinder head. Position valve spring retainer (2) onto valve spring (3).

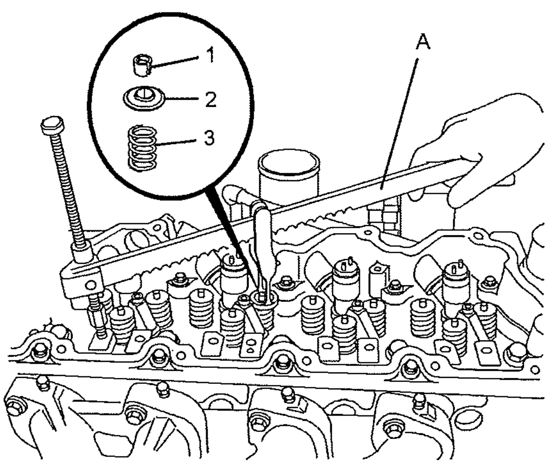

Illustration 90 g01469809

Typical example

WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

6. Install Tooling (A) in the appropriate position on the cylinder head in order to compress valve spring (3).

NOTICE

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

7. Apply sufficient pressure to Tooling (A) in order to install valve keepers (1).

Note: Do not compress the spring so that valve spring retainer (2) touches valve stem seal (4).

WARNING

The valve spring keepers can be thrown from the valve when the valve spring compressor is released. Ensure that the valve spring keepers are properly installed on the valve stem. To help prevent personal injury, keep away from the front of the valve spring keepers and valve springs during the installation of the valves.

8. Carefully release the pressure on Tooling (A).

9. Repeat Step 5 through Step 8 for the remaining valves.

10. Remove Tooling (A) from the cylinder head.

11. Use a suitable lifting device to position the cylinder head on a support. Ensure that the heads of the valves are not obstructed.

End By:

a. Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

i02933621

Engine Oil Filter Base - Remove and Install

Removal Procedure

Table 21

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Strap Wrench	1

Note: The oil filter may be installed vertically or the oil filter may be installed horizontally.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

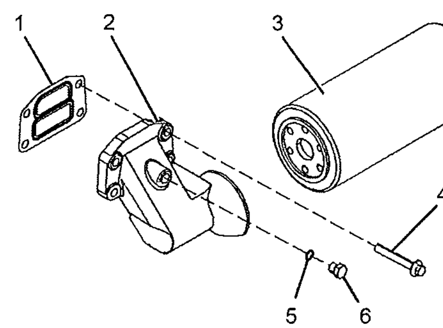

Illustration 91 g01254186

Typical example

1. Use Tooling (A) to remove engine oil filter (3). Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".
2. If the engine oil pressure sensor is located in the engine oil filter base, remove the engine oil pressure sensor. Refer to Disassembly and Assembly, "Engine Oil Pressure Sensor - Remove and Install".
3. Remove bolts (4) and remove engine oil filter base (2).
4. Remove gasket (1).
5. If the engine oil filter base has a spacer plate, remove the spacer plate and remove the gasket.

Note: Mark the orientation of the spacer plate.

6. If necessary, remove plug (6) from engine oil filter base (2). Remove O-ring seal (5) from the plug.

Installation Procedure

Table 22

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
B	21820117	POWERPART Threadlock and Nutlock	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

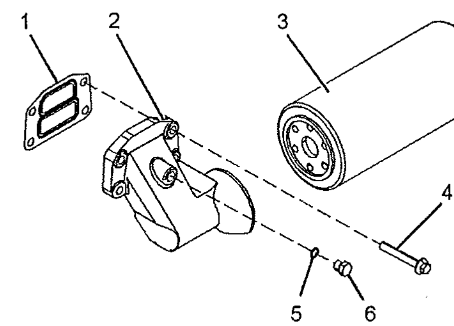

Illustration 92 g01254186

Typical example

1. Ensure that the engine oil filter base is clean. Clean the gasket surface of the cylinder block.
2. If necessary, install a new O-ring seal (5) to plug (6). Install plug (6) to engine oil filter base (2). Tighten the plug to a torque of 12 N·m (106 lb in).
3. Install bolts (4) to engine oil filter base (2).
4. Install a new gasket (1) onto bolts (4). If the engine oil filter base has a spacer plate, install the spacer plate and a new gasket onto the bolts.

Note: Ensure the correct orientation of spacer plate.

5. Apply Tooling (B) to the threads of the bolts. Install the assembly of the engine oil filter base to the cylinder block.
6. Tighten bolts (4) to a torque of 22 N·m (16 lb ft).
7. If the engine oil pressure sensor is located in the engine oil filter base, Install the engine oil pressure sensor. Refer to Disassembly and Assembly, "Engine Oil Pressure Sensor - Remove and Install".

8. Install a new engine oil filter (3). If necessary, fill the engine oil pan to the correct level that is indicated on the oil level gauge. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

i02933620

Engine Oil Cooler - Remove

Removal Procedure

Start By:

a. Remove the bracket for the Electronic Control Module. Refer to Disassembly and Assembly, "ECM Mounting Bracket - Remove and Install".

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system into a suitable container. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

2. Drain the engine lubricating oil into a suitable container. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

3. If necessary, remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

4. Position the engine wiring harness away from the assembly of oil cooler (1). If necessary, cut the cable strap.

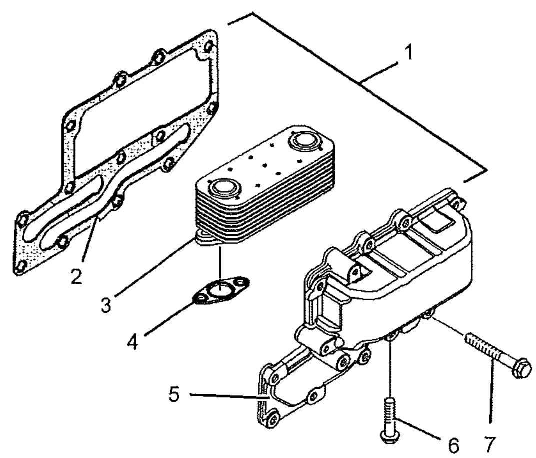

Illustration 93 g01254472

Typical example

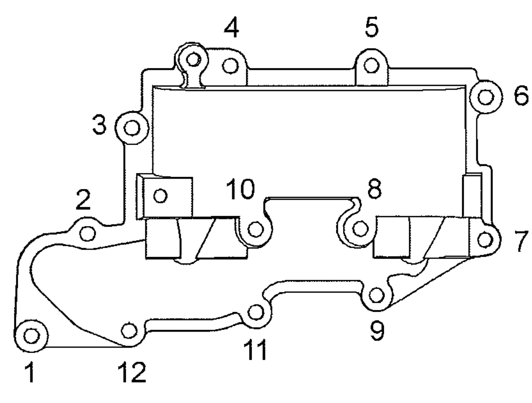

Illustration 94 g01254473

Tightening sequence for the engine oil cooler

5. Loosen bolts (7) in reverse numerical order to the sequence that is shown in Illustration 94. Remove bolts (7). Support the assembly of engine oil cooler (1) as the bolts are removed.

Note: Bolts of different lengths are installed. Note the correct position of the bolts. Note the position of any brackets that are secured by the bolts. Do not remove bolts (6) at this time.

6. Remove the assembly of oil cooler (1) from the cylinder block.

7. Remove gasket (2).

8. Follow Step 8.a through Step 8.c in order to disassemble the engine oil cooler.

   a. Remove bolts (6).

   b. Remove cooler matrix (3) from housing (5).

   c. Remove gaskets (4).

i02933619

Engine Oil Cooler - Install

Installation Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

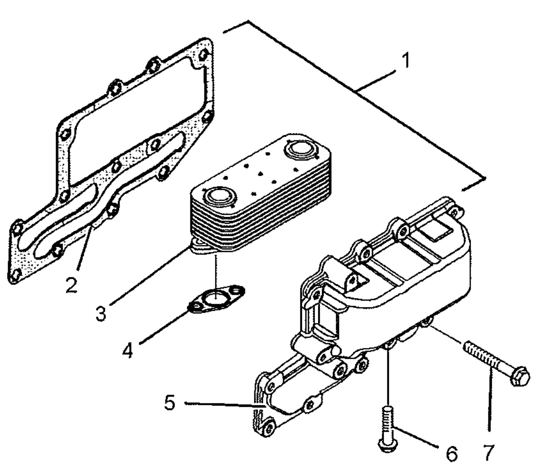

Illustration 95 g01254472

Typical example

1. Follow Step 1.a through Step 1.c in order to assemble the engine oil cooler.

   a. Ensure that cooler matrix (3) is clean and free from damage. Ensure that housing (5) is clean and free from damage. Replace any damaged components.

   b. Position new gasket (4) onto housing (5). Install cooler matrix (3).

   c. Install bolts (6) finger tight.

2. Clean the gasket surface of the cylinder block.

3. Install bolts (7) to the engine oil cooler.

Note: The bolts are different lengths. Ensure that the different bolts are installed in the correct location. Ensure that any brackets that are secured by the bolts are installed in the correct location.

4. Install a new gasket (2) to the assembly of oil cooler (1). Push bolts (7) through the holes in the gasket.

Note: The holes in the gasket have serrations that hold the bolts captive.

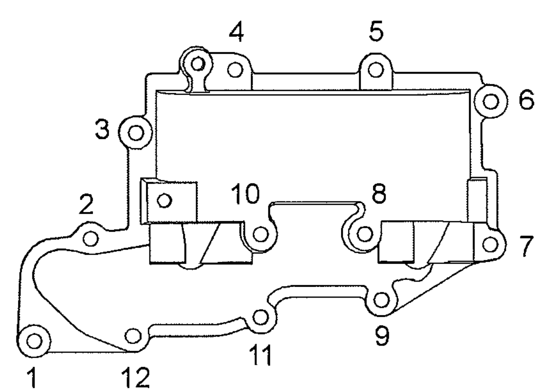

Illustration 96 g01254473

Tightening sequence for the engine oil cooler

5. Install the assembly of oil cooler (1) to the cylinder block. Tighten bolts (7) to a torque of 22 N·m (16 lb ft). Tighten the bolts in the sequence that is shown in Illustration 96.

   Tighten bolts (6) to a torque of 22 N·m (16 lb ft). Refer to Illustration 95.

6. Place the engine wiring harness in the correct position. If necessary, install a new cable strap.

7. If necessary, Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

8. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

9. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

End By:

a. Install the bracket for the Electronic Control Module. Refer to Disassembly and Assembly, "ECM Bracket - Remove and Install".

i02933626

Engine Oil Relief Valve - Remove and Install (Engines with a Balancer Unit)

Removal Procedure

Table 23

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Telescopic Magnet	1

Start By:

a. Remove the engine oil pan. Refer to Disassembly and Assembly , "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

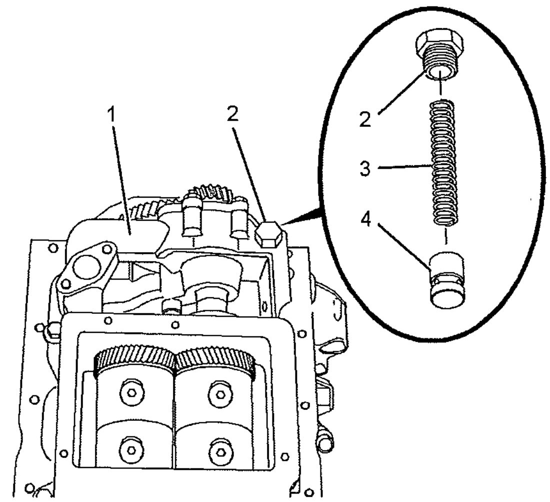

Illustration 97 g01470291

Typical example

WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

1. Loosen cap (2). Carefully remove the cap from balancer (1).

Note: The spring force will be released when the cap is removed.

2. Remove spring (3) from the bore for the relief valve in balancer (1).

3. Use Tooling (A) in order to remove plunger (4) from the bore for the relief valve in balancer (1).

Installation Procedure

Table 24

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Telescopic Magnet	1
B	21820117	POWERPART Threadlock and Nutlock	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

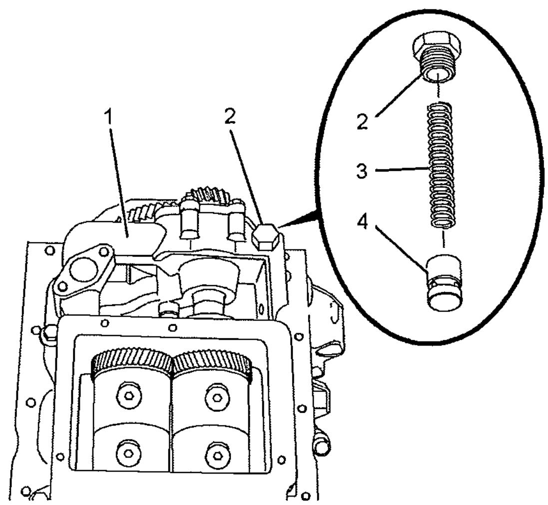

Illustration 98
g01470291

Typical example

WARNING

Improper assembly of parts that are spring loaded can cause bodily injury.

To prevent possible injury, follow the established assembly procedure and wear protective equipment.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged. If the bore for the relief valve in balancer (1) is worn or damaged, the complete assembly of the balancer must be replaced.

2. Lubricate plunger (4) with clean engine oil. Install plunger (4) and spring (3) into the bore for the relief valve in balancer (1).

Note: The plunger must slide freely in the bore for the relief valve.

3. Apply Tooling (B) to the threads of cap (2). Install cap (2) to balancer (1). Tighten the cap to a torque of 21 N·m (15 lb ft).

Note: Ensure that the spring is properly located inside the plunger and the cap. Ensure that Tooling (B) does not contaminate the bore for the relief valve in balancer (1).

End By:

a. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

i02933627

Engine Oil Relief Valve - Remove and Install (Engines Without a Balancer Unit)

Removal Procedure

Table 25

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Telescoping Magnet	1

Start By:

a. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

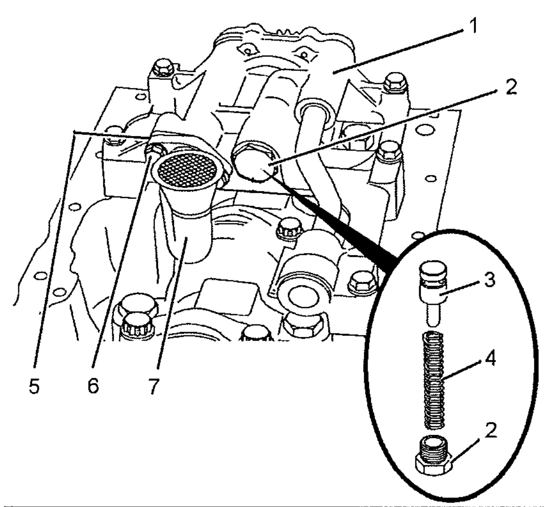

Illustration 99
g01470289

Typical example

⚠ WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

1. Remove bolts (6) and suction pipe (7).
2. Remove gasket (5) (not shown) from the suction pipe .
3. Loosen cap (2). Carefully remove cap (2) from the housing of engine oil pump (1).

Note: The spring force will be released when the cap is removed.

4. Remove spring (4) from the bore for the relief valve in the housing of engine oil pump (1).
5. Use Tooling (A) to remove plunger (3) from the bore for the relief valve in the housing of engine oil pump (1).

Installation Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

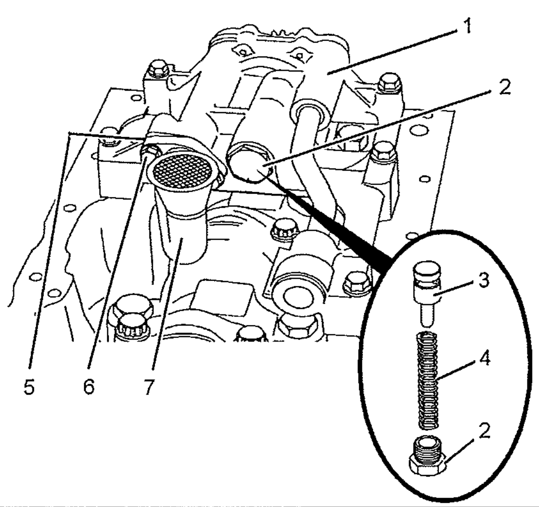

Illustration 100 g01470289

Typical example

⚠ WARNING

Improper assembly of parts that are spring loaded can cause bodily injury.

To prevent possible injury, follow the established assembly procedure and wear protective equipment.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged. If the bore for the relief valve in the housing of engine oil pump (1) is worn or damaged, the complete assembly of the engine oil pump must be replaced.
2. Lubricate plunger (3) with clean engine oil. Use long nose pliers to install plunger (3) and spring (4) into the bore for the relief valve in the housing of engine oil pump (1).

Note: The plunger must slide freely in the bore for the relief valve.

3. Install cap (2) to engine oil pump (1). Tighten the cap to a torque of 45 N·m (33 lb ft).

Note: Ensure that the spring is properly located inside the plunger and the cap.

4. Install suction pipe (7) and a new gasket (5) (not shown) to the assembly of the engine oil pump.
5. Install bolts (6). Tighten the bolts to a torque to 22 N·m (16 lb ft).

End By:

a. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

i02933625

Engine Oil Pump - Remove and Install (Engines Without a Balancer Unit)

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

Note: This procedure is for the removal of the engine oil pump on engines that are not equipped with a balancer. Refer to Disassembly and Assembly, "Balancer - Remove" for information on the removal of the engine oil pump for engines that are equipped with a balancer.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

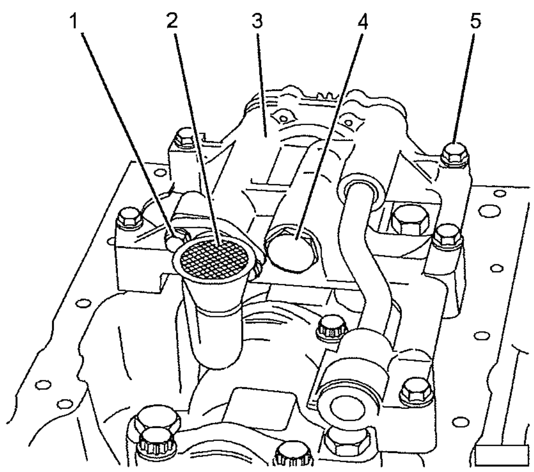

Illustration 101 g01255703

Typical example

1. Remove bolts (1) and suction pipe (2).
2. Remove the gasket from the suction pipe.
3. Remove bolts (5). Remove the assembly of the engine oil pump (3) from the cylinder block.
4. If necessary, remove pressure relief valve (4) from the housing of engine oil pump (3). Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install".

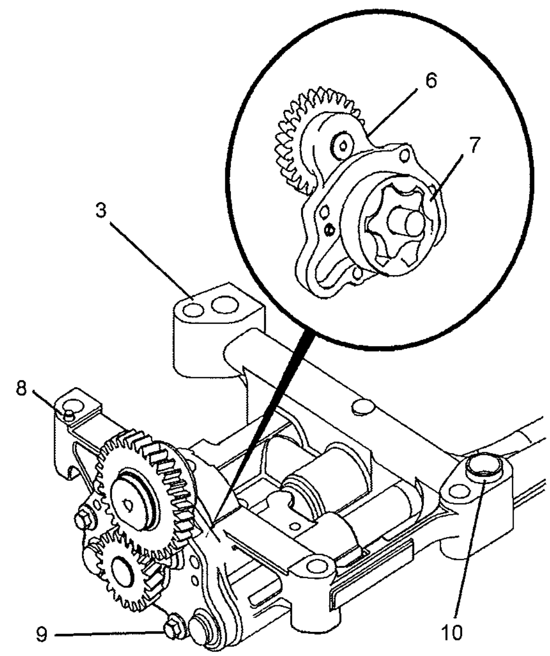

Illustration 102 g01470295

Typical example

5. If necessary, remove bolts (9) and front cover assembly (6). Remove outer rotor (7) from the housing of engine oil pump (3).

Note: Do not remove dowels (8) and (10) from the housing of the engine oil pump unless the dowels are damaged.

Installation Procedure

Table 26

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825617	Dial Indicator Group	1
	-	Finger Clock	1

Note: This procedure is for the installation of the engine oil pump on engines that are not equipped with a balancer. Refer to Disassembly and Assembly, "Balancer - Install" for information on the installation of the engine oil pump for engines that are equipped with a balancer.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

If any of the parts on the engine oil pump are worn or damaged, the entire pump must be replaced.

1. Ensure that all components of the engine oil pump are clean and free from wear or damage. Check the clearance between the outer rotor of the oil pump and the oil pump body. Check the clearance between the outer rotor and the inner rotor. Check the end play of the rotor. Refer to Systems Operation, Testing and Adjusting, "Engine Oil Pump - Inspect". Replace the complete assembly of the engine oil pump if any of the components are worn or damaged.

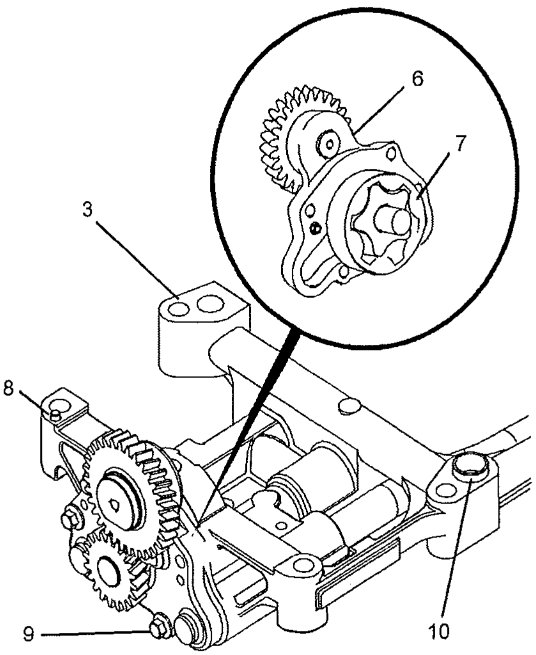

Illustration 103 g01470295

Typical example

2. If necessary, lubricate the internal components of the assembly of the engine oil pump with clean engine oil. Install outer rotor (7) and front cover (6) to the housing of engine oil pump (3). Install bolts (9). Tighten the bolts to a torque of 9.5 N·m (84 lb in).

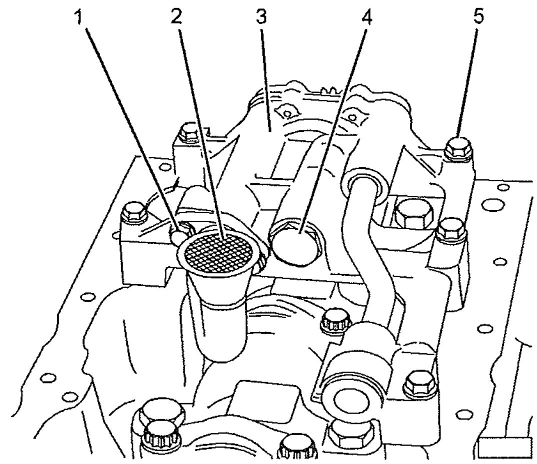

Illustration 104 g01255703

Typical example

3. If necessary, install pressure relief valve (4). Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install" for further information.

4. Ensure that dowel (8) and dowel (10) are correctly located in the housing of engine oil pump (3). Position the assembly of the engine oil pump onto the cylinder block.

Note: Ensure that the dowels in the housing of the engine oil pump are aligned with the holes in the cylinder block.

5. Install bolts (5). Tighten the bolts to a torque of 44 N·m (32 lb ft).

6. Install suction pipe (2) and a new gasket to the assembly of the engine oil pump.

7. Install bolts (1). Tighten the bolts to a torque to 22 N·m (16 lb ft).

8. Use Tooling (A) in order to check the backlash between the idler gear of the oil pump and the crankshaft gear. Refer to Specifications, "Gear Group - Front" for further information.

End By:

a. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

i02933681

Water Pump - Remove

Removal Procedure

Start By:

a. Remove the fan and the fan pulley. Refer to Disassembly and Assembly, "Fan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

2. Loosen the hose clamps and remove the hose from the water pump inlet.

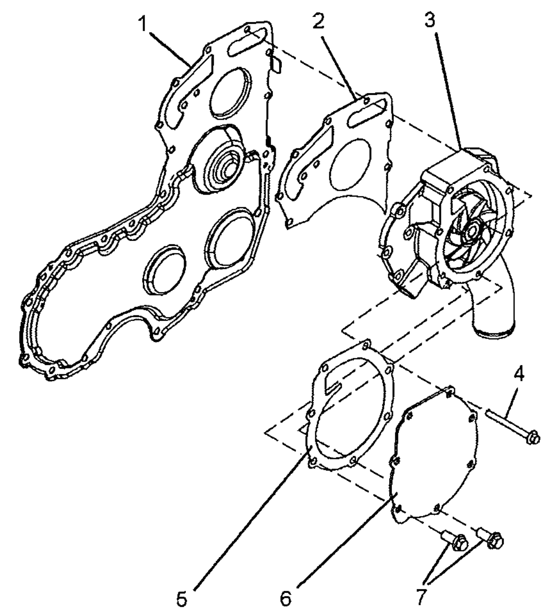

Illustration 105 g01263054

Typical example

3. Remove bolts (4). The bolts are different lengths. Note the positions of the different bolts.

Note: Do not remove bolts (7) at this time.

4. Remove water pump (3) from front cover (1).

Note: If necessary, tap the water pump with a soft hammer in order to loosen the water pump.

5. Remove gasket (2).

6. If necessary, remove cover (6) from the water pump. Follow Step 6.a through Step 6.c in order to remove the cover.

    a. Remove bolts (7).

    b. Remove cover (6).

    c. Remove gasket (5).

i02933680

Water Pump - Install

Installation Procedure

Table 27

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 by 80 mm	2

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the water pump is clean and free from wear or damage. If necessary, replace the water pump.

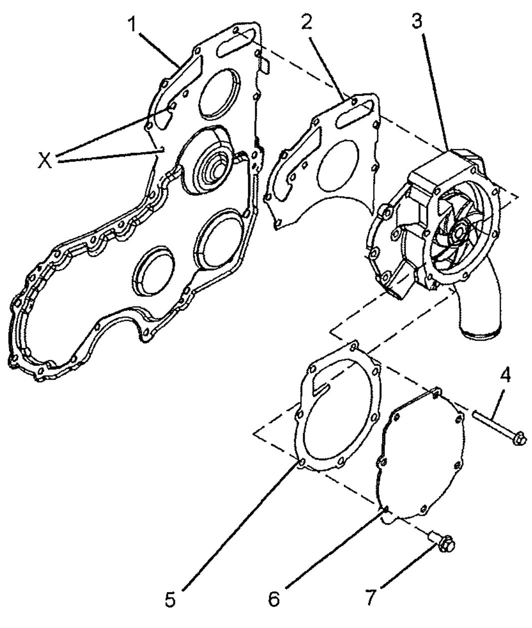

Illustration 106 g01269391

Typical example

2. If necessary, install cover (6) to water pump (3). Follow Step 2.a through Step 2.d in order to install the cover.

   a. Clean the gasket surface of cover (6).

   b. Position a new gasket (5) onto water pump (3).

   c. Install cover (6) to water pump (3).

   d. Install bolts (7) to cover (6). Tighten the bolts finger tight.

3. Clean the gasket surface of front cover (1).

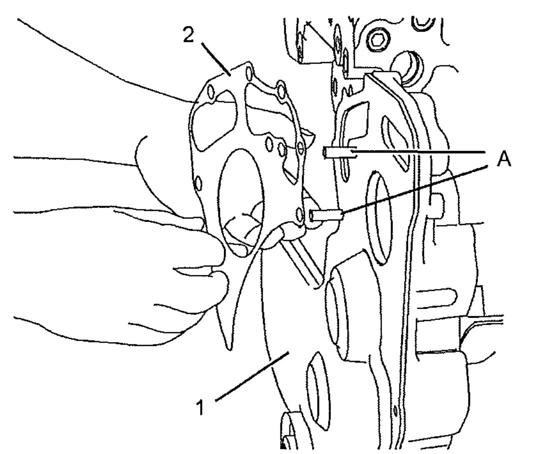

Illustration 107 g01269392

4. Install Tooling (A) in Position (X).

5. Use Tooling (A) in order to align a new gasket (2) to front cover (1). Install the gasket to the front cover.

6. Align water pump (3) with Tooling (A). Install the water pump to front cover (1).

Note: Ensure that the gear of the water pump and the gear of the fuel injection pump mesh.

7. Install bolts (4). Refer to Illustration 106. Tighten the bolts finger tight.

Note: Ensure that bolts of different lengths are installed in the correct positions.

8. Remove Tooling (A) and install remaining bolts (4) finger tight.

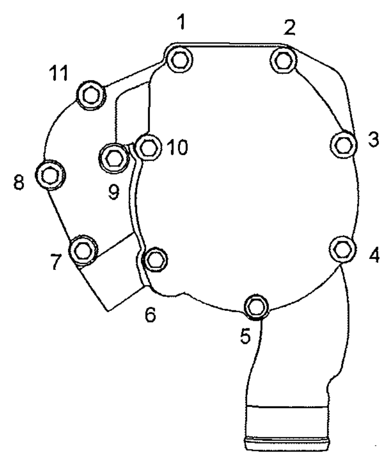

Illustration 108 g01269393

Tightening sequence for the water pump

9. Tighten bolts (4) and bolts (7) to a torque of 22 N·m (16 lb ft). Refer to Illustration 106. Tighten the bolts in the sequence that is shown in Illustration 108.

10. Install the hose to the water pump inlet. Tighten the hose clamps securely.

11. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

End By:

a. Install the fan and the fan pulley. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933682

Water Temperature Regulator - Remove and Install

Removal Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system to a level below the water temperature regulator, into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

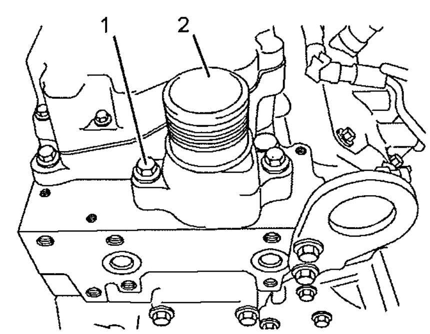

Illustration 109 g01269478

Typical example

2. Loosen the hose clamps from the upper radiator hose and disconnect the upper radiator hose from water temperature regulator housing (2).

3. Remove bolts (1) from water temperature regulator housing (2).

4. Remove water temperature regulator housing (2) from the cylinder head.

Note: Note the orientation of the water temperature regulator housing.

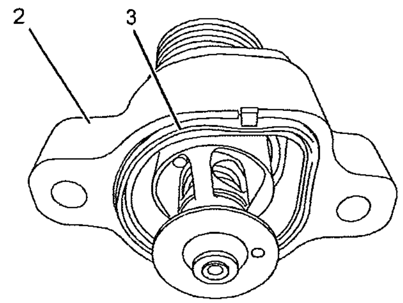

Illustration 110 g01269481

Typical example

5. Remove O-ring seal (3) from water temperature regulator housing (2).

Installation Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

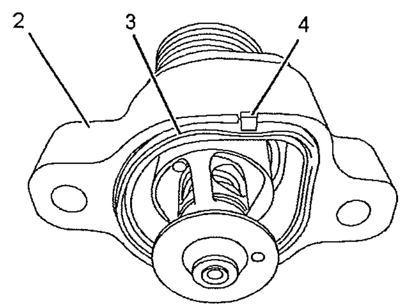

Illustration 111 g01263044

Typical example

1. Ensure that all components of water temperature regulator housing (2) are clean and free of wear or damage. Check the water temperature regulator for correct operation. Refer to Systems Operation, Testing and Adjusting, "Water Temperature Regulator - Test" for the procedure to test the water temperature regulator. If any components of the water temperature regulator housing are worn or damaged, the complete assembly must be replaced.

2. If the original water temperature regulator housing is installed, position a new O-ring seal (3) into the groove in the water temperature regulator housing (2). Ensure that locating tab (4) is correctly seated in water temperature regulator housing (2).

   A new water temperature regulator housing is supplied with a new O-ring seal.

3. Install water temperature regulator housing (2) to the cylinder head.

Note: Ensure the correct orientation of the water temperature regulator housing.

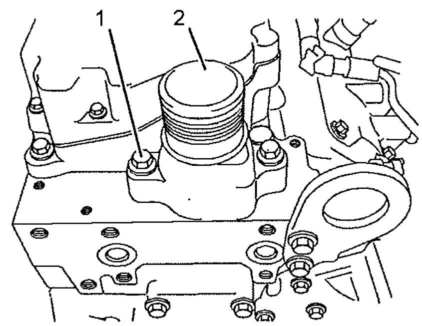

Illustration 112 g01269478

Typical example

4. Install bolts (1). Tighten the bolts to a torque of 44 N·m (32 lb ft).

5. Connect the upper radiator hose and tighten the hose clamps securely.

6. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check" and Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.

i02933633

Flywheel - Remove

Removal Procedure

Table 28

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud 1/2 inch - 20 UNF by 4 inch	2

Start By:

a. Remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

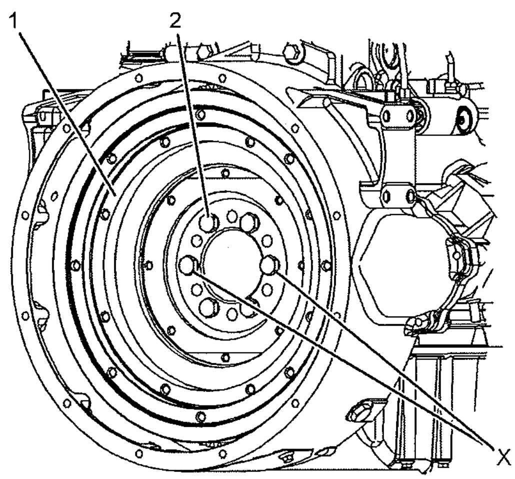

Illustration 113 g01245126
Typical example

1. Remove two bolts from Positions (X) on flywheel (1).

2. Install Tooling (A) to Positions (X) on flywheel (1).

3. Attach a suitable lifting device to flywheel (1). Support the weight of the flywheel. The weight of the flywheel is approximately 71 kg (155 lb).

4. Remove remaining bolts (2).

5. Use the lifting device in order to remove the flywheel from the engine.

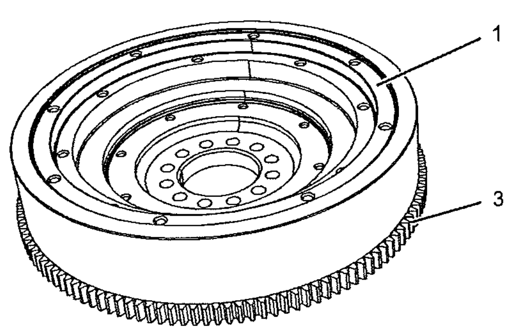

Illustration 114 g01245152
Typical example

6. Inspect flywheel (1) and ring gear (3) for wear or damage. Replace any components that are worn or damaged.

7. To remove the flywheel ring gear, follow Step 7.a and Step 7.b.

   a. Place the flywheel assembly on a suitable support.

Note: Identify the orientation of the teeth on the flywheel ring gear.

   b. Use a hammer and a punch in order to remove ring gear (3) from flywheel (1).

i02933632

Flywheel - Install

Installation Procedure

Table 29

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud 1/2 inch - 20 UNF by 4 inch	2

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

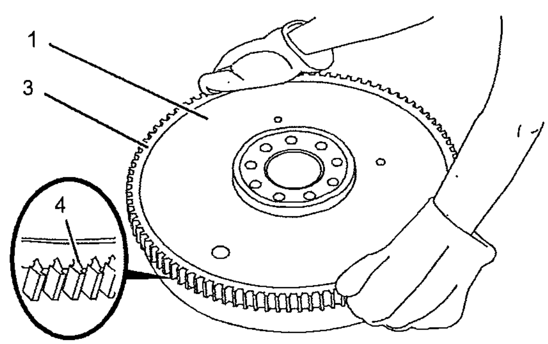

Illustration 115 g01470362
Typical example

WARNING

Always wear protective gloves when handling parts that have been heated.

1. If the flywheel ring gear was removed, follow Step 1.a through Step 1.c in order to install a new ring gear to the flywheel.

    a. Identify the orientation of teeth (4) on new ring gear (3).

Note: The chamfered side of the ring gear teeth must face toward the starting motor when the flywheel is installed. This will ensure the correct engagement of the starting motor.

    b. Heat flywheel ring gear (3) in an oven to a maximum temperature of 250 °C (482 °F) prior to installation.

Note: Do not use a torch to heat the ring gear.

    c. Ensure that the orientation of ring gear (3) is correct and quickly install the ring gear onto flywheel (1).

2. Inspect the crankshaft rear seal for leaks. If there are any oil leaks, replace the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove" and Disassembly and Assembly, "Crankshaft Rear Seal - Install" for the correct procedure.

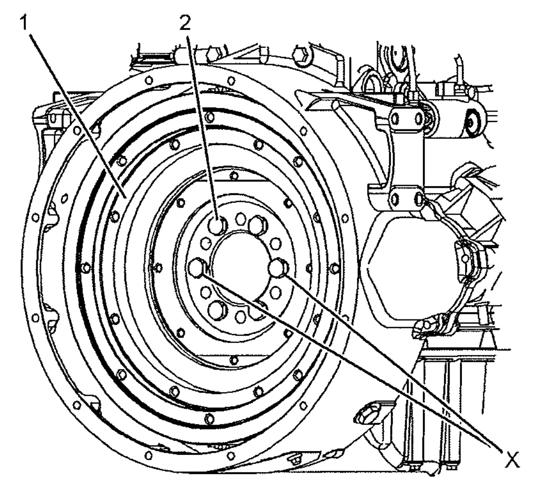

Illustration 116 g01245126

Typical example

3. Install a suitable lifting device to flywheel (1). The weight of the flywheel is approximately 71 kg (155 lb).

4. Install Tooling (A) to Positions (X) on the crankshaft.

5. Use the lifting device in order to position flywheel (1) onto Tooling (A).

6. Install bolts (2) to flywheel (1) finger tight.

7. Remove Tooling (A) and install remaining bolts (2) to flywheel (1).

8. Remove the lifting device from flywheel (1).

9. Use a suitable tool to prevent the flywheel from rotating. Tighten bolts (2) to a torque of 115 N·m (85 lb ft).

10. Check the run out of the flywheel. Refer to Specifications, "Flywheel" for further information.

End By:

a. Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

i02933610

Crankshaft Rear Seal - Remove

Removal Procedure

Table 30

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	E12 Torx Socket	1

Start By:

a. Remove the flywheel. Refer to Disassembly and Assembly, "Flywheel - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: The crankshaft rear seal and the housing are manufactured as a one-piece assembly. The assembly is not serviceable. If the crankshaft rear seal is removed, the assembly must be replaced.

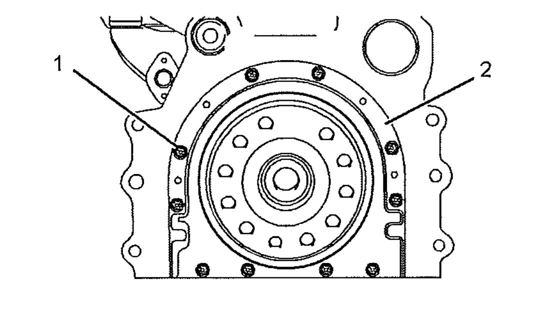

Illustration 117 g01269512

Typical example

1. Use Tooling (A) in order to remove torx screws (1) from crankshaft rear seal (2).

2. Remove crankshaft rear seal (2) from the cylinder block. Discard the crankshaft rear seal.

i02933609

Crankshaft Rear Seal - Install

Installation Procedure

Table 31

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	E12 Torx Socket	1
B	27610306	Alignment Tool	1

Note: The crankshaft rear seal and the housing are manufactured as a one-piece assembly.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

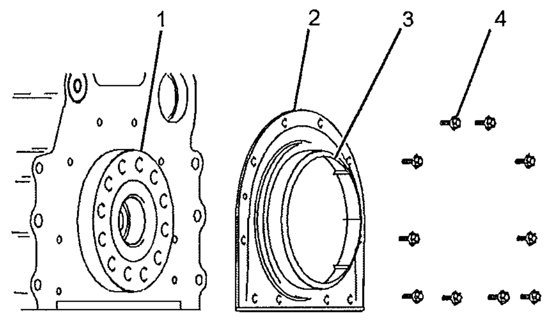

Illustration 118 g01258105

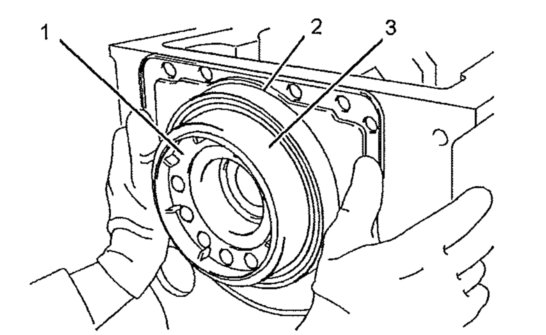

Illustration 119 g01255709

Typical example

1. Ensure that crankshaft flange (1) is clean, dry and free from damage.

2. Ensure that the face of the cylinder block and the bridge piece are clean and dry.

3. A new crankshaft rear seal is supplied with a plastic sleeve (3). Ensure that the plastic sleeve is squarely installed within crankshaft rear seal (2).

Note: The plastic sleeve is included in order to protect the lip of the seal as the seal is pushed over the crankshaft flange.

Note: Do not lubricate the crankshaft rear seal or the crankshaft flange. The crankshaft rear seal must be installed dry.

4. Align plastic sleeve (3) with crankshaft flange (1). Ensure that the plastic sleeve is engaged onto the crankshaft flange. Push new crankshaft rear seal (2) squarely onto the crankshaft flange.

   During this process, the plastic sleeve will be forced out of the crankshaft rear seal. Discard the plastic sleeve.

5. Align the two molded locators on crankshaft rear seal (2) with the holes in the cylinder block. Ensure that the crankshaft rear seal is seated against the cylinder block.

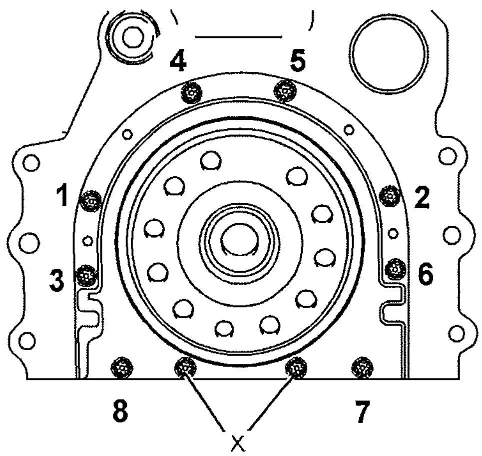

Illustration 120 g01258357

Tightening sequence for the crankshaft rear seal

6. Install torx screws (4) finger tight.

Note: Do not install torx screws to Positions (X) at this stage.

7. Install Tooling (B) to crankshaft rear seal (2) and to crankshaft flange (1).

8. Use Tooling (A) in order to tighten torx screws (4) to a torque of 22 N·m (16 lb ft). Tighten torx screws (4) in the sequence that is shown in Illustration 120.

9. Remove Tooling (B).

10. Install remaining torx screws (4) to Positions (X). Use Tooling (A) in order to tighten the torx screws to a torque of 22 N·m (16 lb ft). Refer to Illustration 120.

End By:

a. Install the flywheel. Refer to Disassembly and Assembly, "Flywheel - Install".

i02933634

Flywheel Housing - Remove and Install

Removal Procedure

Table 32

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M10 by 100 mm	2

Start By:

a. Remove the flywheel. Refer to Disassembly and Assembly, "Flywheel - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

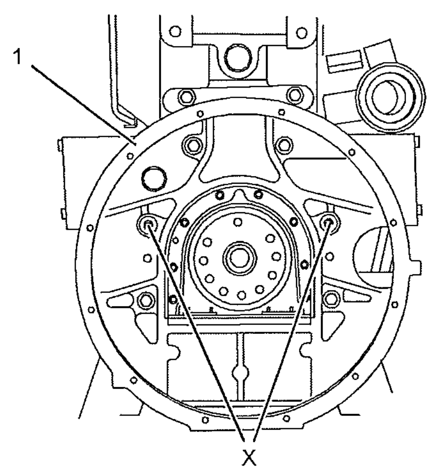

Illustration 121 g01470403

Typical example

1. Remove the bolts from Position (X) from flywheel housing (1).

2. Install Tooling (A) into Position (X) on flywheel housing (1).

3. Install a suitable lifting device to the flywheel housing in order to support the flywheel housing. The flywheel housing weighs approximately 30 kg (66 lb).

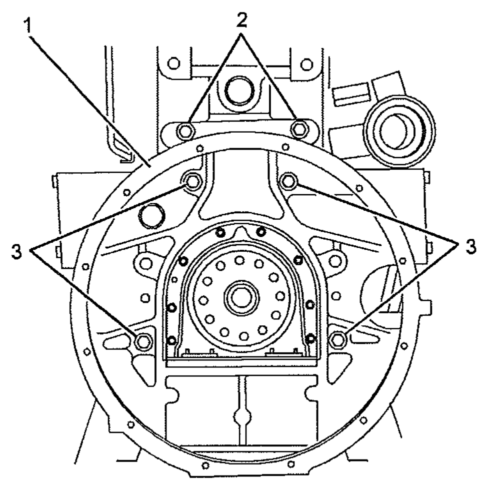

Illustration 122 g01763013

Typical example

4. Remove bolts (2) and remaining bolts (3) from flywheel housing (1).

5. Use the lifting device in order to remove flywheel housing (1) from the cylinder block.

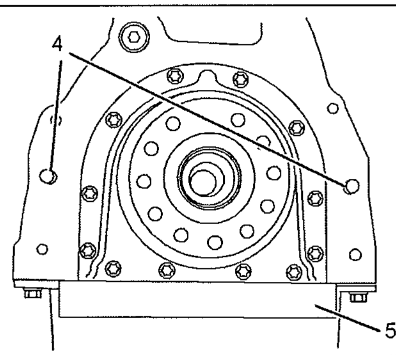

Illustration 123 g01470418

Typical example

6. If the engine has an aluminum oil pan, remove dust seal (5).

7. If necessary, remove dowels (4) from the cylinder block.

Installation Procedure

Table 33

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Bolt M10 by 100 mm	2
B	21825617	Dial Indicator Group	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the flywheel housing is clean and free from damage. If necessary, replace the flywheel housing.

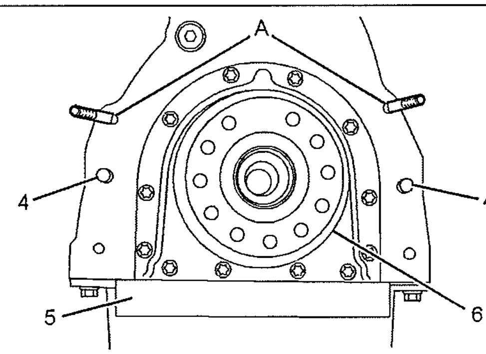

Illustration 124 g01244056

Typical example

2. Inspect crankshaft rear seal (6) for leaks. If there are any oil leaks, replace the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove" and refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

3. Clean the rear face of the cylinder block. If necessary, install dowels (4) to the cylinder block.

4. Install Tooling (A) to the cylinder block.

5. Install dust seal (5).

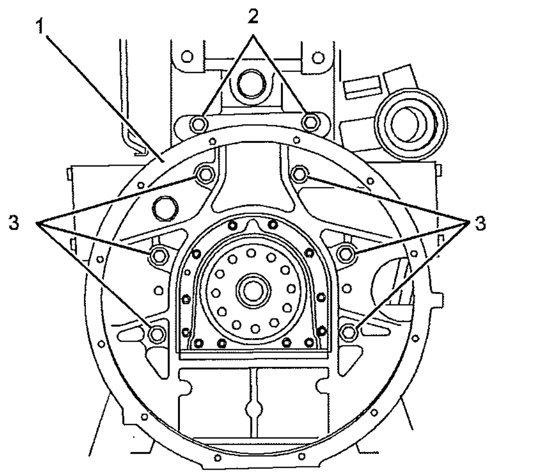

Illustration 125 g01763034

Typical example

6. Install a suitable lifting device to the flywheel housing. The flywheel housing weighs approximately 30 kg (66 lb).

7. Use the lifting device to align flywheel housing (1) with Tooling (A). Install the flywheel housing to the cylinder block.

8. Install bolts (2) and bolts (3) finger tight.

9. Remove Tooling (A). Install remaining bolts (3).

10. Tighten bolts (3) to a torque of 63 N·m (46 lb ft).

11. Tighten bolts (2) to a torque of 75 N·m (55 lb ft).

12. Use Tooling (B) to check the alignment of the flywheel housing with the crankshaft. Refer to Systems Operation, Testing and Adjusting, "Flywheel Housing - Inspect".

End By:

a. Install the flywheel. Refer to Disassembly and Assembly, "Flywheel - Install".

i02933607

Crankshaft Pulley - Remove and Install (Engines With an Automatic Belt Tensioner)

Removal Procedure

Start By:

a. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

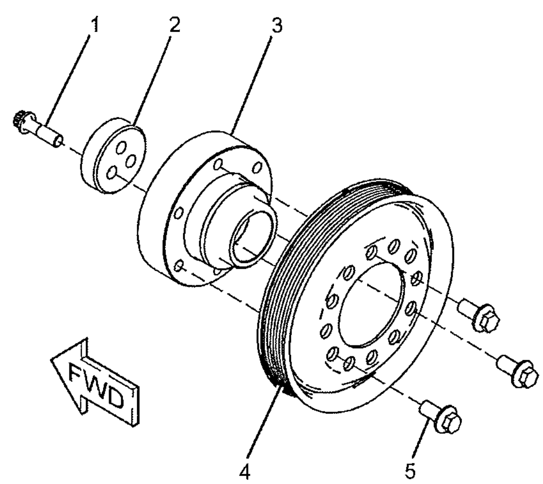

Illustration 126 g01249049

1. Use a suitable tool in order to prevent the crankshaft from rotating. Remove bolts (1).

2. Remove thrust block (2).

3. Carefully remove the assembly of the crankshaft pulley from the crankshaft.

4. Follow Step 4.a through Step 4.b in order to disassemble the crankshaft pulley.

   a. Remove bolts (5).

   b. Remove crankshaft pulley (4) from crankshaft adapter (3).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the crankshaft adapter, the pulley and the thrust block are clean and free from damage. Replace any components that are damaged.

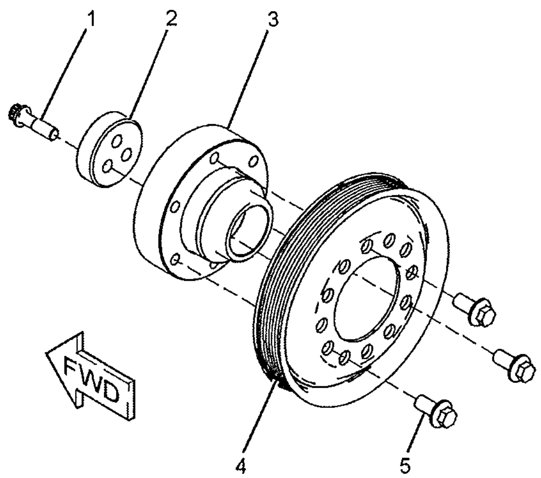

Illustration 127 g01249049

2. If necessary, follow Step 2.a through Step 2.b in order to assemble the crankshaft pulley.
   a. Install crankshaft pulley (4) to crankshaft adapter (3).
   b. Install bolts (5) to the assembly of the crankshaft pulley, and the crankshaft adapter. The bolts should be evenly spaced.
   c. Tighten the bolts to a torque of 78 N·m (58 lb ft).
3. Ensure that the front of the crankshaft is clean and free from damage. Install the assembly of crankshaft pulley (3) to the crankshaft.

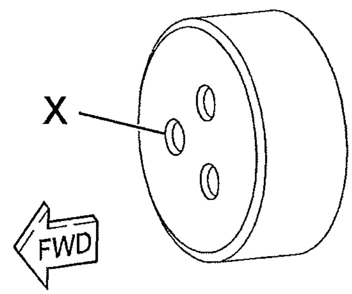

Illustration 128 g01471632

4. Align the holes in the thrust block with the holes in the crankshaft.

Note: Ensure chamfered Holes (X) in the thrust block. Face toward the front of the engine.

5. Install thrust block (2) to the assembly of the crankshaft pulley.
6. Install bolts (1) to thrust block (2).
7. Use a suitable tool in order to prevent the crankshaft from rotating. Tighten the bolts to a torque of 115 N·m (85 lb ft).
8. Repeat Step 7 in order to ensure correct torque.

End By:

a. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

i02933608

Crankshaft Pulley - Remove and Install (Engines Without an Automatic Belt Tensioner)

Removal Procedure

Start By:

a. Remove the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

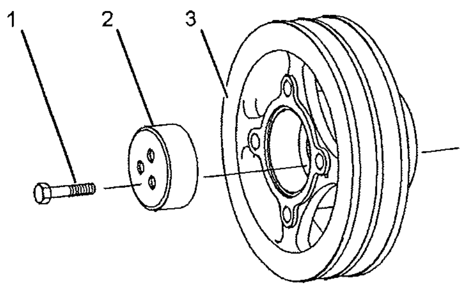

Illustration 129 g01255707

1. Use a suitable tool in order to prevent the crankshaft from rotating. Remove bolts (1).
2. Remove thrust block (2).
3. Carefully remove crankshaft pulley (3) from the crankshaft.

Installation Procedure

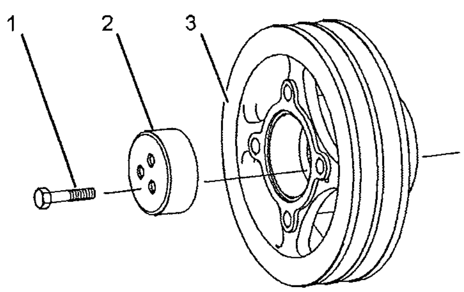

Illustration 130 g01255707

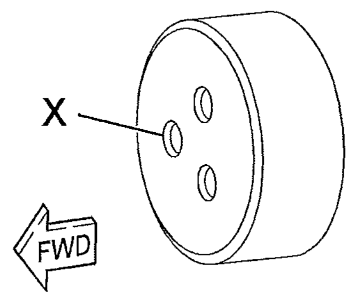

Illustration 131 g01471632

1. Ensure that the crankshaft pulley and the thrust block are clean and free from damage. Replace any components that are damaged.
2. Ensure that the front of the crankshaft is clean and free from damage. Install crankshaft pulley (3) to the crankshaft.
3. Align the holes in the thrust block with the holes in the crankshaft.

Note: Ensure that chamfered Holes (X) in the thrust block face toward the front of the engine.

4. Install thrust block (2) to the crankshaft pulley.
5. Install bolts (1) to thrust block (2).
6. Use a suitable tool in order to prevent the crankshaft from rotating. Tighten the bolts to a torque of 115 N·m (85 lb ft).
7. Repeat Step 6 in order to ensure correct torque.

End By:

a. Install the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

i02933603

Crankshaft Front Seal - Remove and Install

Removal Procedure

Table 34

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	27610230	Puller	1

Start By:

a. Remove the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

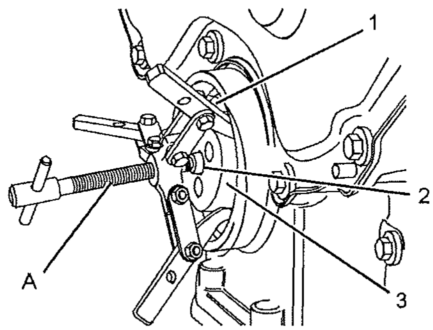

Illustration 132 g01266942

1. Install the legs of Tooling (A) behind crankshaft front seal (1). Install a suitable spacer (2) between Tooling (A) and crankshaft (3). Use Tooling (A) in order to pull the crankshaft front seal out of the front housing.

Note: Do not damage the bore for the crankshaft front seal in the front housing.

Installation Procedure

Table 35

Required Tools			
Tool	Part Number	Part Description	Qty
B	21825577	Threaded Bar	1
	21825580	Anchor Plate	1
	21825579	Sleeve	1
	21825578	Pressure Plate	1
	21825581	Adapter	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the bore for the crankshaft front seal in the front housing is clean and free from damage.

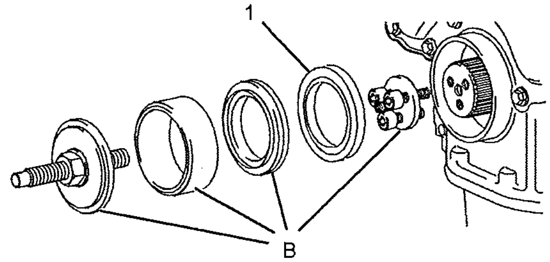

Illustration 133 g01266453
Typical example

2. Assemble Tooling (B).

3. Align a new crankshaft front seal (1) to the front housing.

4. Use Tooling (B) to install crankshaft front seal (1). Ensure that the front face of the seal is installed to a depth of 9 ± 0.2 mm (0.354 ± 0.008 inch) into the front housing.

5. Remove Tooling (B) from the crankshaft.

End By:

a. Install the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

i02933635

Front Cover - Remove and Install

Removal Procedure

Start By:

a. If the engine is equipped with a fan, remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

b. Remove the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove".

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: In order to remove the front cover, it is not necessary to remove the crankshaft pulley or the alternator.

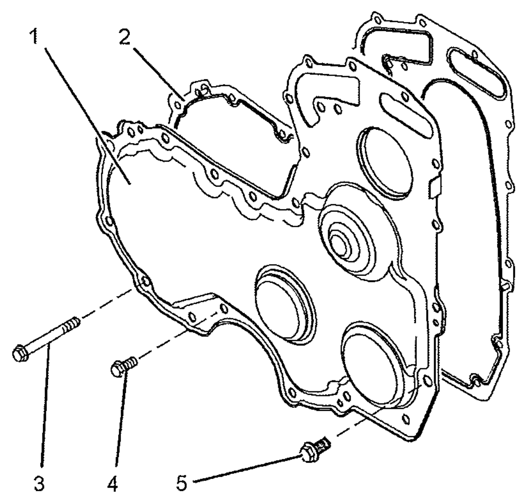

Illustration 134 g01258462

Typical example

1. Remove bolts (3), (4) and (5). Identify the positions of the different bolts.
2. Remove front cover (1) from the front housing.
3. Remove gasket (2) from front cover (1).

Installation Procedure

Table 36

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Bolt M8 by 80 mm	2

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

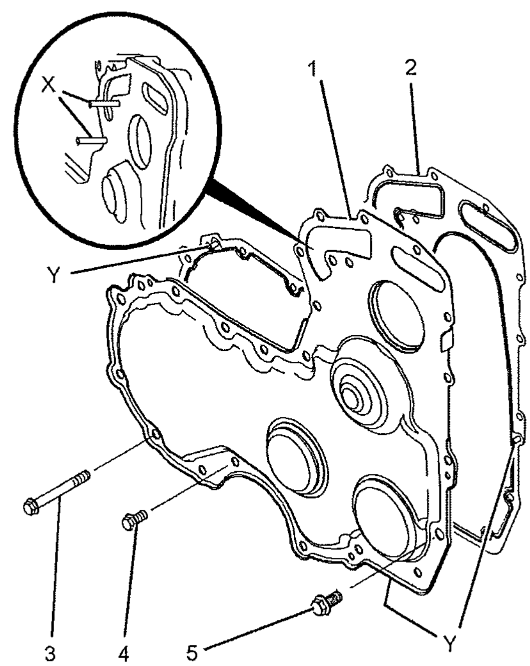

Illustration 135 g01471654

Typical example

1. Thoroughly clean the gasket surface of the front housing.
2. If the original front cover is installed, follow Step 2.a and Step 2.b in order to install the gasket.
   a. Thoroughly clean the gasket surface of the front cover.
   b. Install a new gasket (2) to front cover (1). Engage Locators (Y) into the holes in the front cover.
3. Install Tooling (A) into Holes (X) in the front housing.

4. Use Tooling (A) in order to position the front cover assembly onto the front housing.

5. Install bolts (3), (4) and (5) finger tight. Ensure that the different bolts are installed in the correct positions.

6. Loosely install the water pump assembly and remove Tooling (A). Refer to Disassembly and Assembly, "Water Pump - Install" for the correct procedure.

7. Tighten bolts (3), (4) and (5) to a torque of 22 N·m (16 lb ft).

8. Tighten the bolts for the water pump to a torque of 22 N·m (16 lb ft).

End By:

a. If the engine is equipped with a fan, install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933652

Gear Group (Front) - Remove and Install

Removal Procedure

Table 37

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the front gear group. Carefully follow the procedure in order to remove the gear group.

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

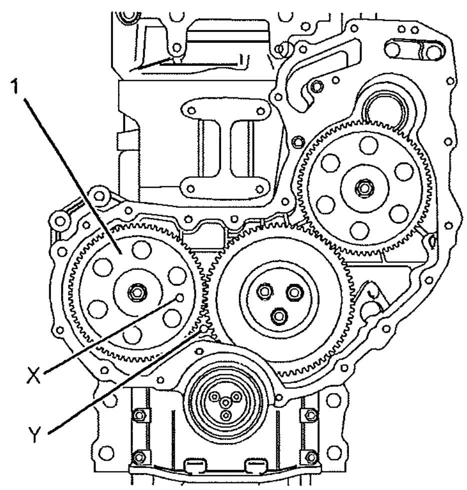

Illustration 136 g01471714

Typical example

2. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position. Install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

Note: Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

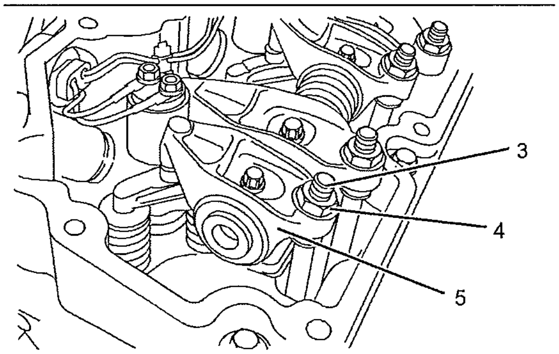

Illustration 137 g01471717

Typical example

3. Loosen nuts (4) on all rocker arms (5). Unscrew adjusters (3) on all rocker arms (5) until all valves are fully closed.

Note: Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.

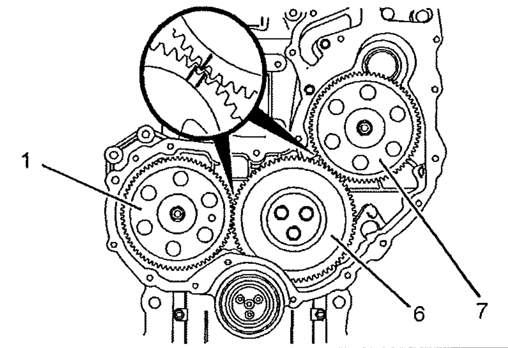

Illustration 138 g01471718

Typical example

4. Apply sufficient pressure to fuel injection pump gear (7) in a counterclockwise direction in order to remove the backlash. Lock the fuel injection pump in this position. Refer to Disassembly and Assembly, "Fuel Pump Gear - Remove" for the correct procedure.

5. Mark gears (1), (6) and (7) in order to show alignment. Refer to Illustration 138.

Note: Identification will ensure that the gears can be installed in the original alignment.

6. Remove fuel pump gear (7). Refer to Disassembly and Assembly, "Fuel Pump Gear - Remove" for the correct procedure.

7. Remove camshaft gear (1). Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".

8. Remove idler gear (6). Refer to Disassembly and Assembly, "Idler Gear - Remove".

Installation Procedure

Table 38

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
B	27610212	Camshaft Timing Pin	1
C	27610286	Crankshaft Timing Pin	1
D	21825617	Dial Indicator Group	1
	-	Finger Clock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The fuel injection pump must remain locked until the procedure instructs you to unlock the fuel injection pump.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

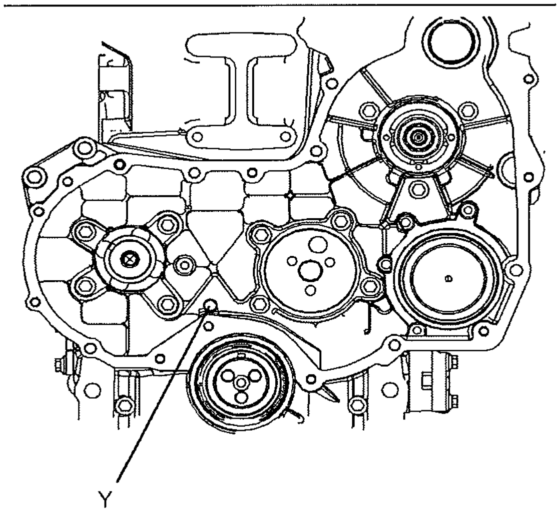

Illustration 139 g01488044
Typical example

2. If necessary, install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

Note: Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

3. Ensure that all of the components of the front gear group are clean and free from wear of damage. If necessary, replace any components that are worn or damaged.

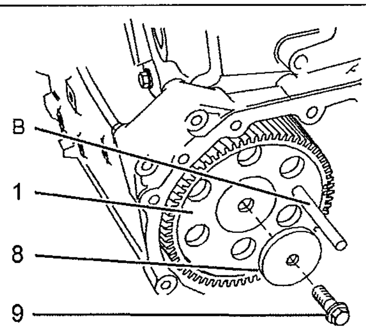

Illustration 140 g01471735
Typical example

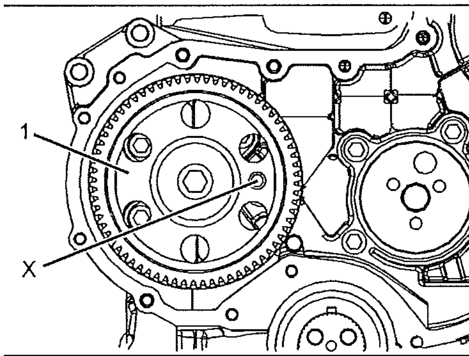

Illustration 141 g01488055
Typical example

4. Install camshaft gear (1). Loosely install bolt (9) and washer (8). Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install" for more information.

5. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing.

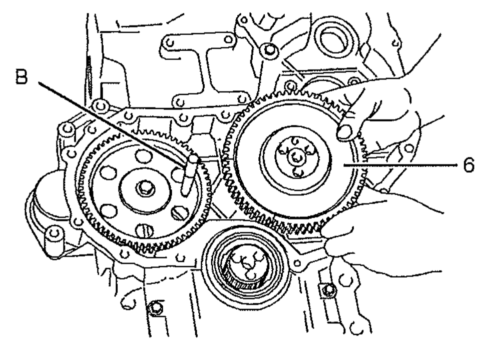

Illustration 142 g01471736
Typical example

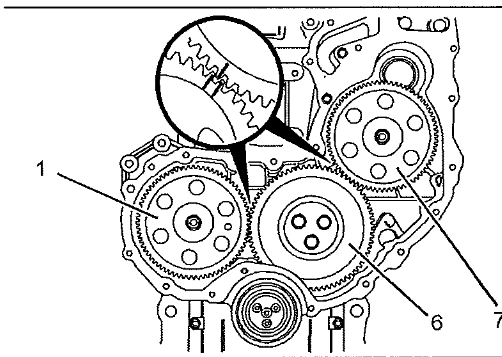

Illustration 143 g01471718
Alignment of timing marks

6. Install idler gear (6). Ensure that the timing marks on gears (1) and (6) are in alignment and that the mesh of the gears is correct. Refer to Disassembly and Assembly, "Idler Gear - Install". Check the end play of the idler gear. Refer to Specifications, "Gear Group (Front)" and refer to Disassembly and Assembly, "Idler Gear - Install" for further information.

7. Remove Tooling (B) and Tooling (C). Tighten bolt (9) for the camshaft gear to a torque of 95 N·m (70 lb ft). Check the end play of the camshaft gear. Refer to Specifications, "Camshaft" for more information.

   Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing and install Tooling (C) into Hole (Y) in the front housing.

8. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

9. Install fuel injection pump gear (7). Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install" for the correct procedure. Ensure that timing marks on gear (6) and gear (7) are in alignment. See Illustration 143. Ensure that the mesh of the gears is correct.

10. Remove Tooling (B) and Tooling (C).

11. Use Tooling (D) in order to measure the backlash for gears (1), (6) and (7). Ensure that the backlash for the gears is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

12. Lubricate each gear with clean engine oil.

13. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

End By:

a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

b. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

c. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

d. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

e. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

i03496189

Idler Gear - Remove

Removal Procedure (Early Heavy-Duty Idler Gear)

Table 39

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610212	Camshaft Timing Pin	1
B	27610211	Crankshaft Timing Pin	1

Start By:

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

Note: Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The assembly of heavy-duty idler gear is not serviceable. Do not disassemble the heavy-duty idler gear.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to the Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

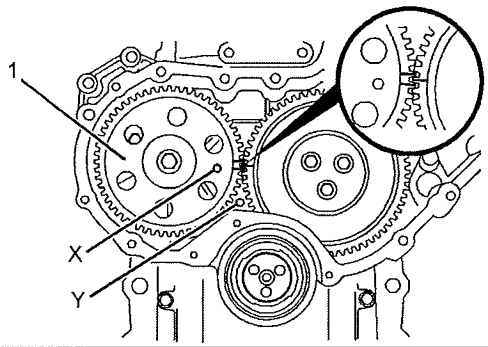

Illustration 144 g01473492

Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

Note: Ensure that the gears are marked in order to show alignment.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

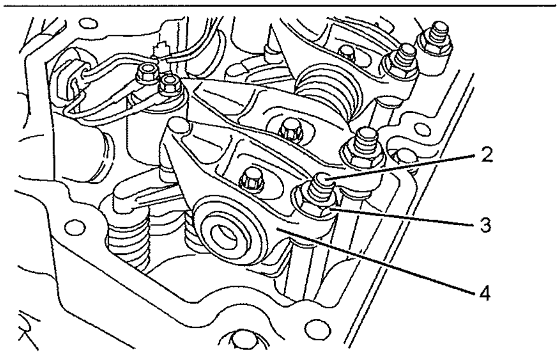

Illustration 145 g01831356

Typical example

4. Loosen nuts (3) on all rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

Note: Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.

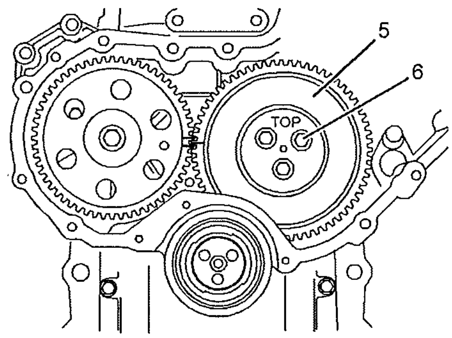

Illustration 146 g01832735

Typical example

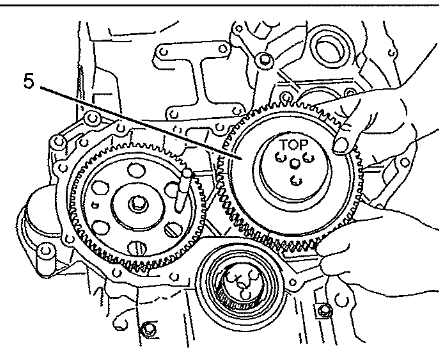

Illustration 147 g01832736

Typical example

5. Remove bolts (6) from the assembly of heavy-duty idler gear (5).

6. Remove the assembly of idler gear (5) from the recess in the front housing.

Note: The idler gear must be tilted during removal.

i03496187

Idler Gear - Remove

Removal Procedure (Standard Idler Gear)

Table 40

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610212	Camshaft Timing Pin	1
B	27610211	Crankshaft Timing Pin	1

Start By:

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

Note: Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

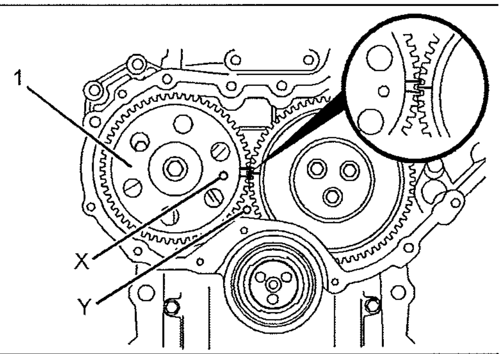

Illustration 148 g01473492

Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

Note: Ensure that the gears are marked in order to show alignment.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

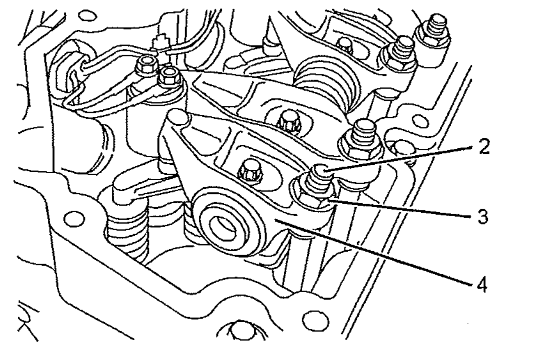

Illustration 149 g01831356

Typical example

4. Loosen nuts (3) on all rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

Note: Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.

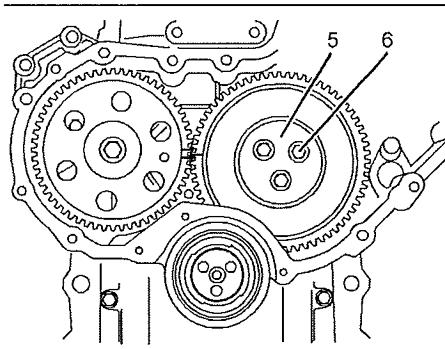

Illustration 150 g01473497

Typical example

5. Mark plate (5) in order to show orientation.

Note: Identification will ensure that the plate can be installed in the original orientation.

6. Remove bolts (6).

7. Remove plate (5).

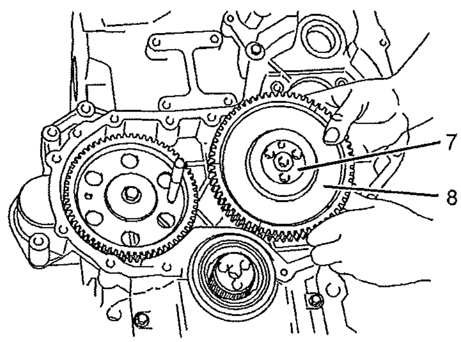

Illustration 151 g01473494

Typical example

8. Remove the assembly of idler gear (8) and hub (7) from the recess in the front housing.

Note: The idler gear must be tilted during removal.

9. Remove hub (7) from idler gear (8).

i02933658

Idler Gear - Remove

Removal Procedure (Latest Heavy-Duty Idler Gear)

Table 41

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610212	Camshaft Timing Pin	1
B	27610211	Crankshaft Timing Pin	1
C	-	Bolt M8x80mm	1

Start By:

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

Note: Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The assembly of heavy-duty idler gear is not serviceable. Do not disassemble the heavy-duty idler gear.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

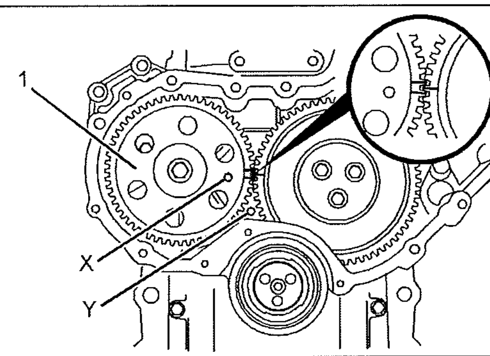

Illustration 152 g01473492

Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

Note: Ensure that the gears are marked in order to show alignment.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct Position.

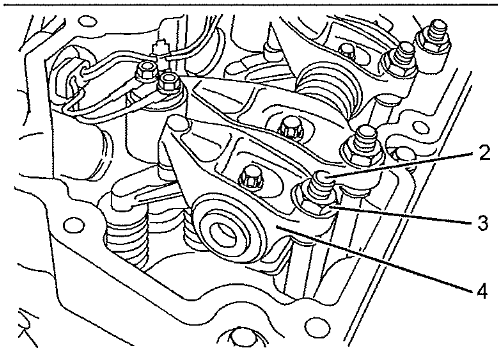

Illustration 153 g01831356

Typical example

4. Loosen nuts (3) on all rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

Note: Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.

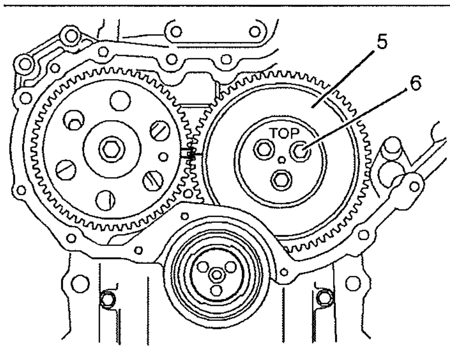

Illustration 154 g01832735

Typical example

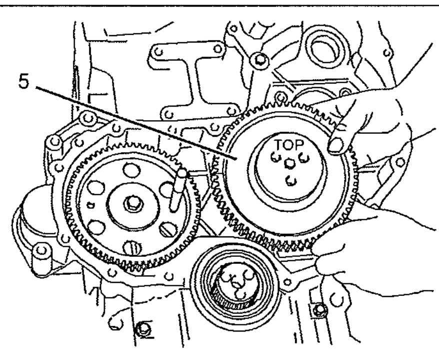

Illustration 155 g01831467

Typical example

5. Remove bolts (6) from the assembly of heavy-duty idler gear (5).

6. Remove the assembly of idler gear (5) from the recess in the front housing.

Note: The idler gear must be tilted during removal.

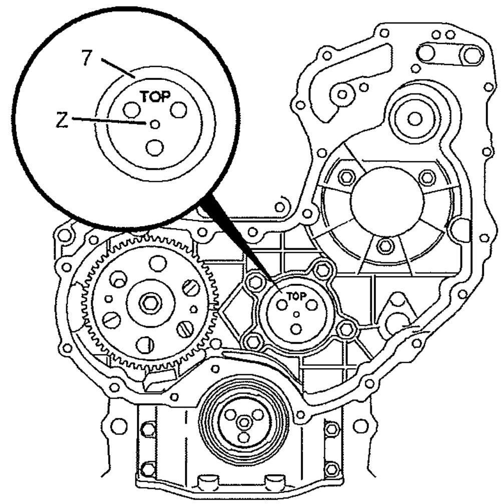

Illustration 156 g01831473

Typical example

7. If necessary, remove plate (7). Install Tooling (C) into threaded Hole (Z) in order to remove plate (7).

i03496182

Idler Gear - Install

Installation Procedure (Heavy-Duty Idler Gear)

Table 42

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610212	Camshaft Timing Pin	1
B	27610211	Crankshaft Timing Pin	1
C	21825617	Dial Indicator Group	1
	-	Finger Clock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

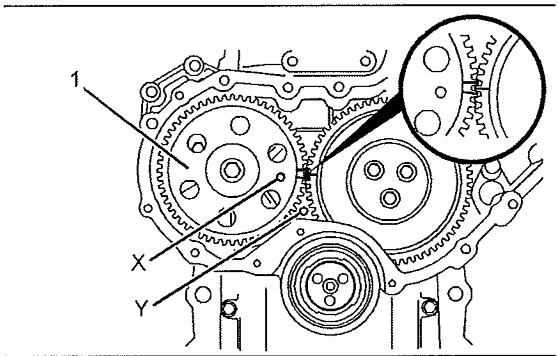

Illustration 157 g01473492

Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

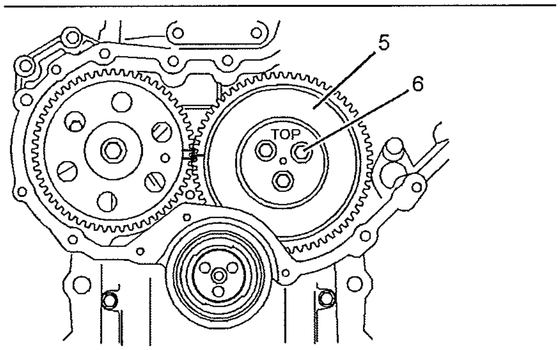

Illustration 158 g01832735

Typical example

4. Clean the assembly of idler gear (5) and inspect the assembly of the idler gear for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the assembly of the idler gear.

5. Lubricate the bearings in the assembly of idler gear (5) with clean engine oil.

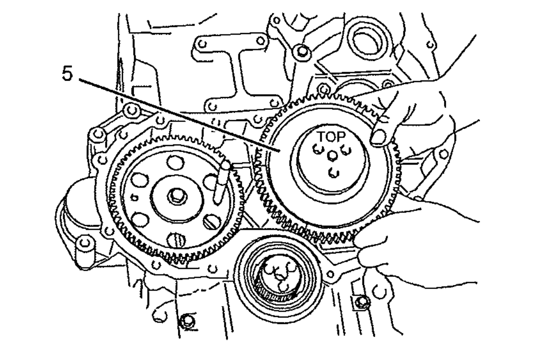

Illustration 159 g01831467

Typical example

6. Align the timing mark on idler gear (5) with the timing mark on the camshaft gear. Refer to Illustration 157. Install the assembly of idler gear (5) into the recess in the timing case. Ensure that the identification mark TOP is upward.

Note: The idler gear must be tilted during installation. Ensure that the holes in assembly of the idler gear are aligned with the holes in the cylinder block.

7. Install bolts (6). Tighten bolts (6) to a torque of 44 N·m (32 lb ft).

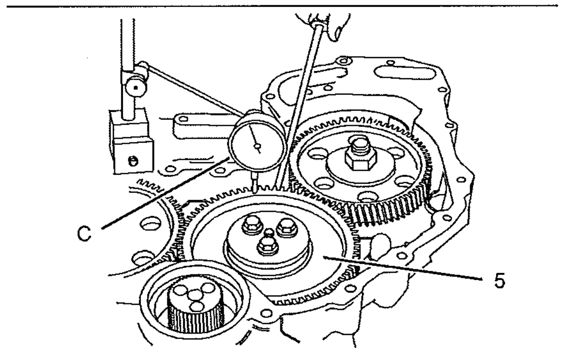

Illustration 160 g01832813

Checking end play by using a dial indicator group

8. Use Tooling (C) in order to check the end play of the idler gear. Refer to Specifications, "Gear Group (Front)" for more information.

9. Use Tooling (C) in order to check the backlash between the idler gear and the camshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

10. Use Tooling (C) in order to check the backlash between the idler gear and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

11. Lightly lubricate all of the gears with clean engine oil.

12. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

End By:

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install".

b. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

c. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

d. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

e. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i03496180

Idler Gear - Install

Installation Procedure (Standard Idler Gear)

Table 43

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610212	Camshaft Timing Pin	1
B	27610211	Crankshaft Timing Pin	1
C	21825617	Dial Indicator Group	1
	-	Finger Clock	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

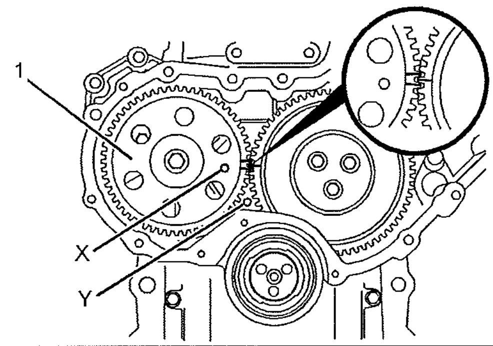

Illustration 161 g01473492
Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

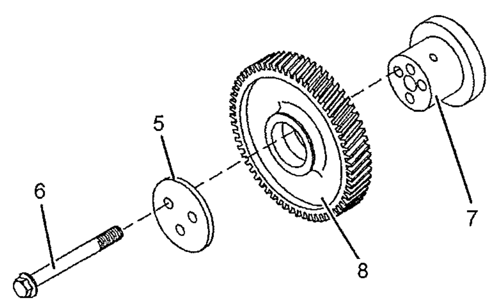

Illustration 162 g01832693
Typical example

4. Clean idler gear (8) and inspect the idler gear for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the idler gear.

5. Clean hub (7) and inspect the hub for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the hub.

6. Lubricate hub (7) with clean engine oil. Slide the hub into idler gear (8). Ensure that the timing marks are toward the front of the idler gear.

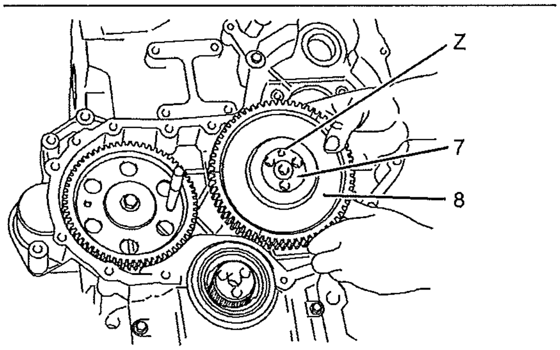

Illustration 163 g01832695

Typical example

7. Align the timing mark on idler gear (8) with the timing mark on the camshaft gear. Refer to the Illustration 161. Install the assembly of idler gear (8) and hub (7) into the recess in the timing case. Ensure that oil Hole (Z) is to the top of the hub.

Note: The idler gear must be tilted during installation. Ensure that the holes in the hub are aligned with the holes in the cylinder block.

8. Clean plate (5) and inspect the plate for wear or damage. If necessary, replace the plate.

9. Lubricate plate (5) with clean engine oil. A used plate should be installed in the original orientation. If a new plate is installed, ensure that the holes in plate (5) are aligned with the holes in hub (7). Install plate (5) to hub (7).

10. Install bolts (6). Tighten the bolts to a torque of 44 N·m (32 lb ft).

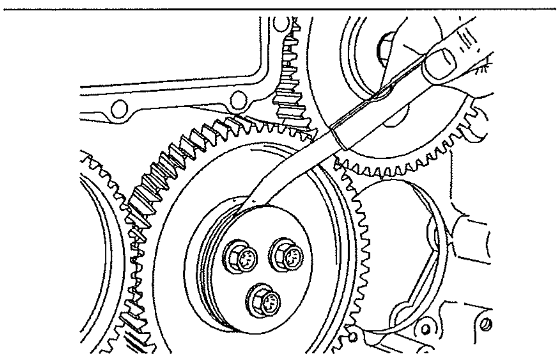

Illustration 164 g01269936

Checking end play by using a set of feeler gauge's

11. Use a set of feeler gauge's in order to check the end play of the idler gear. Refer to Specifications, "Gear Group (Front)" for more information.

12. Use Tooling (C) in order to check the backlash between the idler gear and the camshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

13. Use Tooling (C) in order to check the backlash between the idler gear and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

14. Lightly lubricate all of the gears with clean engine oil.

15. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

End By:

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install".

b. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

c. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

d. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

e. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933657

Idler Gear - Install

Installation Procedure (Latest Heavy-Duty Idler Gear)

Table 44

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610212	Camshaft Timing Pin	1
B	27610211	Crankshaft Timing Pin	1
D	21825617	Dial Indicator Group	1
	-	Finger Clock	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center Position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

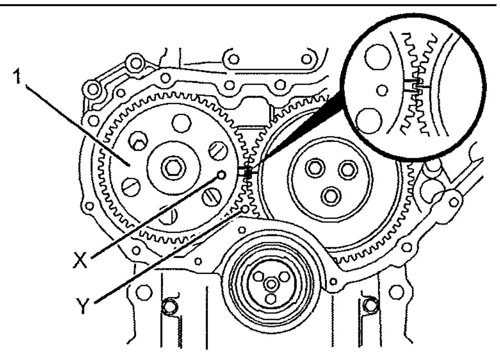

Illustration 165 g01473492

Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

3. Ensure that Tooling (B) is installed in Hole (Y) in the cylinder block. Use Tooling (B) in order to lock the crankshaft in the correct position.

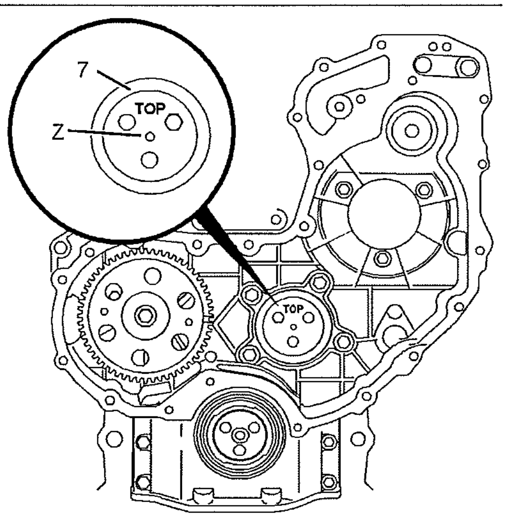

Illustration 166 g01831473

Typical example

4. Install plate (2) into the recess in the front housing.

Note: Ensure that the identification mark TOP is upward.

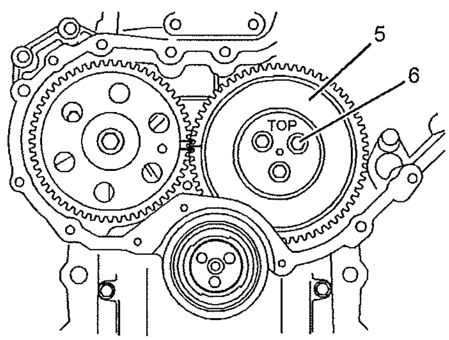

Illustration 167 g01832735

Typical example

5. Clean the assembly of idler gear (5) and inspect the assembly of the idler gear for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the assembly of the idler gear.

6. Lubricate the bearings in the assembly of idler gear (5) with clean engine oil.

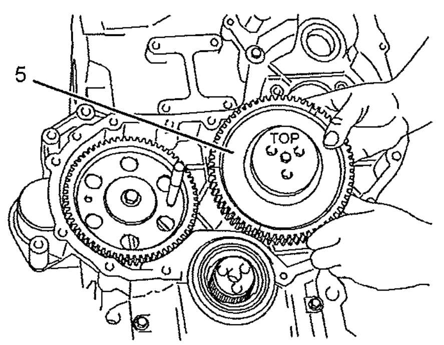

Illustration 168 g01831467

Typical example

7. Align the timing mark on idler gear (5) with the timing mark on the camshaft gear. Refer to Illustration 165. Install the assembly of idler gear (5) into the recess in the timing case. Ensure that the identification mark TOP is upward.

Note: The idler gear must be tilted during installation. Ensure that the holes in the assembly of the idler gear are aligned with the holes in the cylinder block.

8. Install bolts (6). Tighten the bolts to a torque of 44 N·m (32 lb ft).

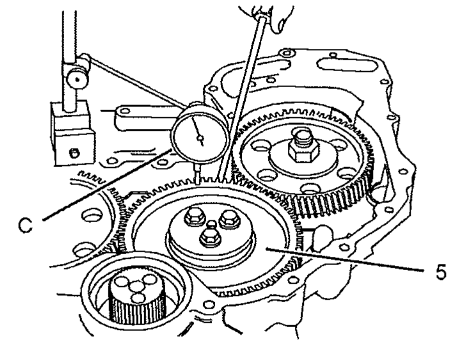

Illustration 169 g01832813

Checking end play by using a dial indicator group

9. Use Tooling (D) in order to check the end play of idler gear (5). Refer to Specifications, "Gear Group (Front)" for more information.

10. Use Tooling (D) in order to check the backlash between the idler gear and the camshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

11. Use Tooling (D) in order to check the backlash between the idler gear and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

12. Lightly lubricate all of the gears with clean engine oil.

13. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

End By:

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install".

b. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

c. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

d. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

e. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933656

Housing (Front) - Remove

Removal Procedure

Start By:

a. Remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

b. Remove the alternator. Refer to Disassembly and Assembly, "Alternator - Remove".

c. Remove the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

d. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

e. Remove the timing gears. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install".

f. Remove the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Ensure that the coolant is drained into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

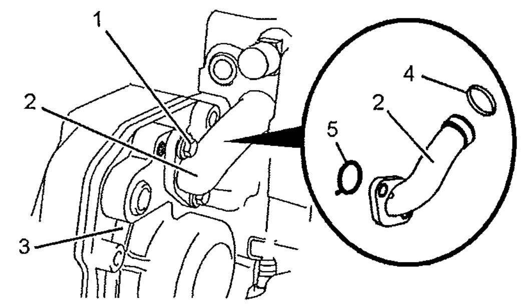

Illustration 170 g01475066

Typical example

2. Remove bolts (1) that secure bypass tube (2) to front housing (3). Remove bypass tube (2). Remove O-ring seal (4) and O-ring seal (5) from bypass tube (2).

Note: Note the position of any brackets that are secured by the bolts.

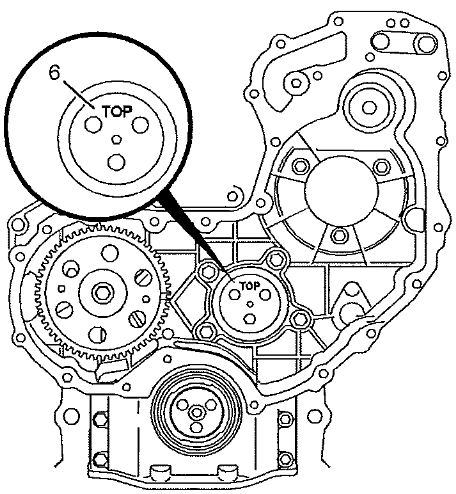

Illustration 171 g01475068

Typical example

3. If the engine is equipped with a heavy duty idle gear. Remove plate (6). Refer to Disassembly and Assembly, "Idler Gear - Remove" for the correct procedure.

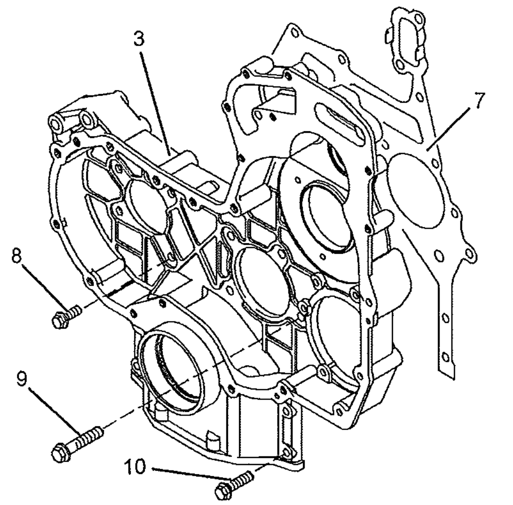

Illustration 172 g01475067

Typical example

4. Remove bolts (8), (9) and (10) from front housing (3).

Note: The bolts are three different lengths. Note the positions of the different bolts.

5. Remove front housing (3) from the cylinder block.

6. Remove gasket (7).

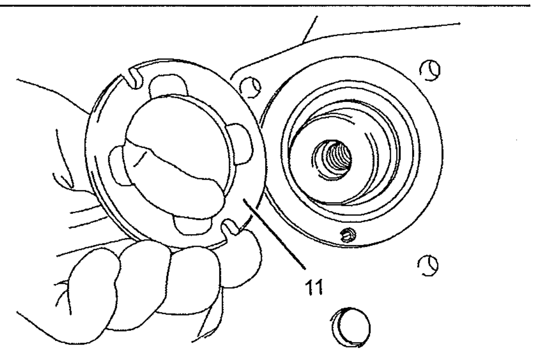

Illustration 173 g01475069

Typical example

7. Remove thrust washer (11) from the cylinder block.

i02933655

Housing (Front) - Install

Installation Procedure

Table 45

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820117	POWERPART Threadlock and Nutlock	1
B	-	Guide Stud (M8 by 80 mm)	2
C	27610216	Alignment Tool	1
	-	Bolts (M10 by 50 mm)	3
D	-	Straight Edge	1
E	21820221	POWERPART Rubber Grease	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the front housing is clean and free from damage. If necessary, replace the front housing.

   If necessary, install blanking plugs to a new front housing. Use Tooling (A) to seal all D-plugs.

2. Check the condition of the crankshaft front seal. If the front seal is damaged, remove the front seal from the front housing.

3. Clean the surfaces of the cylinder block.

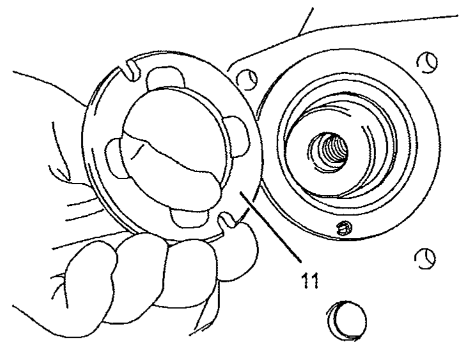

Illustration 174 g01475069

Typical example

4. Install thrust washer (11) into the recess in the cylinder block. Refer to Disassembly and Assembly, "Camshaft - Install" for more information.

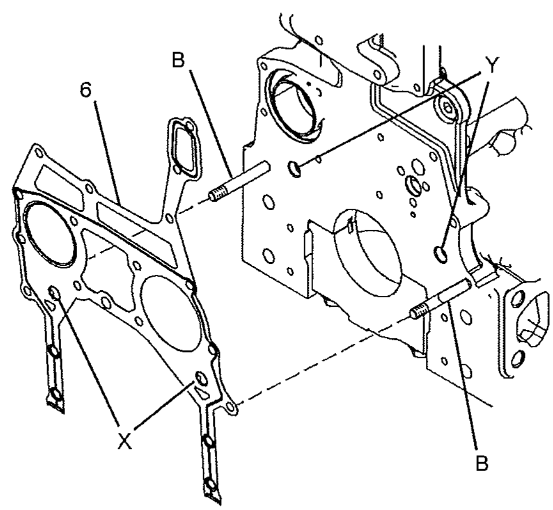

Illustration 175 g01475134

Typical example

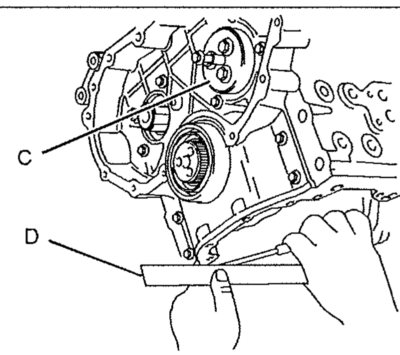

Illustration 176 g01269947

Typical example

5. Install Tooling (B) to the cylinder block. Refer to Illustration 175.

6. Install Tooling (C) to the cylinder block.

7. Align a new gasket (6) with Tooling (B) and Tooling (C). Install the gasket to the cylinder block.

Note: Ensure that Tabs (X) on the gasket are engaged in Holes (Y) in the cylinder block.

8. Install the front housing over Tooling (B) and over Tooling (C) onto the cylinder block.

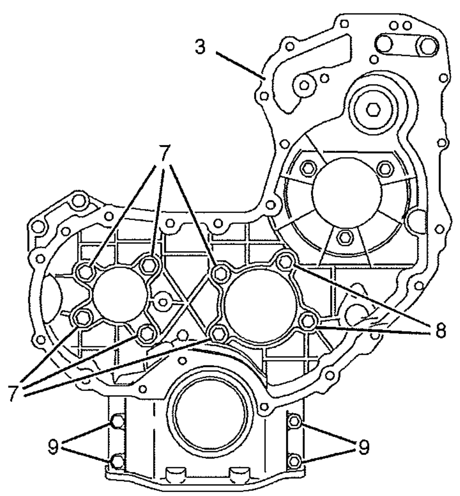

Illustration 177 g01269948

(7) M8 by 20 mm
(8) M8 by 35 mm
(9) M8 by 25 mm

9. Install bolts (9) to front housing (3) finger tight.

10. Remove Tooling (B).

11. Loosely install bolt (7) and bolt (8). Refer to Illustration 177 for the correct position of the bolts.

12. Align the bottom face of front housing (3) to the lower machined face of the cylinder block. Use Tooling (D) and a feeler gauge in order to check the alignment between the front housing and the cylinder block. Refer to Illustration 176. Refer to Specifications, "Front Housing and Covers" for further information.

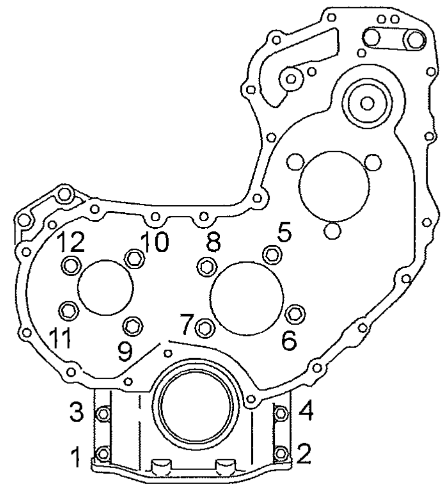

Illustration 178 g01269949

Tightening sequence for the front housing

13. Tighten bolts (7), (8) and (9) to a torque of 28 N·m (20 lb ft). Tighten the bolts in the sequence that is shown in Illustration 178.

Note: Ensure that the housing and the cylinder block are correctly aligned.

14. Remove Tooling (C) from the cylinder block.

15. If necessary, install a new crankshaft front seal. Refer to Disassembly and Assembly, "Crankshaft Front Seal - Remove and Install".

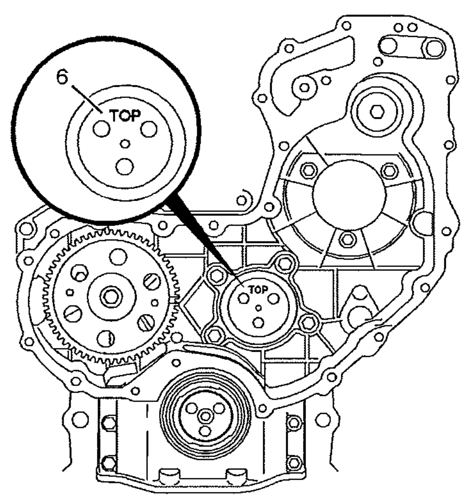

Illustration 179 g01475068

Typical example

16. If the engine is equipped with a heavy duty idle gear. Install plate (6). Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure.

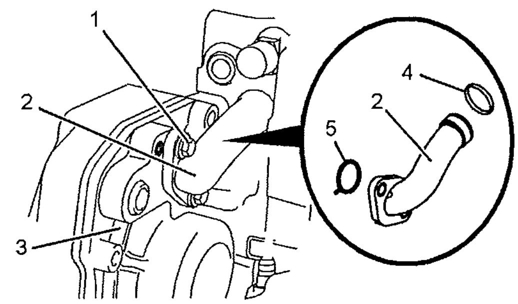

Illustration 180 g01475066

Typical example

17. Install new O-ring seal (4) and O-ring seal (5) to bypass tube (2). Use Tooling (E) in order to lubricate O-ring seal (5). Install bypass tube (2) to front housing (3). Install bolts (1). Tighten the bolts to a torque of 22 N·m (16 lb ft).

Note: Ensure that any brackets that are secured by the bolts are installed in the correct location.

18. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

End By:

a. Install the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

b. Install the timing gears. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install".

c. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

d. Install the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

e. Install the alternator. Refer to Disassembly and Assembly, "Alternator - Install".

f. Install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933583

Accessory Drive - Remove

Removal Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

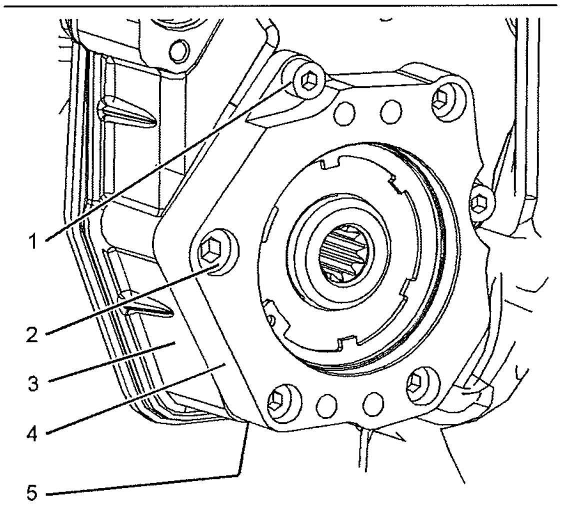

Illustration 181 g01441026

Typical example

1. Remove allen head screw (1) from accessory drive housing (4). Remove allen head screws (2) from accessory drive housing (4).
2. Remove accessory drive housing (4) from front housing (3).
3. Remove O-ring seal (5) (not shown) from accessory drive housing (4).

i02933581

Accessory Drive - Disassemble

Disassembly Procedure

Table 46

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bearing Puller	1
	-	Puller	1
	-	Crossblock	1
	-	Puller Leg	2

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

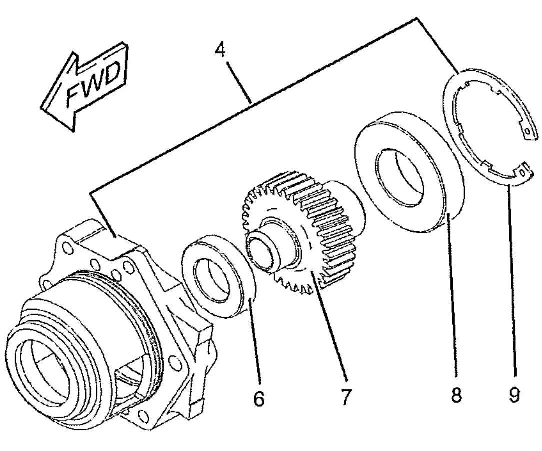

Illustration 182 g01440573

Typical example

1. Remove circlip (9) from accessory drive housing (4).

2. Place accessory drive housing (4) onto a suitable support. Press the assembly of gear (7), bearing (6) and bearing (8) out of accessory drive housing (4).

3. Use a Tooling (A) in order to remove bearing (6) and bearing (8) from gear (7).

i02933580

Accessory Drive - Assemble

Assembly Procedure

Table 47

Required Tools			
Tool	Part Number	Part Description	Qty
B	21820603	POWERPART Retainer	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

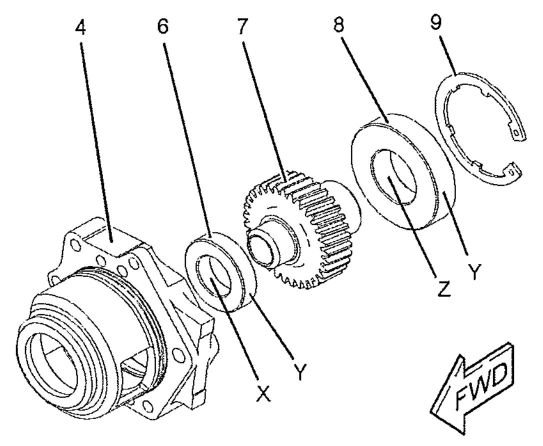

Illustration 183 g01440577

Typical example

1. Inspect the condition of the teeth and the splines of gear (7) for wear or damage. Inspect bearing (6) and bearing (8). Inspect circlip (9), and front housing (4) for wear or damage. Replace any components that are worn or damaged.

2. Apply a small continuous bead of Tooling (B) to inner Surface (X) of bearing (6). Place the gear shaft on a suitable support. Press on the inner race of bearing (6) until bearing (6) is against the shoulder of gear (7). Remove any excess sealant.

3. Apply a small continuous bead of Tooling (B) to inner Surface (Z) of bearing (8). Place the inner race of bearing (8) onto a suitable support. Press the shaft of gear (7) onto bearing (8) until the shoulder of the gear is against the bearing. Remove any excess sealant.

4. Apply a small continuous bead of Tooling (B) to outer Surface (Y) of bearing (6) and bearing (8). Place accessory drive housing (4) on a suitable support. Press the assembly of the gear into the accessory drive housing. Ensure that bearing (6) is against the front face of the recess in accessory drive housing (4). Remove any excess sealant.

5. Install circlip (9) into the groove in accessory drive housing (4). Ensure that circlip (9) is correctly positioned in the groove.

i02933582

Accessory Drive - Install

Installation Procedure

Table 48

Required Tools			
Tool	Part Number	Part Description	Qty
C	21820221	POWERPART Rubber Lubricant	1
D	21820117	POWERPART Threadlock and Nutlock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

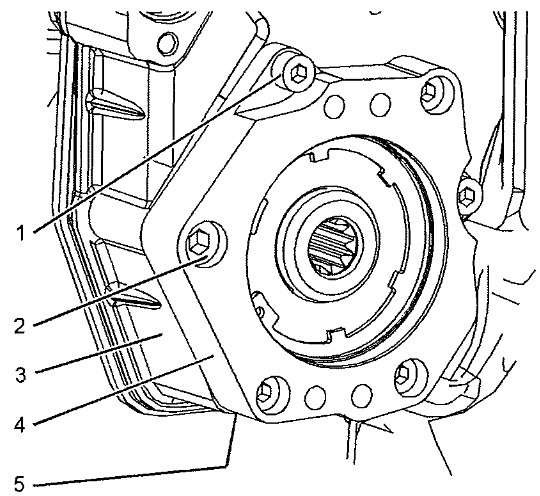

Illustration 184 g01441026

Typical example

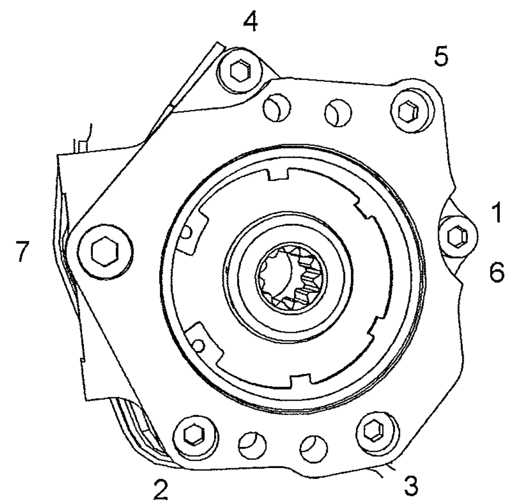

Illustration 185 g01444555

Sequence for tightening accessory drive

1. Inspect the bore in front housing (3) for damage. If necessary, replace the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove" and Disassembly and Assembly, "Housing (Front) - Install".

2. Lightly lubricate a new O-ring seal (5) (not shown) with Tooling (C). Install the O-ring seal (not shown) into the groove in accessory drive housing (4).

3. Lightly lubricate all bearings, and all gears with clean engine lubricating oil. Install the assembly of the accessory drive to the front housing. Ensure that the flange on the accessory drive housing is flush with the front housing.

4. Apply Tooling (D) to allen head screws (1) and allen head screw (2).

5. Install allen head screws (1) and allen head screw (2) to accessory drive housing (4).

6. Tighten allen head screws (1) to a torque of 22 N·m (16 lb ft).

   Tighten allen head screw (2) to a torque of 44 N·m (32 lb ft). Tighten allen head screws (1) and (2) in the sequence that is shown in Illustration 185.

7. Ensure that there is tactile backlash between the idler gear and the accessory drive gear.

i02933599

Crankcase Breather - Remove and Install (Filtered Breather)

Removal Procedure

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

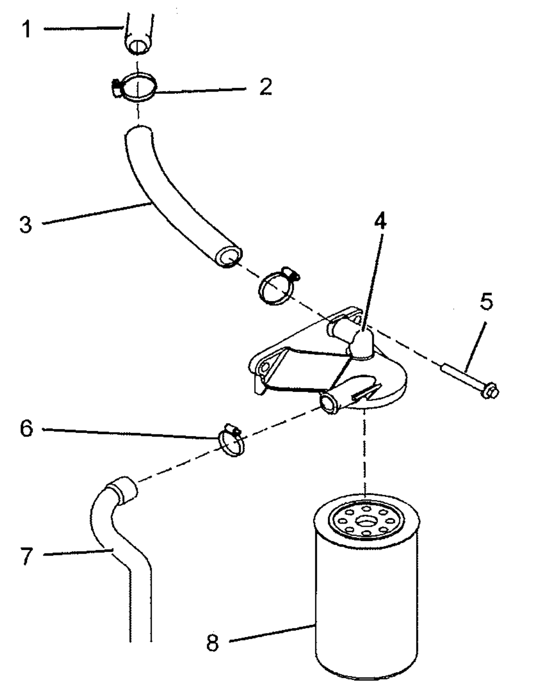

Illustration 186 g01475258

Typical example

1. Remove canister (8). Refer to Operation and Maintenance Manual, "Crankcase Breather (Canister) - Replace".

2. Loosen clamp (6) and remove hose (7).

3. Release spring clamps (2) in order to remove hose (3). Remove the hose from connection (1) on the valve mechanism cover and from filter base (4).

4. Remove bolts (5) and remove filter base (4).

Note: If a spacer is installed between the filter base and the engine, remove the spacer.

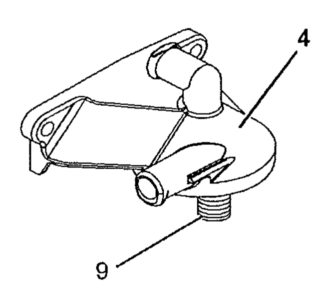

Illustration 187 g01903114

5. If necessary, use a suitable tool in order to remove connection (9) from filter base (4).

Installation Procedure

Table 49

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820118	Thread Lock Compound	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.

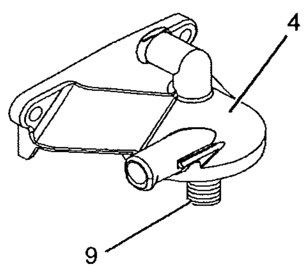

Illustration 188 g01903114

2. If necessary, install connection (9) to filter base (4). Follow Step 2.a through Step 2.c in order to install connection (9) to filter base (4).

   a. Apply a bead of Tooling (A) to the threads of connection (9).

   b. Install connection (9) to filter base (4).

   c. Tighten connection (9) to a torque of 50 N·m (37 lb ft).

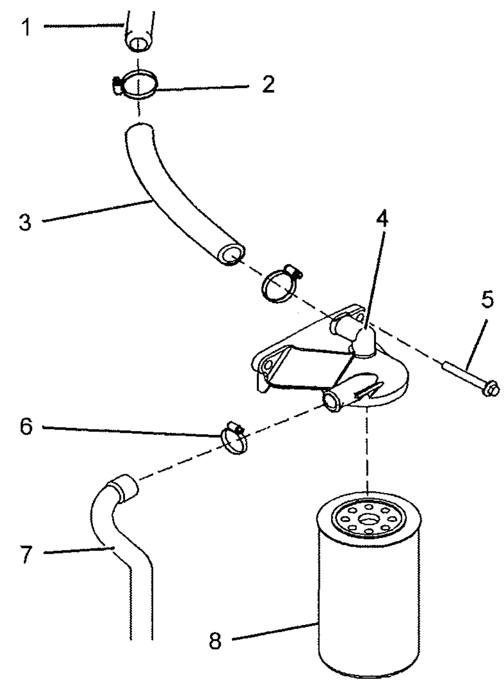

Illustration 189 g01475258

Typical example

3. Install bolts (5) to filter base (4).

Note: If spacers are installed, position the spacers over the bolts.

4. Install the assembly of the filter base to the engine.

5. Tighten bolts (5) to a torque of 22 N·m (16 lb ft).

6. Install spring clamps (2) to hose (3). Install hose (3) to connection (1) on the valve mechanism cover and to filter base (4).

Note: Ensure that the spring clamps are correctly positioned in order to secure the hose.

7. Install clamp (6) to hose (7). Install hose (7) to filter base (4). Tighten the clamp securely.

8. Install a new canister (8) to filter base (4). Refer to Operation and Maintenance Manual, "Crankcase Breather (Canister) - Replace".

i02933600

Crankcase Breather - Remove and Install (Unfiltered Breather)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

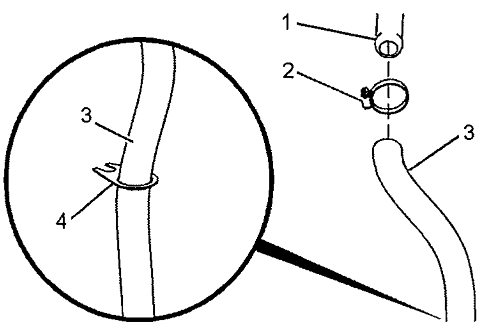

Illustration 190 g01475234

Typical example

1. Loosen clamp (2) and remove hose (3) from connection (1) on the valve mechanism cover. Withdraw hose (3) from clip (4) and remove the hose.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.

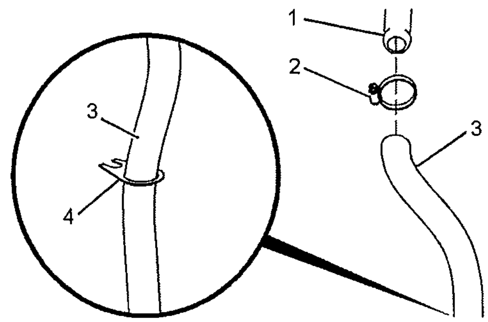

Illustration 191 g01475234

Typical example

2. Connect hose (3) to connection (1) on the valve mechanism cover. Tighten clamp (2). Install hose (3) into clip (4).

i02933677

Valve Mechanism Cover - Remove and Install

Removal Procedure

Start By:

a. Disconnect the crankcase breather or remove the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

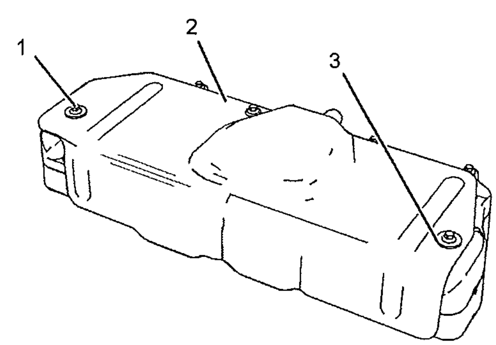

Illustration 192 g01788614

1. If the valve mechanism cover is equipped with a heat shield, remove bolts (1) and washers (3) from heat shield (2).

Note: The washers are two different sizes. Note the position of the washers for installation purposes.

2. Remove heat shield (2).

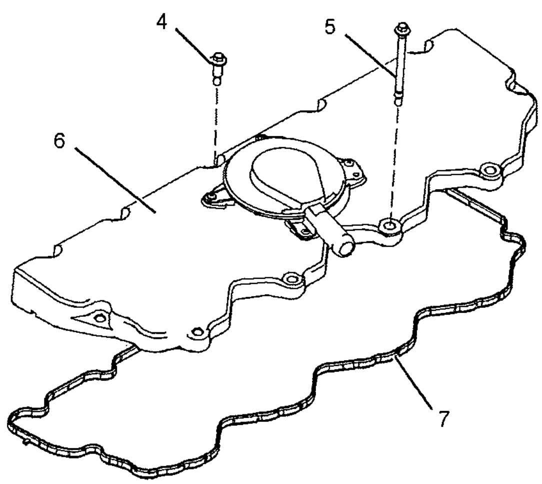

Illustration 193 g01788720

Typical example

3. Remove bolts (4) and bolts (5) from valve mechanism cover (6).

4. Remove valve mechanism cover (6) from the valve mechanism cover base.

5. Remove gasket (7) from valve mechanism cover (6).

Installation Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the valve mechanism cover. Clean the faces of the valve mechanism cover base.

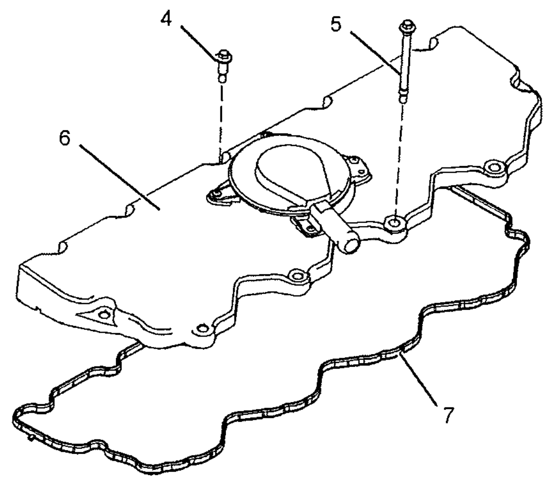

Illustration 194 g01788720

Typical example

2. Install a new gasket (7) to valve mechanism cover (6).

Note: Ensure that the gasket is fully seated into the groove of the valve mechanism cover.

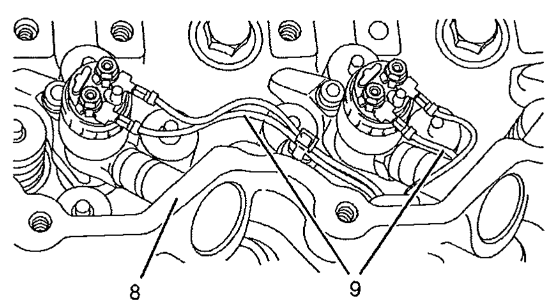

Illustration 195 g01788815

Typical example

3. Ensure that harness assemblies (9) are not in contact with the rocker arms or in contact with the valve mechanism cover base. Position valve mechanism cover (6) onto valve mechanism cover base (8). Ensure that harness assemblies (9) are not trapped during the assembly procedure. Install bolts (4) and bolts (5).

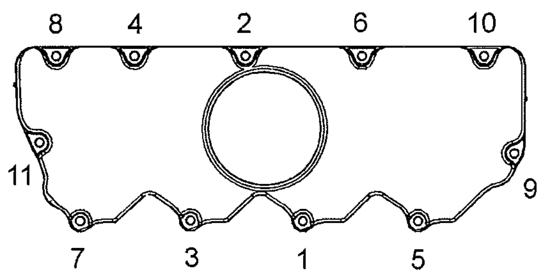

Illustration 196 g01245162

Tightening sequence for the valve mechanism cover

4. Tighten bolts (4) and bolts (5) in the numerical sequence that is shown in Illustration 196. Tighten the bolts to a torque of 6 N·m (53 lb in).

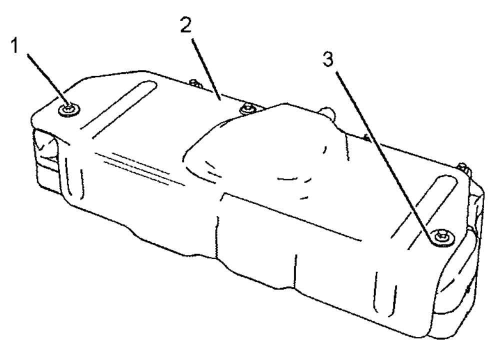

Illustration 197 g01788614

5. If necessary, position heat shield (2) onto the valve mechanism cover.

6. Install bolts (1) and washers (3). Tighten the bolts to a torque of 9 N·m (80 lb in).

End By:

a. Connect the crankcase breather or install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

i02933678

Valve Mechanism Cover Base - Remove and Install

Removal Procedure

Table 50

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Circlip Pliers	1

Start By:

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

b. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

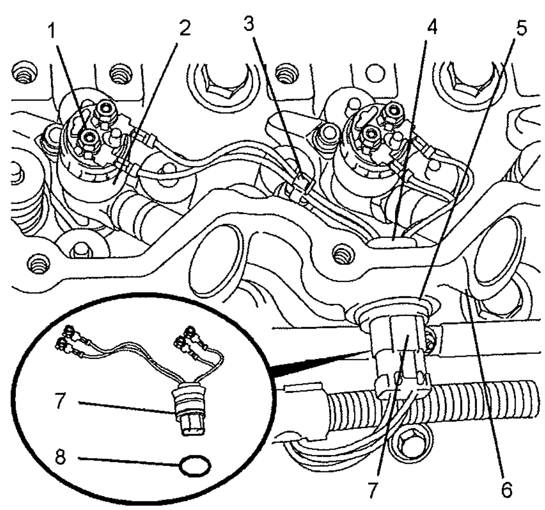

Illustration 198 g01476212

Typical example

1. Make a temporary identification mark on connections (1).

2. Use a deep socket to remove connections (1) from electronic unit injectors (2).

3. Disconnect plugs (7) from harness assemblies (4).

4. If necessary, follow Step 4.a through Step 4.e in order to remove harness assemblies (4) from valve mechanism cover base (6).

   a. Cut cable strap (3).

   b. Use Tooling (A) to remove circlip (5).

   c. From the outside of valve mechanism cover base (6), push harness assembly (4) inward. Withdraw the harness assembly from valve mechanism cover base (6).

   d. Remove O-ring seal (8) from harness assembly (4).

   e. Repeat Step 4.a through Step 4.d in order to remove the remaining harness assembly.

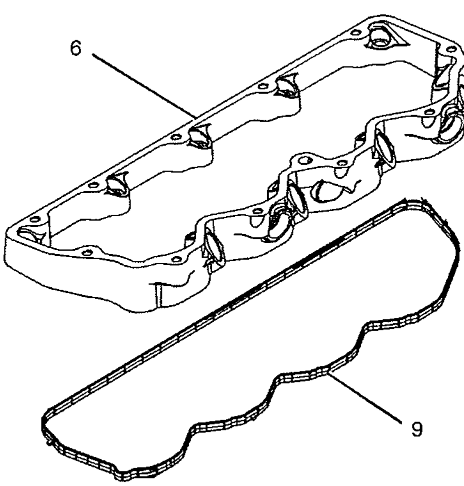

Illustration 199 g01245186

Typical example

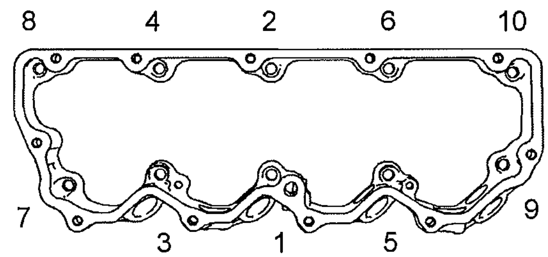

Illustration 200 g01245190

Sequence for loosening captive bolts in valve mechanism

5. Progressively loosen the captive bolts that secure the valve mechanism cover base in reverse numerical order. Refer to Illustration 200. This will help prevent distortion of the valve mechanism cover base.

Note: The captive bolts cannot be removed from the valve mechanism cover base.

6. Remove the valve mechanism cover base from the cylinder head.

7. Remove gasket (9) from the valve mechanism cover base .

Installation Procedure

Table 51

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Circlip Pliers	1
B	21820221	POWERPART Rubber Grease	1
C	27610296	Torque wrench	1
D	27610349	Alignment Pins	2

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

1. Clean the valve mechanism cover base. Ensure that the gasket surfaces are free from damage.

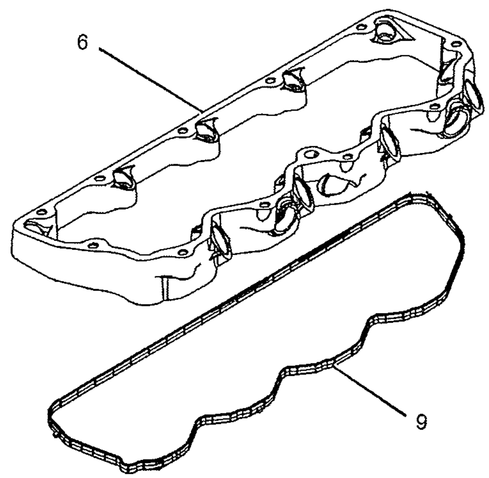

Illustration 201 g01245186

Typical example

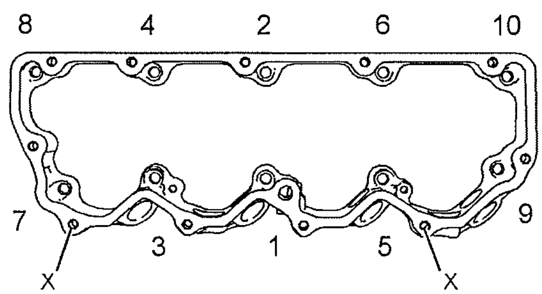

Illustration 202 g01272185

Tightening sequence for the valve mechanism cover base

2. Install gasket (9) to valve mechanism cover base (6). Ensure that the gasket is seated correctly in the groove in the valve mechanism cover base.

3. Position valve mechanism cover base (6) on the cylinder head.

4. Install Tooling (D) into the valve mechanism cover base in Positions (X).

5. Progressively tighten the captive bolts that secure the valve mechanism cover base. Tighten the captive bolts to a torque of 9 N·m (79 lb in) in the sequence that is shown in Illustration 202.

6. Remove Tooling (D).

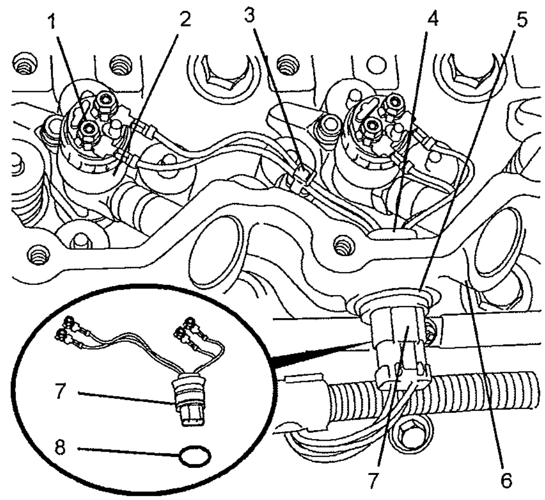

Illustration 203 g01476212

Typical example

7. If necessary, install the harness assemblies for the electronic unit injectors. Follow Step 7.a through Step 7.e in order to install the harness assemblies to the electronic unit injectors.

   a. Ensure that harness assembly (4) and the bore in valve mechanism cover base (6) are clean and free from damage. Replace any damaged components.

   b. Use Tooling (B) to lubricate a new O-ring seal (8). Install O-ring seal (8) onto harness assembly (4).

   c. From the inside of valve mechanism cover base (6), push harness assembly (4) into the valve mechanism cover base.

   d. Use Tooling (A) to install circlip (5).

   e. Repeat Step 7.a through Step 7.e for the remaining harness assembly.

8. Use a deep socket to connect harness (4) to electronic unit injectors (2). Use Tooling (C) to tighten connectors (1) to a torque of 2.4 N·m (21 lb in).

9. If necessary, install new cable strap (3) to harness assemblies (4).

Note: Ensure that the cable straps conform to the Perkins specification.

10. Connect plugs (7) to harness assemblies (4).

End By:

a. Install new fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

b. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933672

Rocker Shaft and Pushrod - Remove

Removal Procedure

Table 52

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	E12 Torx Socket	1

Start By:

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

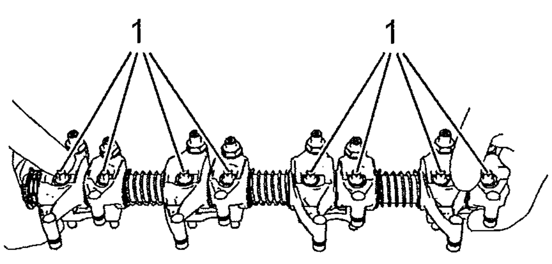

Illustration 204 g01476297

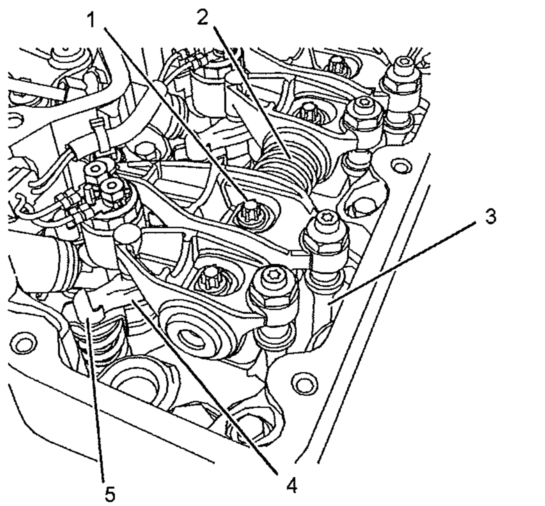

Illustration 205 g01792634

Typical example

1. Use Tooling (A) in order to progressively loosen torx screws (1). Begin at the ends of the rocker shaft assembly and work toward the center.

Note: To avoid distortion of the rocker shaft assembly, each torx screw should be loosened by a quarter of a turn at one time. Repeat the procedure until all torx screws are loosened.

2. Remove torx screws (1) from rocker shaft assembly (2).

3. Remove rocker shaft assembly (2) from the cylinder head.

4. Make a temporary mark on pushrods (3) in order to show the location. Remove the pushrods from the cylinder head.

Note: Identification will ensure that the pushrods can be reinstalled in the original positions. Do not interchange the positions of used pushrods.

5. Make a temporary mark on valve bridges (4) in order to show the location and the orientation. Remove the valve bridges from the cylinder head. If the valve bridges are equipped with shrouds (5), ensure that the shrouds are removed from the cylinder head.

Note: Identification will ensure that the valve bridges can be reinstalled in the original location and the original orientation. Do not interchange the location or the orientation of used valve bridges.

i02933670

Rocker Shaft - Disassemble

Disassembly Procedure

Start By:

a. Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

⚠ WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Make an identification mark on each rocker arm assembly in order to show the location.

Note: The components must be reinstalled in the original location. Do not interchange components.

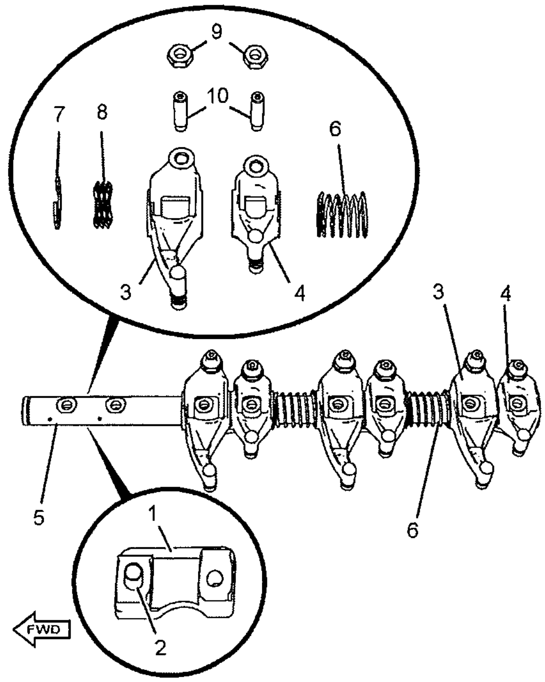

Illustration 206 g01476312

Typical example

2. Remove pedestals (1) from rocker shaft (5). Do not remove dowels (2) from the pedestals.

3. Remove rocker arm assembly (4) for the exhaust valve from rocker shaft (5). Remove rocker arm assembly (3) for the inlet valve from rocker shaft (5). Begin at the rear of the rocker shaft assembly.

Note: The rocker arm assembly for the inlet valve is longer than the rocker arm assembly for the exhaust valve.

4. Remove spring (6) from rocker shaft (5).

5. Repeat Step 3 and Step 4 in order to remove the remaining rocker arms from rocker shaft (5).

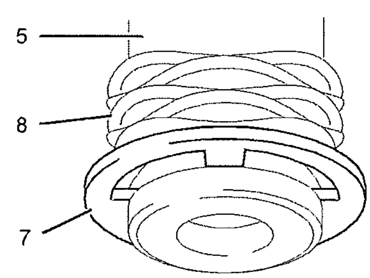

Illustration 207 g01181801

6. If necessary, remove retaining clip (7) and remove spring (8) from the front end of rocker shaft (5).

7. If necessary, remove nuts (9) and adjusters (10) from the rocker arms. Make a temporary identification mark on each adjuster in order to show the location.

Note: The components must be reinstalled in the original location. Do not interchange components.

i02933669

Rocker Shaft - Assemble

Assembly Procedure

WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. Refer to Specifications, "Rocker Shaft" for more information. If necessary, replace any components that are worn or damaged.

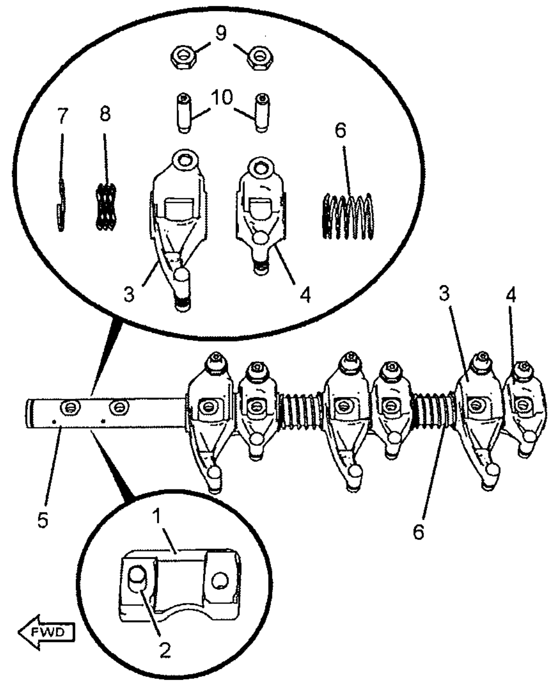

Illustration 208 g01476312

Typical example

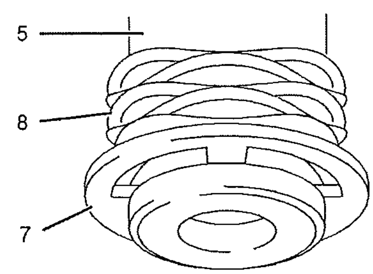

Illustration 209 g01270008

2. If necessary, install nuts (9) and adjusters (10) to rocker arm assemblies (3) and (4). If the original adjusters are reused, ensure that the adjusters are installed in the original positions.

3. Install retaining clip (7) and spring (8) to the front end of rocker shaft (5).

4. Lubricate the bores of rocker arm assemblies (3) and (4) and rocker shaft (5) with clean engine oil.

5. Place the rocker shaft in the inverted position with the counterbores for the holes downward. Install rocker arm assembly (3) for number 1 cylinder inlet valves to the rocker shaft. Install rocker arm assembly (4) for number 1 cylinder exhaust valves to rocker shaft (5).

Note: The rocker arms for the inlet valves are longer than the rocker arms for the exhaust valves. Install rocker arms in the inverted position. Used components should be installed in the original location.

6. Ensure that dowel (2) is correctly seated in pedestal (1). Align the dowel with the appropriate hole in rocker shaft (5). Install the pedestal to the rocker shaft.

7. Install spring (6) to rocker shaft (5).

8. Repeat Step 5 through Step 7 in order to assemble the remaining components to rocker shaft (5).

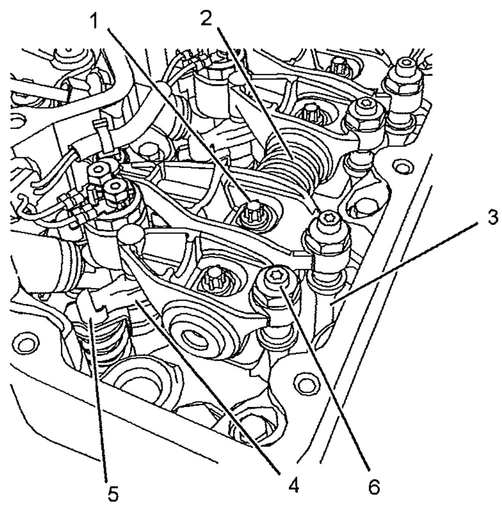

Illustration 210 g01794035

End By:

a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install".

i02933671

Rocker Shaft and Pushrod - Install

Installation Procedure

Table 53

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	E10 Torx Socket	1
B	27610298	Feeler Gauge	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the valve bridges. Inspect the valve bridges for wear or damage. Replace any valve bridges that are worn or damaged.

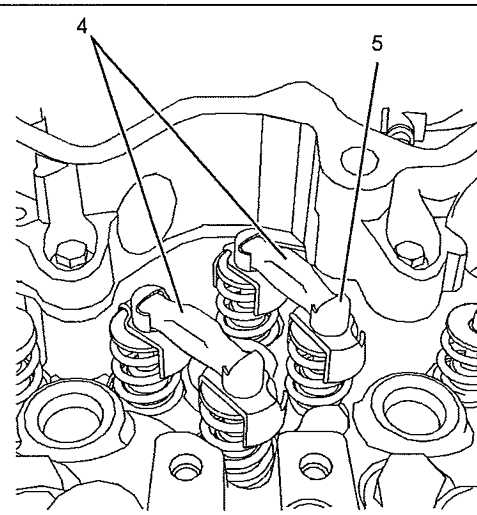

Illustration 211 g01794053

The correct location of valve bridges on valve stems is shown. The electronic unit injector is not shown for clarity.

NOTICE
Failure to ensure that ALL valve bridges are correctly seated onto the valve stems will cause interference between the pistons and the valves, resulting in damage to the engine.

2. Lubricate valve bridges (4) with clean engine oil. Install the valve bridges to the cylinder head.

3. Install valve bridges (4) to the cylinder head. If the valve bridges are equipped with shrouds (5), ensure that the shrouds are located correctly.

Note: Install used valve bridges in the original location and in the original orientation. Ensure that the valve bridges are correctly seated on the valves. New valve bridges may be installed in either orientation.

4. Clean pushrods (3). Inspect the pushrods for wear or damage. Replace any pushrods that are worn or damaged.

5. Apply clean engine lubricating oil to both ends of pushrods (3). Install the pushrods to the engine with the cup upward.

Note: Ensure that the pushrods are installed in the original location and that the ball end of each pushrod is correctly seated in the valve lifters.

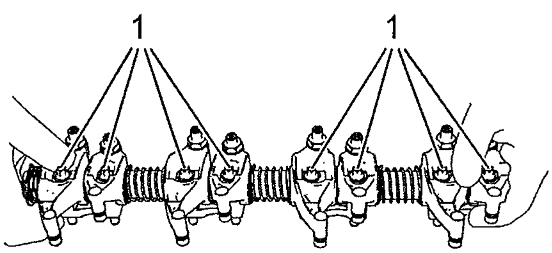

Illustration 212 g01476297

6. Ensure that the rocker shaft assembly is clean and free from wear or damage. Install torx screws (1) in the rocker shaft.

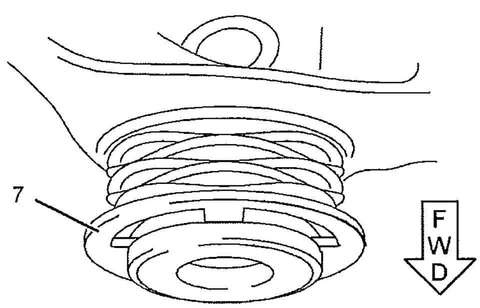

Illustration 213 g01794061

7. Position rocker shaft assembly (2) onto the cylinder head. Retaining clip (7) should face the front of the engine.

Note: Ensure that adjustment screws (6) are properly seated in the ends of pushrods (3).

8. Use Tooling (A) to gradually tighten torx screws (1).

Note: To avoid distortion of rocker shaft assembly (2), tighten the torx screws in the center first. Work toward the outside of the rocker shaft assembly.

Tighten the torx screws to a torque of 35 N·m (26 lb ft).

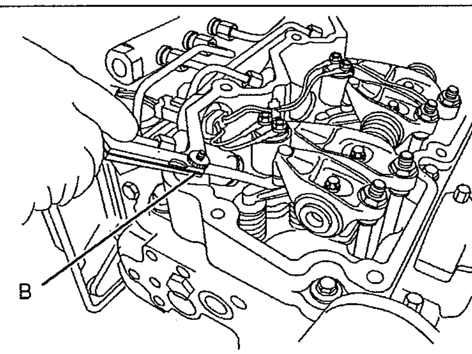

Illustration 214 g01259267

Typical example

9. Use Tooling (B) in order to check the valve lash. If necessary, adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust" for the correct procedure.

End By:

a. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933613

Cylinder Head - Remove

Removal Procedure

Start By:

a. Remove the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install".

b. Remove the fuel manifold. Refer to Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install".

c. Remove the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, "ECM Mounting Bracket- Remove and Install".

d. Remove the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

e. Remove the valve mechanism cover base. Refer to Disassembly and Assembly, "Valve Mechanism Cover Base - Remove and Install".

f. Remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. If the alternator bracket is mounted on the cylinder head, remove the alternator. Refer to Disassembly and Assembly, " Alternator - Remove".

2. If the fuel priming pump and the primary fuel filter are mounted on the cylinder head, remove the fuel priming pump and the primary fuel filter. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

3. Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

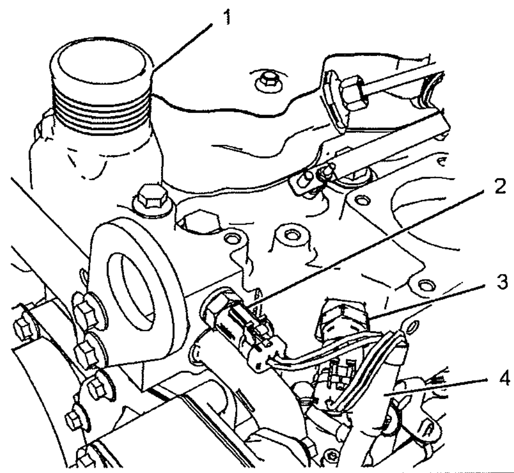

Illustration 215 g01245537

Typical example

4. Disconnect the upper radiator hose from water temperature regulator housing (1).

5. If necessary, remove the air hose from the inlet connection.

6. Follow Step 6.a and Step 6.b in order to disconnect harness assembly (4) from coolant temperature sensor (2).

   a. Slide the locking tab into the unlocked position.

   b. Disconnect harness assembly (4) from coolant temperature sensor (2).

7. If necessary, follow Step 7.a and Step 7.b in order to disconnect harness assembly (4) from boost pressure sensor (3).

   a. Slide the locking tab into the unlocked position.

   b. Disconnect harness assembly (4) from boost pressure sensor (3).

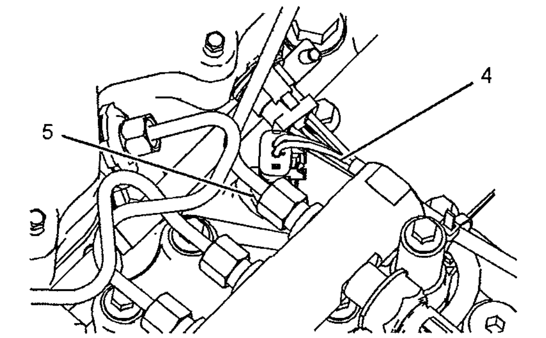

Illustration 216 g01249835

Typical example

8. Follow Step 8.a and Step 8.b in order to disconnect harness assembly (4) from inlet air temperature sensor (5).

a. Slide the locking tab into the unlocked position.

b. Disconnect harness assembly (4) from inlet air temperature sensor (5).

9. Remove all cable straps that secure harness assembly (4) to the cylinder head. The harness assembly should be positioned in order to avoid causing an obstruction during the removal of the cylinder head.

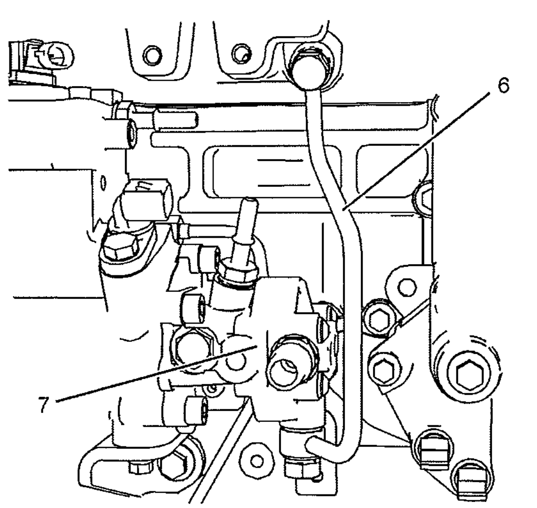

Illustration 217 g01249474

Typical example

10. Remove tube assembly (6) from the cylinder head and from transfer pump (7).

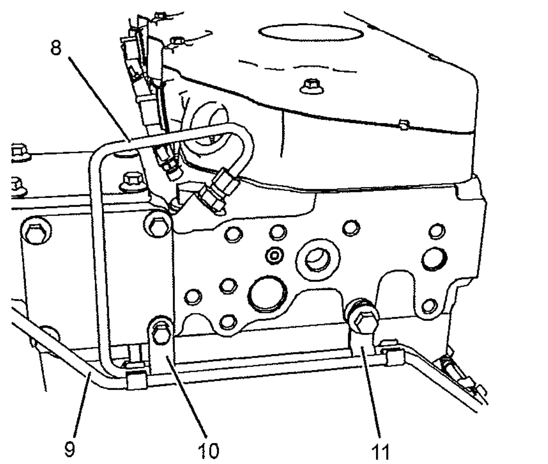

Illustration 218 g01249479

Typical example

11. If the engine is equipped with a wastegate solenoid, remove harness assembly (9) from tube assembly (8). Remove the bolts for tube clip (10) and tube clip (11). Remove tube assembly (8) from the wastegate solenoid and from the cylinder head.

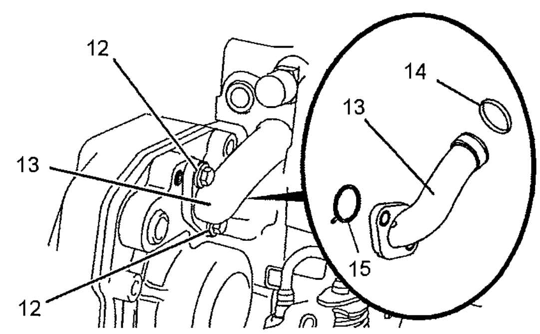

Illustration 219 g01476537

Typical example

12. Remove bolts (12). Note the position of any brackets that are secured by the bolts. Remove bypass tube (13) from the cylinder head. Remove O-ring seals (14) and (15) from the bypass tube.

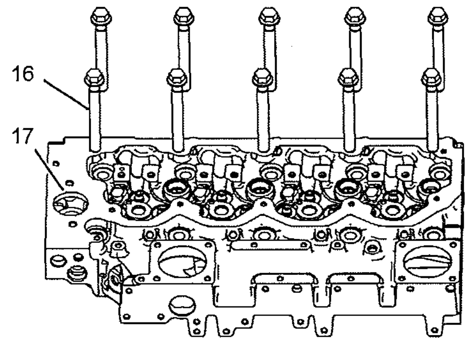

Illustration 220 g01245538

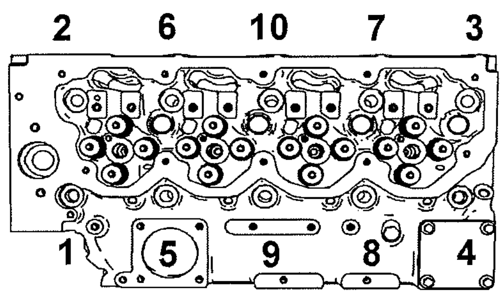

Illustration 221 g01250785

Sequence for loosening the bolts for the cylinder head

13. Gradually loosen bolts (16) in the reverse numerical order to the sequence that is shown in Illustration 221.

Note: Follow the correct sequence in order to help prevent distortion of the cylinder head.

14. Remove bolts (16) from cylinder head (17).

15. Attach a suitable lifting device to cylinder head (17). Support the weight of the cylinder head. The weight of the cylinder head is approximately 56 kg (124 lb).

16. Use the suitable lifting device to carefully lift cylinder head (17) off the cylinder block.

Note: Do not use a lever to separate the cylinder head from the cylinder block. Take care not to damage the machined surfaces of the cylinder head during the removal procedure.

NOTICE

Place the cylinder head on a surface that will not scratch the face of the cylinder head.

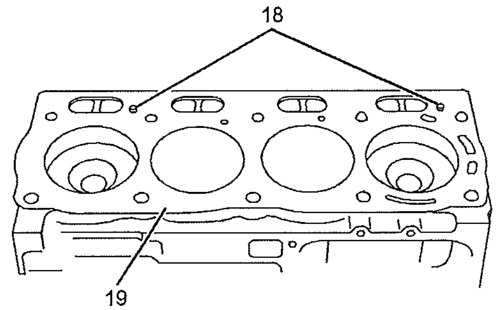

Illustration 222 g01763153

Typical example

17. Remove cylinder head gasket (19).

18. Note the position of dowels (18) in the cylinder block. Do not remove the dowels unless the dowels are damaged.

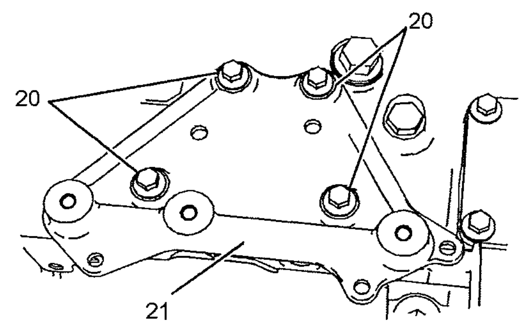

Illustration 223 g01763173

Typical example

19. If necessary, remove screws (20) and remove mounting bracket (21) from the cylinder head.

20. If necessary, remove the water temperature regulator from the cylinder head. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

21. If necessary, remove the electronic sensors from the cylinder head. Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Air Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Boost Pressure Sensor - Remove and Install".

i02933612

Cylinder Head - Install

Installation Procedure

Table 54

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Bolt M16 by 115mm	2
B	-	Straight Edge	1
C	21825607	Angle gauge	1
D	2180221	POWERPART Rubber Grease	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the gasket surfaces of the cylinder head and the cylinder block. Do not damage the gasket surfaces of the cylinder head or the cylinder block. Ensure that no debris enters the cylinder bores, the coolant passages, or the lubricant passages.

2. Inspect the gasket surface of the cylinder head for distortion. Refer to Specifications, "Cylinder Head" for more information. If the gasket surface of the cylinder head is distorted beyond maximum permitted limits, replace the cylinder head.

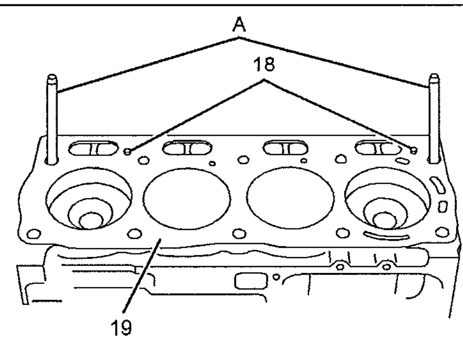

Illustration 224 g01763193

3. Inspect dowels (18) for damage. If necessary, replace the dowels in the cylinder block.

4. Install Tooling (A) to the cylinder block. Refer to Illustration 224.

5. Align cylinder head gasket (19) with Tooling (A) and with dowels (18). Install the cylinder head gasket onto the cylinder block.

6. Use a suitable lifting device to lift the cylinder head. The weight of the cylinder head is approximately 56 kg (124 lb).

7. Use Tooling (A) to align cylinder head (17) with the cylinder block. Install the cylinder head to the cylinder block.

Note: Ensure that the cylinder head is correctly positioned onto dowels (18).

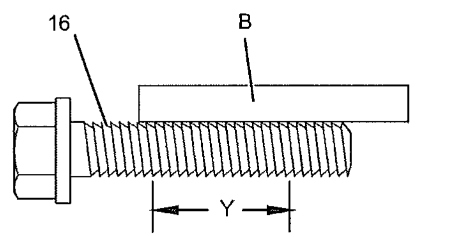

Illustration 225 g01250784

8. Clean bolts (16). Follow Step 8.a and Step 8.b for the procedure to inspect the bolts.

   a. Check the length of the bolts.

   b. Use Tooling (B) in order to check the threads of the bolts. Refer to Illustration 225. Replace any bolts that show visual reduction in the diameter of the thread over length (Y).

9. Lubricate the threads and the shoulder of bolts (16) with clean engine oil.

10. Remove Tooling (A).

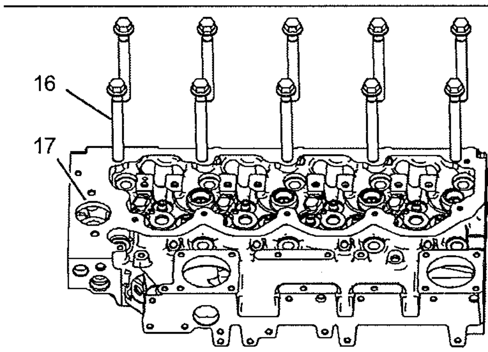

Illustration 226 g01245538

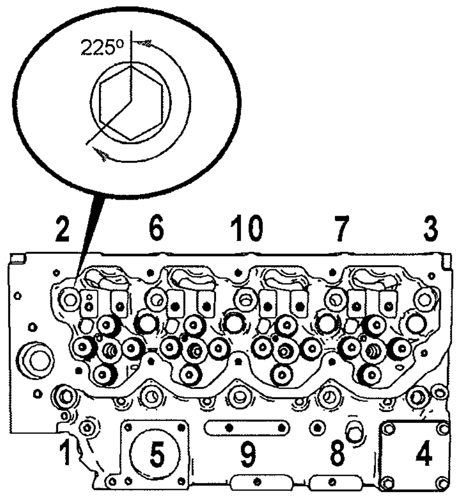

Illustration 227 g01476553

Sequence for tightening the bolts for the cylinder head

11. Install bolts (16) to cylinder head (17).

12. Tighten bolts (16) to a torque of 50 N·m (37 lb ft) in the sequence that is shown in Illustration 227.

13. Tighten bolts (16) to a torque of 100 N·m (74 lb ft) in the sequence that is shown in Illustration 227.

14. Use Tooling (C) to turn bolts (16) through an additional 225 degrees. Turn bolts (16) in the sequence that is shown in Illustration 227.

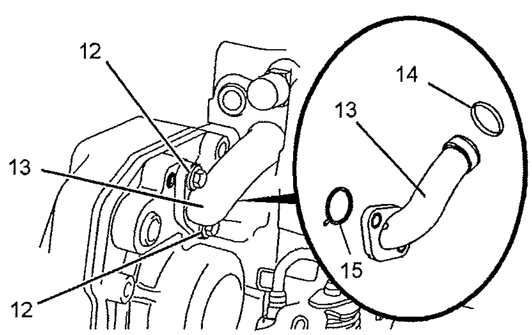

Illustration 228 g01476537

Typical example

15. Install new O-ring seal (14) and O-ring seal (15) to bypass tube (13). Use Tooling (D) in order to lubricate O-ring seal (14). Install the bypass tube to the cylinder head. Install bolts (12). Tighten the bolts to a torque of 22 N·m (16 lb ft).

Note: Ensure that any brackets that are secured by the bolts are installed in the correct position.

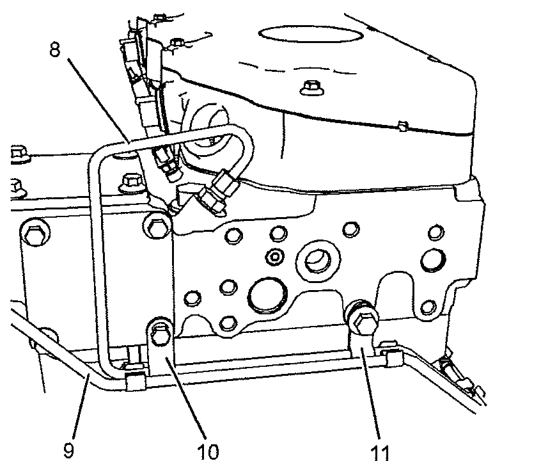

Illustration 229 g01249479

Typical example

16. If the engine is equipped with a wastegate solenoid, install tube assembly (9) to the wastegate solenoid and to the cylinder head. Install the bolts for tube clip (10) and tube clip (11). Tighten M8 bolts to a torque of 22 N·m (16 lb ft). Tighten M10 bolts to a torque of 44 N·m (32 lb ft). Secure harness assembly (9) to tube assembly (8).

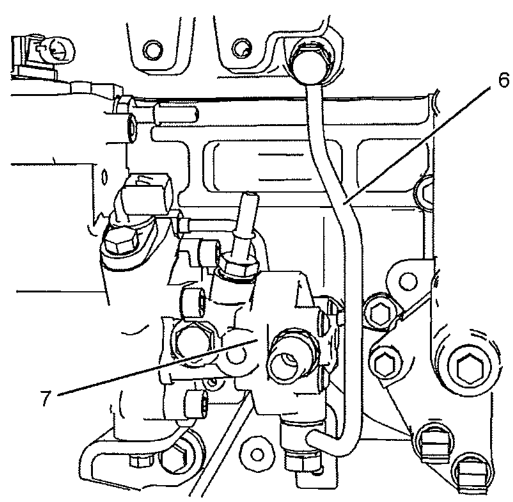

Illustration 230 g01249474

Typical example

17. Follow Step 17.a through Step 17.c in order to install tube assembly (6) for the fuel return.

a. Install the banjo bolts and new sealing washers to tube assembly (6).

b. Install tube assembly (6) to the cylinder head and to transfer pump (7).

c. Tighten the banjo bolts to a torque of 21 N·m (15 lb ft).

18. If necessary, install the electronic sensors to the cylinder head. Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Air Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Boost Pressure Sensor - Remove and Install".

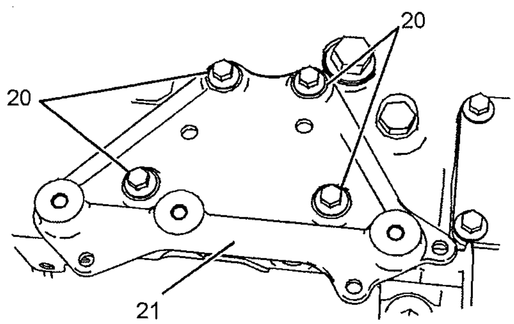

Illustration 231 g01763173

Typical example

19. If necessary, install mounting bracket (21) and install screws (20) to the cylinder head. Tighten the screws to a torque of 22 N·m (16 lb ft).

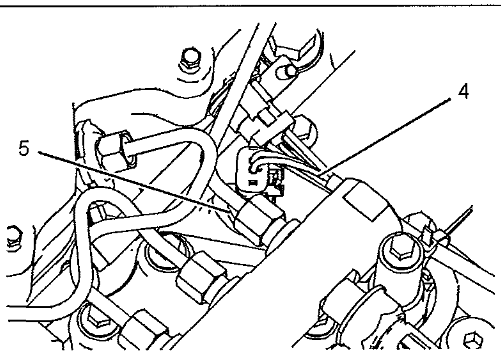

Illustration 232 g01249835

Typical example

20. Follow Step 20.a and Step 20.b in order to connect harness assembly (4) to inlet air temperature sensor (5).

a. Connect harness assembly (4) to inlet air temperature sensor (5).

b. Slide the locking tab into the locked position.

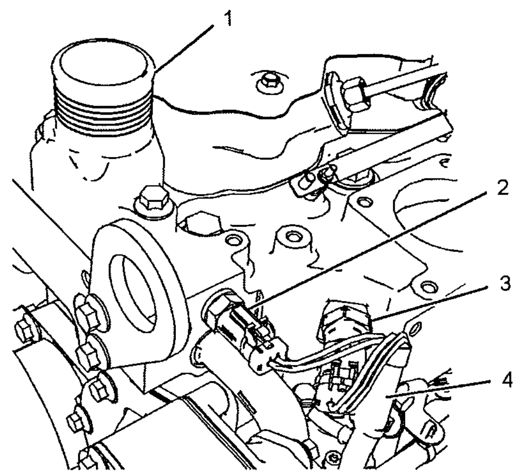

Illustration 233 g01245537

Typical example

21. If necessary, install water temperature regulator housing (1) to the cylinder head. Refer to Disassembly and Assembly, "Water Temperature Regulator Housing - Remove and Install".

22. Connect the upper radiator hose to water temperature regulator housing (1). Tighten the hose clip securely.

23. Follow Step 23.a and Step 23.b in order to connect harness assembly (4) to boost pressure sensor (3).

a. Connect harness assembly (4) to boost pressure sensor (3).

b. Slide the locking tab into the locked position.

24. Follow Step 24.a and Step 24.b in order to connect harness assembly (4) to coolant temperature sensor (2).

a. Connect harness assembly (4) to coolant temperature sensor (2).

b. Slide the locking tab into the locked position.

25. Use new cable straps in order to secure the harness assembly to the cylinder head. Ensure that the harness assembly is not strained.

Note: Ensure that the harness assembly is clear of other engine components.

26. Install the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, "ECM Mounting Bracket - Remove and Install".

27. Install the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

28. Install the valve mechanism cover base. Refer to Disassembly and Assembly, "Valve Mechanism Cover Base - Remove and Install".

29. Install the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

30. Install the fuel manifold. Refer to Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install".

31. Install the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install".

32. If necessary, install the fuel filter base and the secondary fuel filter. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install".

33. If necessary, install the fuel priming pump and the primary fuel filter. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

34. If the alternator bracket is mounted on the cylinder head, install the alternator. Refer to Disassembly and Assembly, " Alternator - Install".

35. If necessary, install the air hose to the inlet connection.

36. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.

37. If necessary, fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check".

i02933662

Lifter Group - Remove and Install

Removal Procedure

Table 55

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825576	Crankshaft Turning Tool	1
B	-	Telescopic Magnet	1

Start By:

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

b. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft in order to gain access to the lifters.

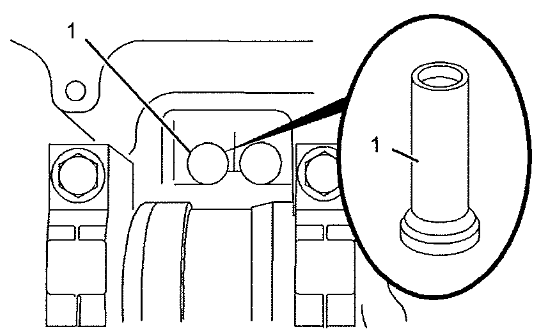

Illustration 234 g01476632

Typical example

2. Use Tooling (B) in order to remove lifters (1).

Note: Place a temporary identification mark on each lifter in order to identify the correct location.

3. Repeat Step 1 through Step 2 in order to remove the remaining lifters.

Installation Procedure

Table 56

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825576	Crankshaft Turning Tool	1
B	-	Telescopic Magnet	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

It is strongly recommended that all lifters should be replaced when a new camshaft is installed.

1. Clean the lifters. Follow Step 1.a through Step 1.c in order to inspect the lifters. Replace lifters that are worn or damaged.
    a. Inspect the seat of the pushrod in the lifter for visual wear or damage.
    b. Inspect the shank of the lifter for wear or damage. Refer to Specifications, "Lifter Group" for more information.
    c. Inspect the face of the lifter that runs on the camshaft for visual wear or damage.
2. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft. Rotate the crankshaft to access to the cylinder block in order to install lifters (1).
3. Lubricate lifters (1) with clean engine oil.

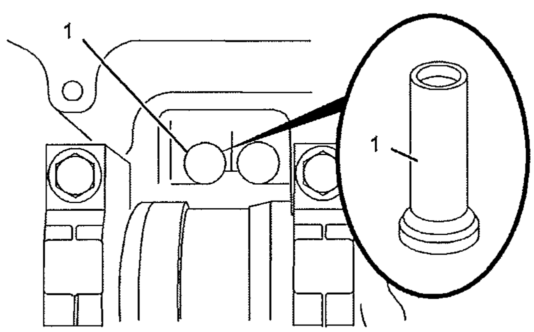

Illustration 235 g01476632

Typical example

4. Use Tooling (B) to install lifters (1) to the cylinder block. Ensure that used lifters are installed in the correct location.

Note: The lifters should be free to rotate.

5. Repeat Step 1 through Step 4 in order to install the remaining lifters.

End By:

a. Install the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

i02933593

Camshaft - Remove and Install

Removal Procedure

Start By:

a. Remove the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

b. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. The engine should be mounted on a suitable stand and placed in the inverted position.

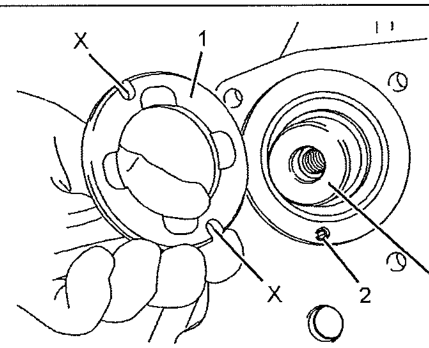

Illustration 236 g01266056

Typical example

2. Remove thrust washer (1) from the cylinder block. Do not remove dowel (2) from the cylinder block unless the dowel is damaged.

Note: The thrust washer can have one or two Slots (X).

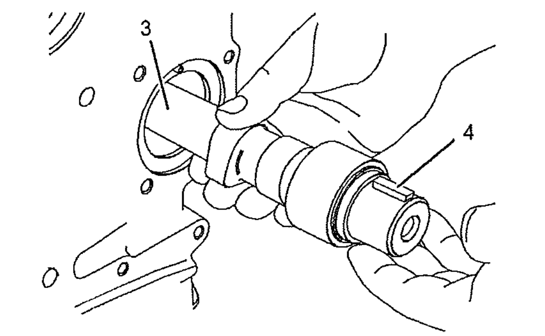

Illustration 237 g01266057

NOTICE
Do not damage the lobes or the bearings when the camshaft is removed or installed.

3. Carefully remove camshaft (3) from the cylinder block.

4. Do not remove key (4) from camshaft (3) unless the key is damaged.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the camshaft and the thrust washer. Inspect the camshaft and the thrust washer for wear and for damage. Refer to Specifications, "Camshaft" for more information. Replace any components that are worn or damaged.

2. Clean the camshaft bearing in the cylinder block. Inspect the camshaft bearing for wear and for damage. Refer to Specifications, "Camshaft Bearings" for more information. If necessary, replace the camshaft bearing. Refer to Disassembly and Assembly, "Camshaft Bearings - Remove and Install".

NOTICE
It is strongly recommended that all lifters should be replaced when a new camshaft is installed.

3. Inspect the lifters for wear and for damage. Refer to Specifications, "Lifter Group" for more information. Replace any worn lifters or any damaged lifters. Refer to Disassembly and Assembly, "Lifter Group - Remove and install".

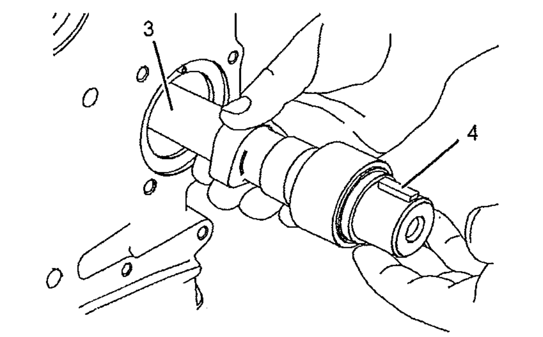

Illustration 238 g01266057

4. If necessary, install a new key (4) to camshaft (3).

5. Lubricate the bearing surfaces of camshaft (3) and lubricate the lobes of the camshaft with clean engine oil.

NOTICE
Do not damage the lobes or the bearings when the camshaft is removed or installed.

6. Carefully install camshaft (3) into the cylinder block.

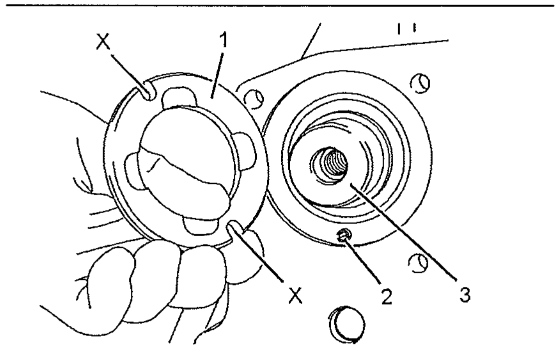

Illustration 239 g01266056

Typical example

7. Lubricate the thrust washer with clean engine oil. Align Slot (X) in thrust washer (1) with dowel (2) in the cylinder block. Install thrust washer (1) into the recess in the cylinder block.

Note: The thrust washer can have one or two slots.

End By:

a. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

b. Install the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install".

i02933595

Camshaft Gear - Remove and Install

Removal Procedure

Table 57

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

b. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

Note: Either Tooling (A) can be used. Use the tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

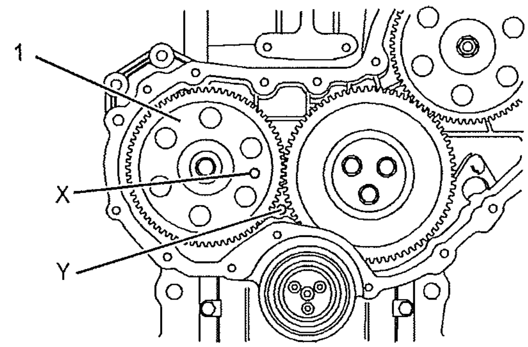

Illustration 240 g01476661
Typical example

2. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position.

3. Install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

Note: Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

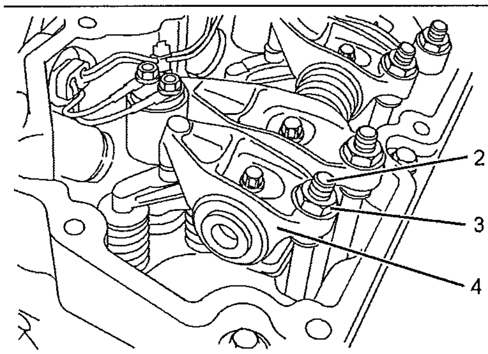

Illustration 241 g01476663
Typical example

4. Loosen nuts (3) on ALL rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

Note: Failure to ensure that all adjusters are fully unscrewed can result in contact between the valves and pistons.

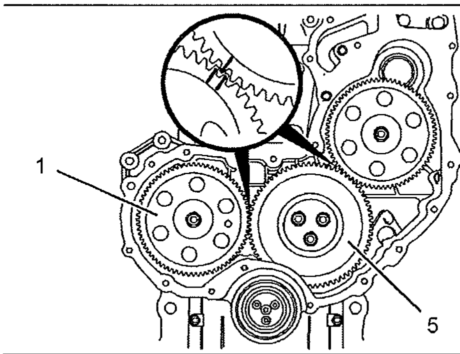

Illustration 242 g01476666

Alignment of timing marks

5. Mark gear (1) and gear (5) in order to show alignment. Refer to Illustration 242.

Note: Identification will ensure that the gears can be installed in the original alignment.

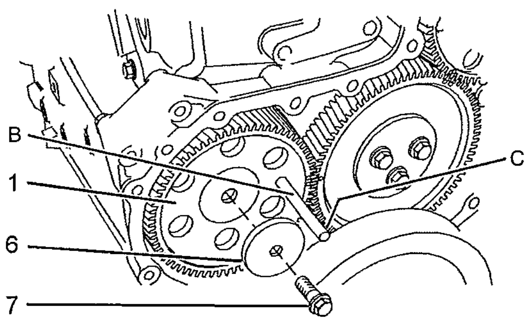

Illustration 243 g01476667

Typical example

6. Remove Tooling (B) and Tooling (C) (not Shown). Remove bolt (7) and washer (6) from camshaft gear (1).

7. Remove camshaft gear (1) from the camshaft.

Note: If the camshaft gear is a tight fit on the nose of the camshaft, use a prybar in order to remove the camshaft gear.

8. If necessary, remove the key from the nose of the camshaft.

Installation Procedure

Table 58

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610212	Camshaft Timing Pin	1
C	27610211	Crankshaft Timing Pin	1
D	21825617	Dial Indicator Group	1
	-	Finger Clock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

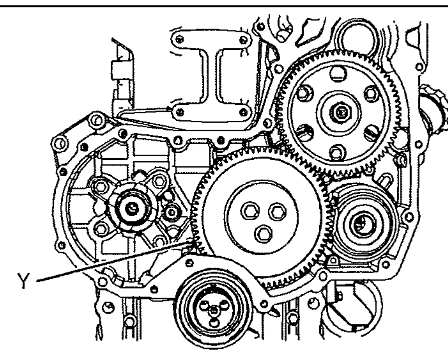

Illustration 244 g01478060

Typical example

2. Install Tooling (C) into Hole (Y) in the cylinder block. Use Tooling (C) in order to lock the crankshaft in the correct position.

3. Ensure that the camshaft gear and the key are clean and free from wear or damage.

4. If necessary, install the key into the nose of the camshaft.

Note: Ensure that the key is squarely seated.

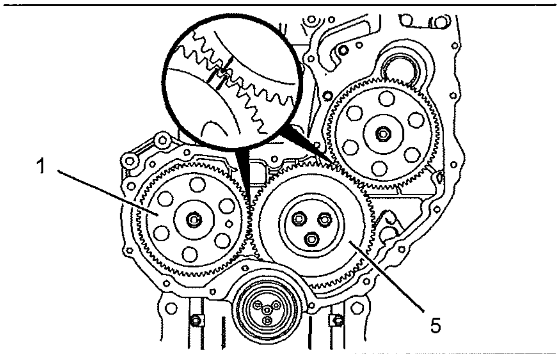

Illustration 245 g01476666

Alignment of timing marks

5. Align the keyway in camshaft gear (1) with the key in the camshaft. Install the camshaft gear onto the camshaft. Ensure that the timing marks on gear (1) and gear (5) are in alignment and that the mesh of the gears is correct. Refer to Illustration 245.

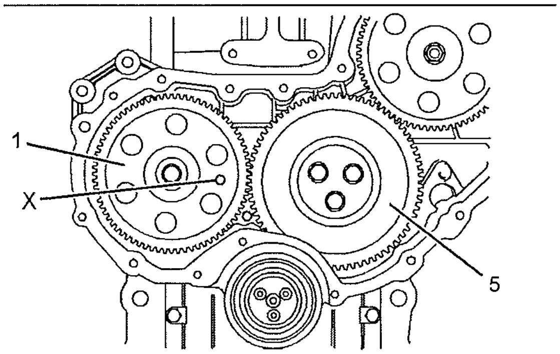

Illustration 246 g01478078

Typical example

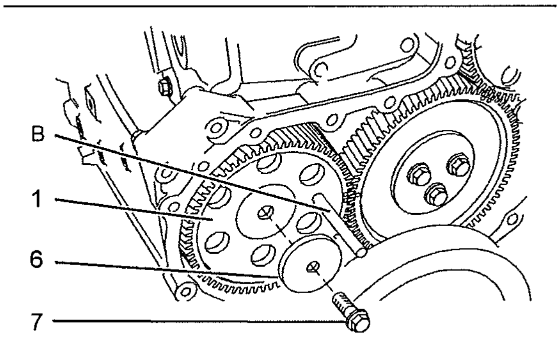

Illustration 247 g01794063

Typical example

6. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing.

7. Install washer (6) and bolt (7) to the camshaft gear.

8. Remove Tooling (B) and (C) (not shown).

9. Tighten bolt (7) to a torque of 95 N·m (70 lb ft).

10. Use Tooling (D) to check the backlash for gear (1) and gear (5). Ensure that the backlash for the gears is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

11. Use Tooling (D) to check the end play for camshaft gear (1). Ensure that the end play is within specified values. Refer to Specifications, "Camshaft" for further information.

12. Lubricate the teeth of the gears with clean engine oil.

13. Adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

End By:

a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

b. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933594

Camshaft Bearings - Remove and Install

Removal Procedure

Table 59

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610275	Bearing Puller	1

Start By:

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

b. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

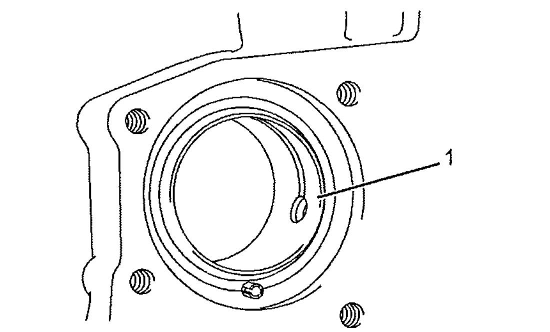

Illustration 248 g01270437

1. Inspect camshaft bearing (1). Refer to Specifications, "Camshaft Bearings" for more information.

2. If camshaft bearing (1) is worn or damaged use Tooling (A) in order to remove the camshaft bearing from the cylinder block.

Note: Remove the camshaft bearing from the front of the cylinder block.

Installation Procedure

Table 60

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	27610275	Bearing Puller	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the bearing housing in the cylinder block. Ensure that the oil holes in the bearing housing are free from debris.

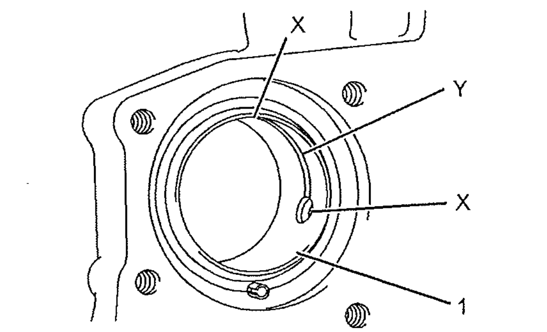

Illustration 249 g01266512

2. Lubricate the bearing housing in the cylinder block with clean engine oil.

3. Accurately align the two oil Holes (X) in camshaft bearing (1) with the two oil holes in the cylinder block.

Note: The Groove (Y) in the camshaft bearing must be to the top of the cylinder block.

4. Use Tooling (A) in order to install camshaft bearing (1) into the cylinder block. Install the camshaft bearing so that the front edge of the bearing is flush with the face of the recess in the cylinder block.

Note: Ensure that all oil holes are correctly aligned. If the oils are not correctly aligned, the camshaft bearing should be removed.

End By:

a. Install the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

i02933623

Engine Oil Pan - Remove and Install (Aluminum and Pressed Steel Oil Pans)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

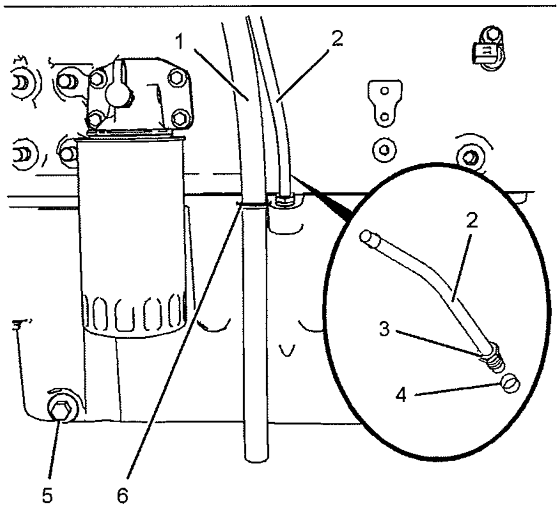

Illustration 250 g01478088

Typical example

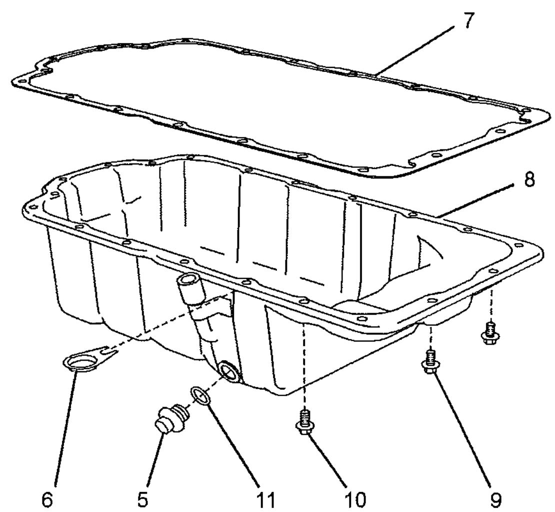

Illustration 251 g01797036

Typical example

1. Place a suitable container below the engine oil pan. Remove drain plug (5) and drain the engine lubricating oil. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

2. Remove O-ring seal (11) from drain plug (5).

3. Disconnect breather hose (1) from clip (6). Position the breather hose away from the engine oil pan.

4. If necessary, remove the assembly of the dipstick tube. Loosen nut (3) and remove tube assembly (2). Remove seal (4) from the tube assembly.

Note: Identify the position and orientation of the tube assembly.

5. Support the assembly of the engine oil pan. Mark the position of clip (6). Loosen bolts (9) and bolts (10). Remove the clip and remove the bolts.

6. Remove engine oil pan (8) and remove gasket (7) from the cylinder block.

Installation Procedure

Table 61

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Bolt M8 by 100 mm	4
B	21826038	POWERPART Silicon Rubber Sealant	1
C	21820117	POWERPART Threadlock and NutLock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the face of the cylinder block is clean and free from damage.

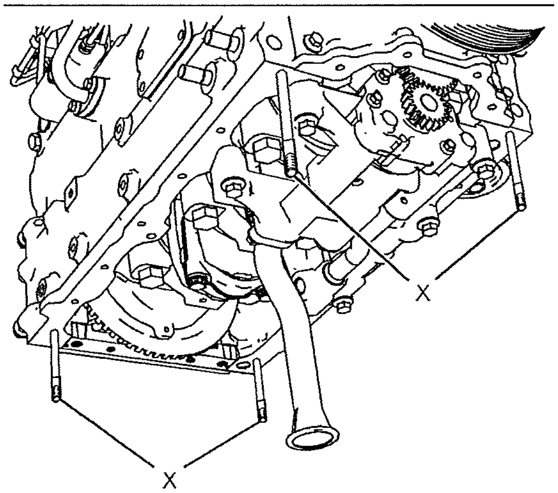

Illustration 252 g01251768

Typical example

2. Install Tooling (A) to Positions (X) in the cylinder block.

3. Ensure that the engine oil pan is clean and free from damage.

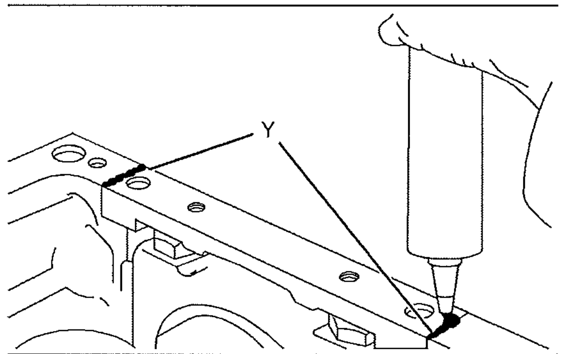

Illustration 253 g01251763

Typical example

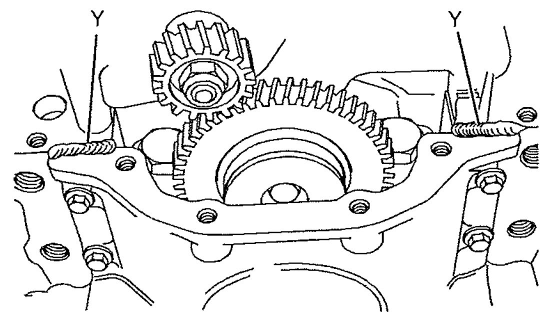

Illustration 254 g01803754

Typical example

4. Apply a bead of Tooling (B) to Positions (Y) on the cylinder block.

Note: If the bridge piece for the cylinder block has just been installed, the engine oil pan must be installed before Tooling (B) has cured.

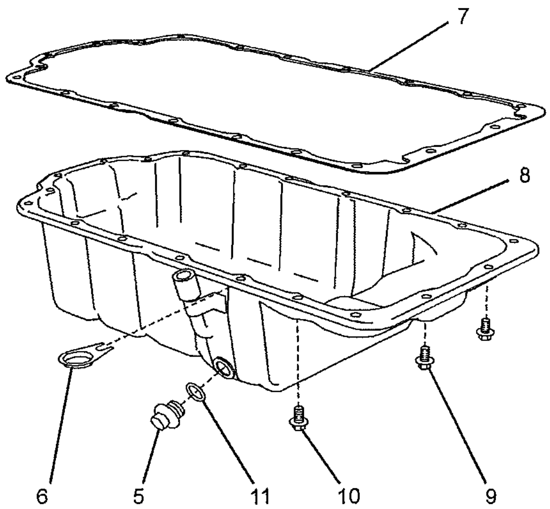

Illustration 255 g01797036

Typical example

5. Position a new gasket (7) onto engine oil pan (8).

6. Align the assembly of the engine oil pan with Tooling (A). Install the assembly of the engine oil pan to the cylinder block. Install clip (6) in the correct position.

7. Install bolts (10) finger tight.

8. Remove Tooling (A).

9. Apply Tooling (C) to bolts (9).

10. Install bolts (9) and the remaining bolts (10).

11. Tighten bolts (9) and bolts (10) to a torque of 22 N·m (16 lb ft). Refer to Specifications, "Engine Oil Pan" for the correct tightening sequence.

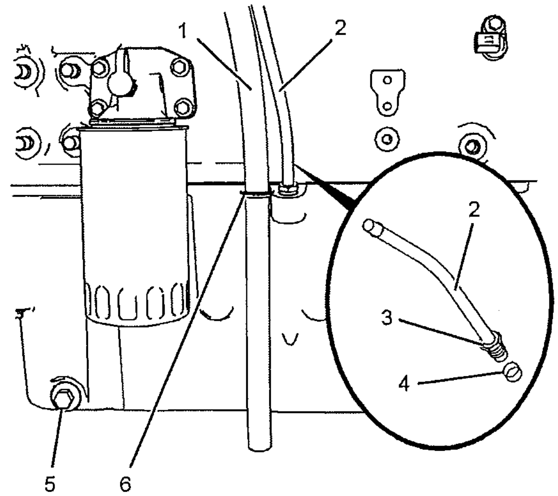

Illustration 256 g01478088

Typical example

12. Install a new O-ring seal to drain plug (5). Install the drain plug to the engine oil pan. Tighten the oil drain plug to a torque of 34 N·m (25 lb ft).

13. If necessary, follow Step 13.a through Step 13.c in order to install the assembly of the dipstick tube.

    a. Install a new seal (4) to tube assembly (2).

    b. Apply Tooling (C) to nut (3). Install the tube assembly to the engine oil pan.

Note: Ensure that the orientation of the tube assembly is correct.

    c. Tighten nut (3) to a torque of 18 N·m (13 lb ft). Install the dipstick.

14. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

i02933622

Engine Oil Pan - Remove and Install (Cast Iron Oil Pan)

Removal Procedure

Note: In order to remove a cast iron oil pan, the engine must be removed from the machine.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Ensure that the engine lubricating oil is drained. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

2. The engine should be mounted in a suitable stand and placed in the inverted position.

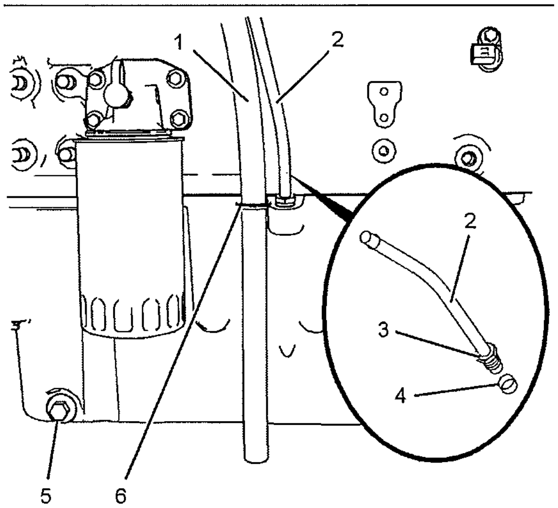

Illustration 257 g01478088

Typical example

3. Disconnect breather hose (1) from clip (6). Position the breather hose away from the engine oil pan.

Note: Identify the position and orientation of the tube assembly before removal.

4. Remove the assembly of the dipstick tube. Loosen nut (3) and remove tube assembly (2). Remove seal (4) from the tube assembly.

5. Mark the position of clip (6). Refer to Illustration 257. Loosen the bolt that secures the clip and remove the clip.

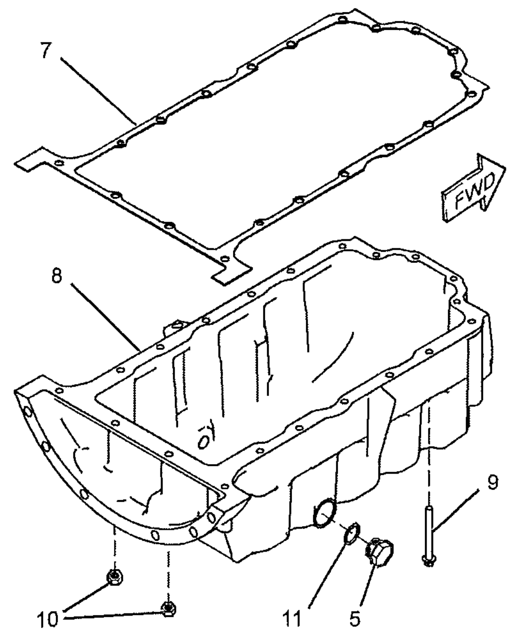

Illustration 258 g01251978

Typical example

6. Remove nuts (10) and bolts (9).

Note: The bolts are different lengths. Note the position of the different bolts.

7. Attach a suitable lifting device to engine oil pan (8). Support the weight of the engine oil pan. The engine oil pan weighs approximately 41 kg (90 lb).

8. Use the lifting device to remove engine oil pan (8) from the cylinder block.

9. Remove gasket (7) from the cylinder block.

10. If necessary, remove drain plug (5). Remove O-ring seal (11) from oil drain plug (5).

Installation Procedure

Table 62

Required Tools			
Tool	Part Number	Part Description	Qty
A	21826038	POWERPART Silicon Rubber Sealant	-
B	21820117	POWERPART Threadlock and NutLock	-
C	-	Straight Edge	1

Note: In order to install a cast iron oil pan, the engine must be removed from the machine.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the face of the cylinder block is clean and free from damage. Inspect the studs in the cylinder block for damage. If necessary, replace the studs.

2. Ensure that the engine oil pan is clean and free from damage.

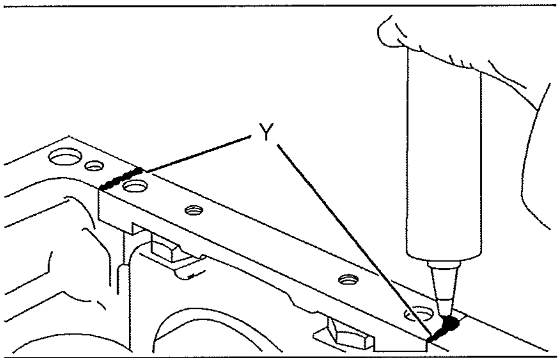

Illustration 259 g01251763
Typical example

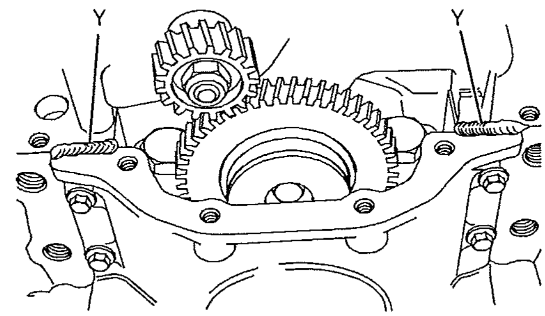

Illustration 260 g01803754
Typical example

3. Apply a bead of Tooling (A) to Positions (Y) on the cylinder block.

Note: If the bridge piece for the cylinder block has just been installed, the engine oil pan must be installed before Tooling (A) has cured.

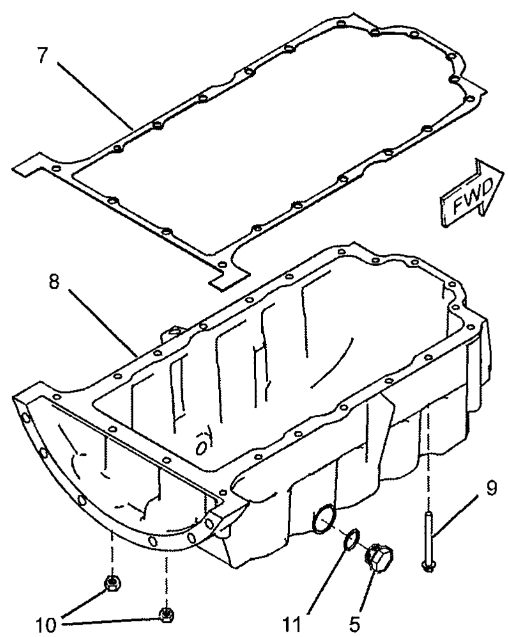

Illustration 261 g01251978
Typical example

4. Align a new gasket (7) with the studs in the cylinder block. Install the gasket to the cylinder block.

5. Attach a suitable lifting device to engine oil pan (8). The engine oil pan weighs approximately 41 kg (90 lb).

6. Use the lifting device to align engine oil pan (8) with the studs in the cylinder block. Install the engine oil pan to the cylinder block. Remove the lifting device from the engine oil pan.

7. Install bolts (9) and nuts (10) finger tight. Install clip (6).

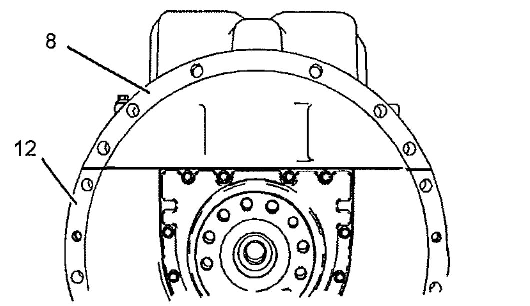

Illustration 262 g01251982

Typical example

8. Align the rear face of engine oil pan (8) to the rear face of cylinder block (12). Use Tooling (C) and a feeler gauge in order to check the alignment between the engine oil pan and the cylinder block. The maximum step that is allowed between the cylinder block and the sump is 0.1 mm (0.004 inch).

9. Tighten bolts (9) and nuts (10) to a torque of 22 N·m (16 lb ft). Refer to Specifications, "Engine Oil Pan" for the correct tightening sequence.

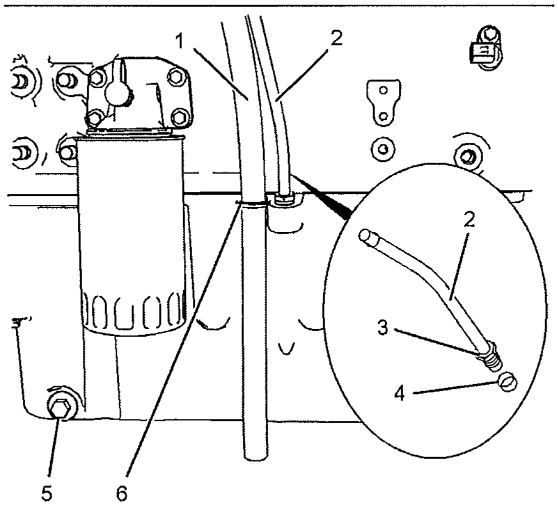

Illustration 263 g01251772

Typical example

10. If necessary, install a new O-ring seal to drain plug (5). Install drain plug (5) to engine oil pan (8). Tighten the drain plug to a torque of 34 N·m (25 lb ft).

11. Follow Step 11.a through Step11.c in order to install the assembly of the dipstick tube.

    a. Install a new seal (4) to tube assembly (2).

    b. Apply Tooling (B) to nut (3). Install the tube assembly to the engine oil pan.

Note: Ensure that the orientation of the tube assembly is correct.

    c. Tighten the nut to a torque of 18 N·m (13 lb ft). Install the dipstick .

12. Install breather hose (1) to clip (6).

Note: After the engine has been installed, ensure that the engine oil pan is filled with lubricating oil to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

i02933591

Balancer - Remove

Removal Procedure

Table 63

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825576	Crankshaft Turning Tool	1
B	27610211	Crankshaft Timing Pin	1
C	27610225	Timing Pin (Balancer)	1
D	-	Puller (Two Leg)	1

Start By:

a. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

b. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

Note: In order to remove the balancer, the engine must be removed from the machine. The engine should be mounted in a suitable stand and placed in the inverted position.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position.

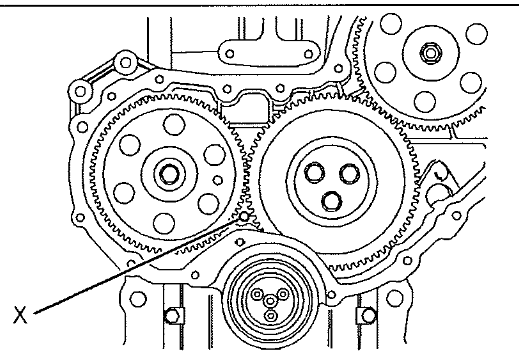

Illustration 264 g01259627

Typical example

2. Install Tooling (B) through Hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

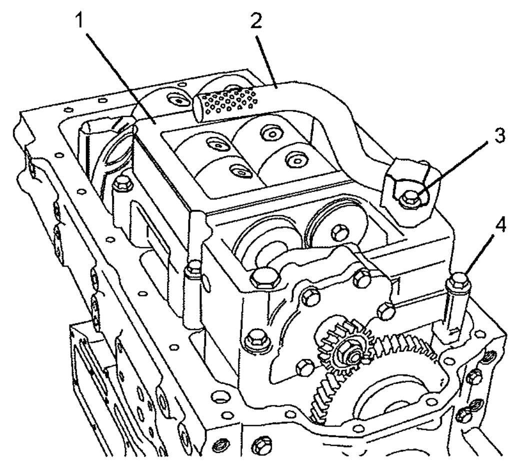

Illustration 265 g01259635

Typical example

3. Remove bolts (3) and suction pipe (2).

4. Remove the gasket from the suction pipe.

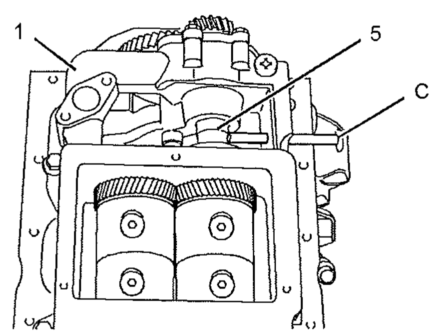

Illustration 266 g01252310

Typical example

5. Install Tooling (C) into balancer (1). Ensure that Tooling (C) is engaged into the hole in drive shaft (5).

6. Attach a suitable lifting device to balancer (1). Support the weight of the balancer. The balancer weighs approximately 23 kg (51 lb).

7. Remove bolts (4). Use the lifting device to remove the balancer.

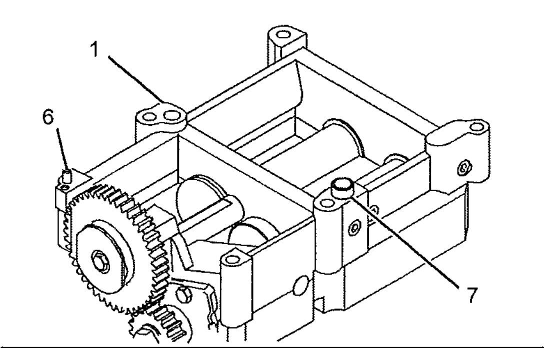

Illustration 267 g01259636

8. Do not remove dowel (6) and dowel (7) unless the dowels are damaged.

Note: The balancer unit is not a serviceable item. The engine oil pump and the engine oil relief valve are the only serviceable parts of the balancer.

Disassembly Procedure

1. Remove the engine oil relief valve. Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install".

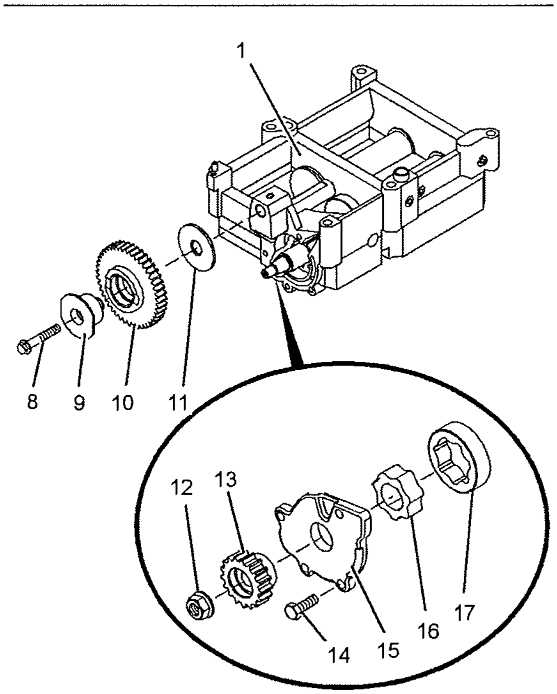

Illustration 268 g01478152

Typical example

2. Remove bolt (8) and hub (9). Remove idler gear (10) and thrust washer (11).

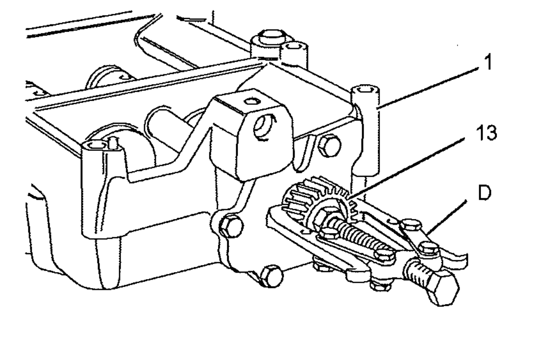

Illustration 269 g01259631

Typical example

3. Remove nut (12). Use Tooling (D) in order to remove gear (13) from the shaft of the oil pump.

Note: Do not use a timing pin to lock the balancer in order to loosen nut (12).

4. Remove bolts (14) and remove front cover (15).

5. Remove outer rotor (17) and remove inner rotor (16).

Note: Mark the direction of rotation of the rotors.

i02933590

Balancer - Install

Assembly Procedure

Table 64

Required Tools			
Tool	Part Number	Part Description	Qty
E	21820117	POWERPART Threadlock and Nutlock	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components of the engine oil pump are clean and free from wear or damage.

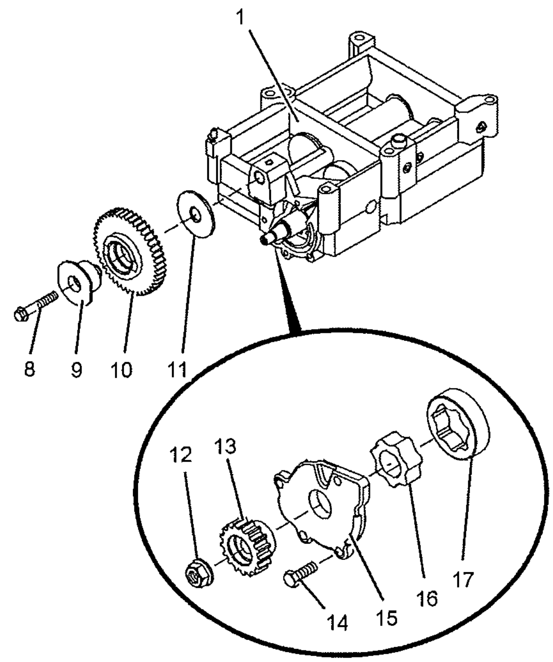

Illustration 270 g01478152

Typical example

2. Install inner rotor (16) and install outer rotor (17). Used rotors should be installed in the original direction of rotation. Check the clearance between the outer rotor and the body of the oil pump. Check the clearance between the inner rotor and the outer rotor. Check the end play of the rotor assembly. Refer to Specifications, "Engine Oil Pump" for more information.

3. Lubricate the assembly of the oil pump with clean engine oil. Install front cover (15). Install bolts (14). Tighten the bolts to a torque of 26 N·m (19 lb ft).

4. Ensure that the shaft of the oil pump is clean and dry. Position gear (13) onto the shaft. Install nut (12). Tighten the nut to a torque of 95 N·m (70 lb ft).

Note: Do not use a timing pin to lock the balancer in order to tighten nut (12).

5. Lubricate hub (9), thrust washer (11) and the bush of idler gear (10) with clean engine oil. Install hub (9) and thrust washer (11) to idler gear (10).

Note: Ensure the correct orientation of the idler gear.

6. Install the assembly of the idler gear to balancer (1).

7. Ensure that the threads of bolt (8) are clean and dry. Apply Tooling (E) to the threads of the bolt. Install bolt (8). Tighten the bolt to a torque of 26 N·m (19 lb ft).

8. Check the end play of idler gear (10). Refer to Specifications, "Engine Oil Pump".

9. Install the engine oil relief valve . Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install" for further information.

Installation Procedure

Table 65

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610211	Crankshaft Timing Pin	1
C	27610225	Timing Pin (Balancer)	1
F	21825617	Dial Indicator Group	1
	-	Finger Clock	1
G	-	Guide Studs (M10 by 75 mm)	1

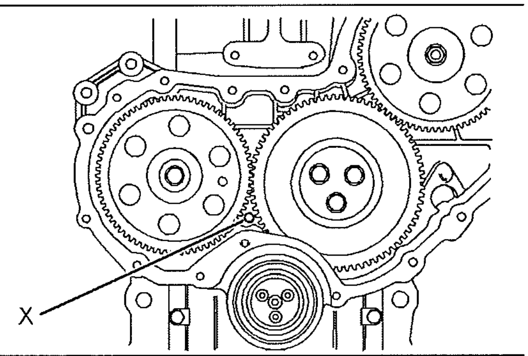

Illustration 271 g01259627

1. Ensure that No. 1 piston is at the top center position and that Tooling (B) is installed to Position (X) in the front housing.

2. Clean the faces of the cylinder block.

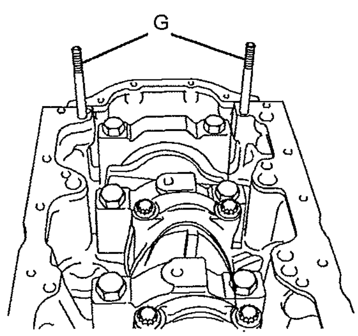

Illustration 272 g01252312

3. Install Tooling (G) to the cylinder block.

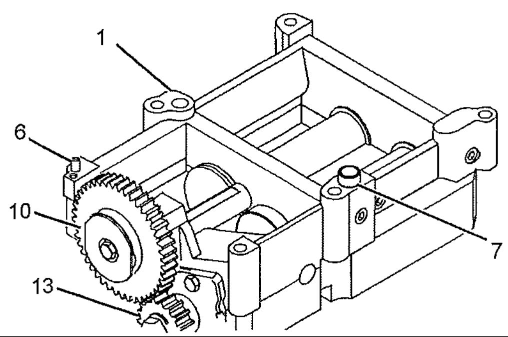

Illustration 273 g01260306

4. Ensure that dowel (6) and dowel (7) are seated in the housing of balancer (1).

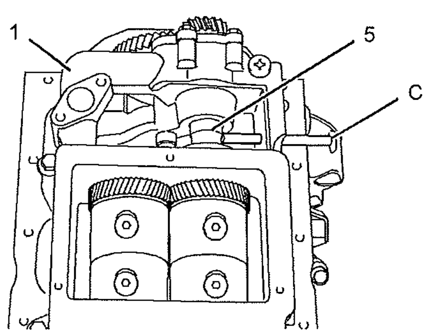

Illustration 274 g01252310

5. Install Tooling (C) to balancer (1). Ensure that Tooling (C) is engaged into shaft (5).

6. Attach a suitable lifting device to the balancer. The balancer weighs approximately 23 kg (51 lb).

7. Use the lifting device to align balancer (1) with Tooling (G). Install the balancer to the cylinder block. Ensure that dowels (6) and (7) are aligned with the holes in the cylinder block. Ensure that gear (10) and the crankshaft gear mesh. Remove the lifting device.

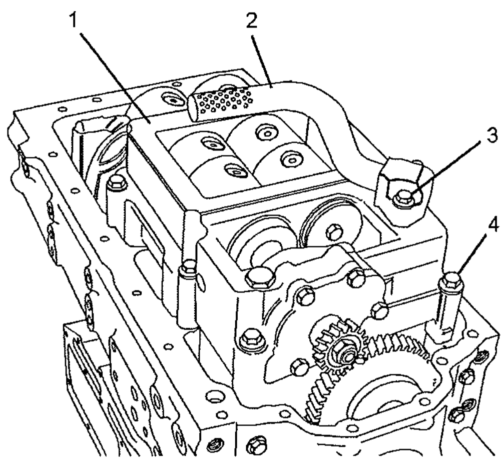

Illustration 275 g01259635

8. Install bolts (4) to balancer (1) finger tight.

9. Remove Tooling (G) and install remaining bolts (4). Tighten the bolts to a torque of 54 N·m (40 lb ft).

10. Remove Tooling (B) and Tooling (C).

11. Install suction pipe (2) and a new gasket to balancer (1).

12. Install bolts (3). Tighten the bolts to a torque to 22 N·m (16 lb ft).

13. Use Tooling (F) in order to check the backlash between gears (10) and (13). Refer to Illustration 273. Refer to Specifications, "Engine Oil Pump".

14. Use Tooling (F) in order to check the backlash between gear (10) and the crankshaft gear. Refer to Specifications, "Gear Group - Front" for further information.

End By:

a. Install the engine oil pan. Refer to Disassembly and Assembly , "Engine Oil Pan - Remove and Install".

b. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

i02933663

Piston Cooling Jets - Remove and Install

Removal Procedure

Table 66

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft in order to gain access to the appropriate piston cooling jet.

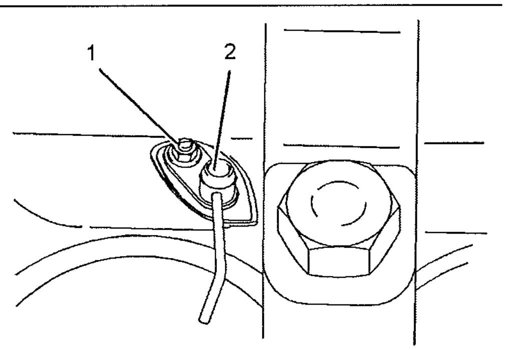

Illustration 276 g01265615

Typical example

2. Remove bolt (1) and piston cooling jet (2) from the cylinder block.

3. Repeat Step 1 and Step 2 for the remaining piston cooling jets.

Installation Procedure

Table 67

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

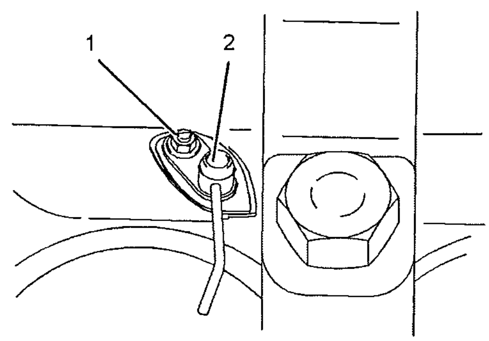

Illustration 277 g01265615

1. Clean the piston cooling jets and inspect the piston cooling jets for damage. Ensure that the valve is free to move within each piston cooling jet. Replace any damaged piston cooling jets.

2. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft in order to access the mounting flange for the piston cooling jet.

3. Position piston cooling jet (2) in the cylinder block. Install bolt (1). Tighten the bolt to a torque of 9 N·m (80 lb in).

4. Repeat Step 2 and Step 3 for the remaining piston cooling jets.

5. If the cylinder head has been removed, it is possible to check the alignment of the piston cooling jets. Refer to Specifications, "Piston Cooling Jet Alignment" for more information.

Note: It is not possible to check the alignment of the piston cooling jets with the cylinder head in position.

End By:

a. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

i02933667

Pistons and Connecting Rods - Remove

Removal Procedure

Table 68

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610274	Ridge Reamer	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. Remove the cylinder head. Refer to Disassembly and Assembly , "Cylinder Head - Remove".

b. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

c. Remove the piston cooling jets. Refer to Disassembly and Assembly , "Piston Cooling Jets - Remove and Install".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Use Tooling (A) to rotate the crankshaft until the crank pin is at the bottom center position.

2. Use Tooling (B) to remove the carbon ridge from the top inside surface of the cylinder bore.

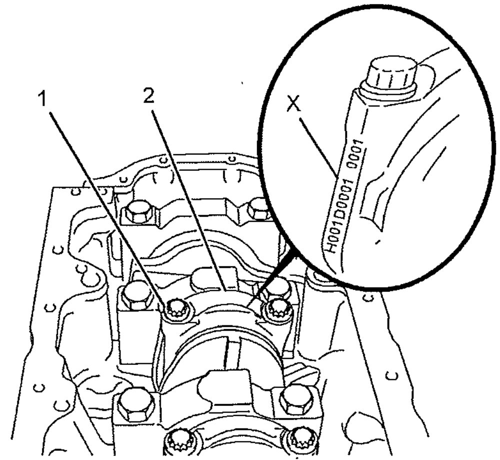

Illustration 278 g01479383

3. The connecting rod and the connecting rod cap should have an etched Number (X) on the side. The number on the connecting rod and the connecting rod cap must match. Ensure that the connecting rod and connecting rod cap (2) are marked for the correct location. If necessary, make a temporary mark on the connecting rod and the connecting rod cap in order to identify the cylinder number.

Note: Do not stamp the connecting rod assembly. Stamping or punching the connecting rod assembly could cause the connecting rod to fracture.

4. Remove bolts (1) and remove connecting rod cap (2) from the connecting rod.

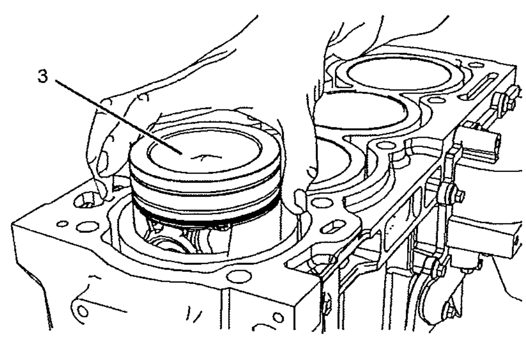

Illustration 279 g01479386
Typical example

5. Carefully push piston (3) and the connecting rod assembly out of the cylinder bore. Lift the piston out of the top of the cylinder block.

Note: Do not push on the fracture split surfaces of the connecting rod as damage may result.

6. Temporarily install connecting rod cap (2) and bolts (1) to the connecting rod when the assembly is out of the engine. Tighten bolts (1) to a torque of 20 N·m (14 lb ft).

Note: Fracture split connecting rods should not be left without the connecting rod caps installed. Ensure that the etched number on connecting rod cap matches the etched number on connecting rod. Ensure the correct orientation of the connecting rod cap.

7. Repeat Step 1 through Step 5 for the remaining pistons and connecting rods.

i02933665

Pistons and Connecting Rods - Disassemble

Disassembly Procedure

Table 69

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Circlip Pliers	1
B	-	Piston Ring Expander	1

Start By:

a. Remove the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Make a temporary mark on the components of the piston and connecting rod assembly. This will ensure that the components of each piston and connecting rod assembly can be reinstalled in the original cylinder. Mark the underside of the piston on the front pin boss. Do not interchange components.

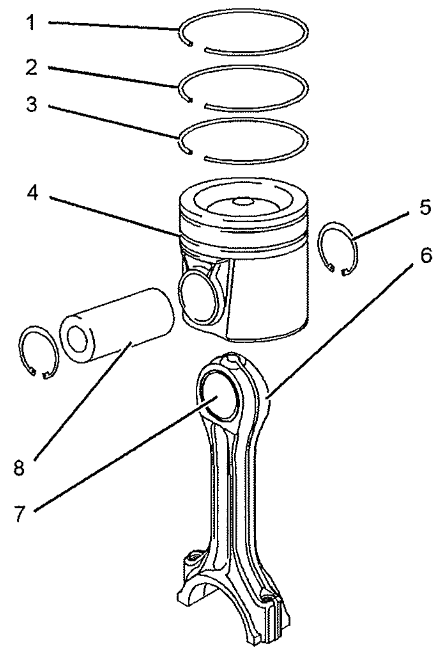

Illustration 280 g01244067

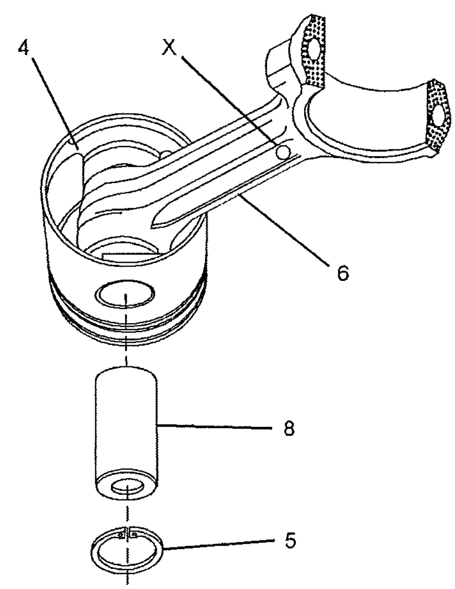

Illustration 281 g01253091

Typical example

2. Place the piston and connecting rod assembly on a suitable surface with the connecting rod upward. Use Tooling (A) in order to remove circlips (5).

Note: Forged Marks (X) identify the front of the connecting rod assembly. The forged marks should be used for the purposes of orientation.

3. Remove piston pin (8) and connecting rod (6) from piston (4).

Note: If the piston pin cannot be removed by hand, heat the piston to a temperature of 45 ± 5 °C (113 ± 9 °F). Do not use a torch to heat the piston. Note the orientation of the connecting rod and the piston.

4. Place the piston on a suitable surface with the crown upward. Use Tooling (B) in order to remove compression rings (1) and (2), and oil control ring (3) from piston (4).

Note: Identify the position and orientation of compression rings (1) and (2), and oil control ring (3).

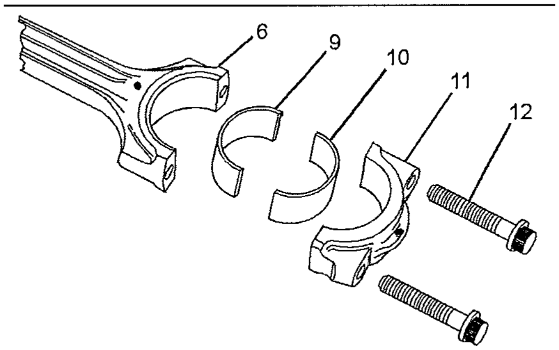

Illustration 282 g01244068

5. Remove bolts (12) and connecting rod cap (11) from connecting rod (6). Discard the bolts.

Note: Fracture split connecting rods should not be left without the connecting rod caps installed. After the disassembly procedure for the piston and connecting rod is completed, carry out the assembly procedure and the installation procedure as soon as possible. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Assemble" and Disassembly and Assembly, "Piston and Connecting Rods - Install".

6. Remove the lower half of connecting rod bearing (10) from connecting rod cap (11). Remove the upper half of connecting rod bearing (9) from connecting rod (6). Keep the connecting rod bearings together.

NOTICE
Removal of the piston pin bushing in the connecting rod must be carried out by personnel with the correct training. Also special machinery is required. For more information refer to your authorized Perkins distributor.

7. Inspect the connecting rod for wear or damage. If necessary, replace connecting rod (6) or replace bush (7) for the piston pin.

Note: If the connecting rod or the bush for the piston pin are replaced, first identify the height grade of the connecting rod. Refer to Specifications, "Connecting Rods".

8. Repeat Step 1 through Step 7 in order to disassemble the remaining pistons and connecting rods.

i02933664

Pistons and Connecting Rods - Assemble

Assembly Procedure

Table 70

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Circlip Pliers	1
B	-	Piston Ring Expander	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.

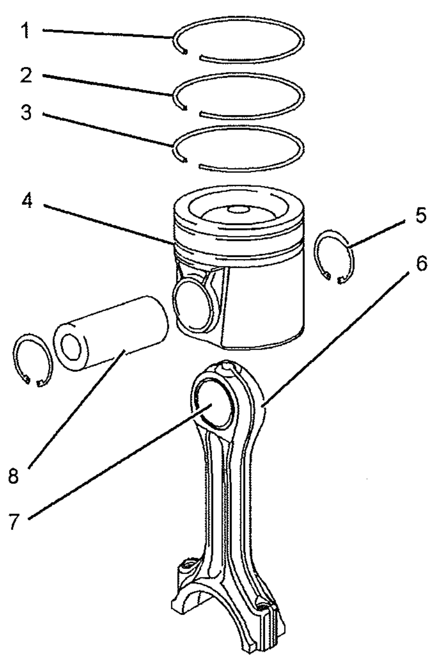

Illustration 283 g01244067

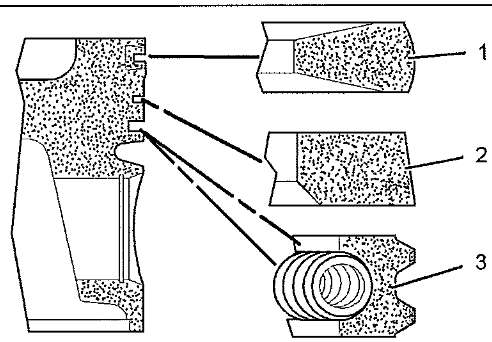

Illustration 284 g01155119

2. If the original piston is assembled, follow Step 2.a through Step 2.e in order to install the piston rings.

   a. Position the spring for oil control ring (3) into the oil ring groove in piston (4). The central wire must be located inside the end of the spring.

   b. Use Tooling (B) to install oil control ring (3) over the spring.

Note: Ensure that the central wire is 180 degrees from the ring gap.

   c. Use Tooling (B) to install intermediate compression ring (2) into the second groove in piston (4). The word "TOP" must be upward. The chamfer on the inner face must be downward.

   d. Use Tooling (B) to install top compression ring (1) into the top groove in piston (4). The word "TOP" must be upward.

   e. Position the piston ring gaps at 120 degrees away from each other.

Note: A new piston assembly is supplied with new piston rings.

NOTICE
Removal of the piston pin bushing in the connecting rod must be carried out by personnel with the correct training. Also special machinery is required. For more information refer to your authorized Perkins distributor.

3. If the connecting rod assembly or the bush for the piston pin have been replaced, ensure that the height grade of the connecting rod is correct. Refer to Specifications, "Connecting Rods" for further information.

4. Lubricate bush (7) and lubricate the bore for the piston pin in piston (4) with clean engine oil.

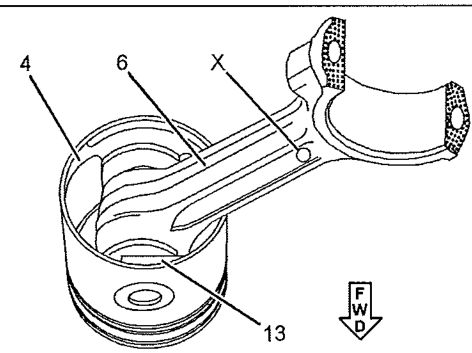

Illustration 285 g01244172

5. Place the piston on a suitable surface with the crown downward. Install connecting rod (6) and piston pin (8) to piston (4). Ensure that square boss (13) on the piston, and forged Mark (X) on the connecting rod are in the correct position. See illustration 285.

Note: If the piston pin cannot be installed by hand, heat the piston to a temperature of 45° ± 5°C (113° ± 9°F).

6. Use Tooling (A) in order to install circlips (5) to the piston pin bore in piston (4).

Note: Ensure that the circlips are seated in the grooves in the piston.

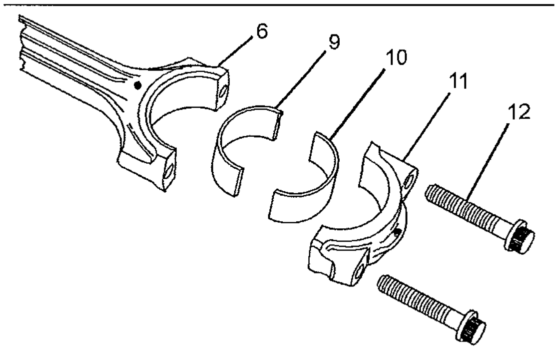

Illustration 286 g01244068

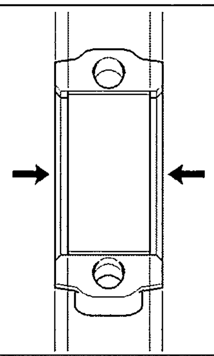

Illustration 287 g01001160

Aligning the connecting rod bearing in the center of the connecting rod

7. Install the upper half of connecting rod bearing (9) to connecting rod (6). Ensure that the connecting rod bearing is centralized in the connecting rod. Refer to Illustration 287.

Note: New connecting rod bearings are supplied with an alignment tool. If new connecting rod bearings are installed, use the tool to align the connecting rod bearing in the connecting rod.

8. Install the lower half of connecting rod bearing (10) to connecting rod cap (11). Ensure that the connecting rod bearing is centralized in the connecting rod cap. Refer to Illustration 287.

Note: New connecting rod bearings are supplied with an alignment tool. If new connecting rod bearings are installed, use the tool to align the connecting rod bearing in the connecting rod cap.

9. Repeat Step 2 through Step 8 for the remaining piston and connecting rod assemblies.

Note: Fracture split connecting rods should not be left without the connecting rod caps installed. After the assembly procedure for the piston and connecting rod is completed, carry out the installation procedure as soon as possible.

End By:

a. Install the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Install".

i02933666

Pistons and Connecting Rods - Install

Installation Procedure

Table 71

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	21825491	Piston Ring Compressor	1
C	21825607	Angle gauge	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Discard all used connecting rod bolts.

1. If the connecting rod caps were temporarily installed, remove the connecting rod caps. If necessary, thoroughly clean all of the components.

2. Apply clean engine oil to the cylinder bore, to the piston rings, to the outer surface of the piston and to the connecting rod bearings.

Note: Install the connecting rod bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil to the connecting rod bearings during final assembly.

3. Use Tooling (A) to rotate the crankshaft until the crankshaft pin is at the bottom center position. Lubricate the crankshaft pin with clean engine oil.

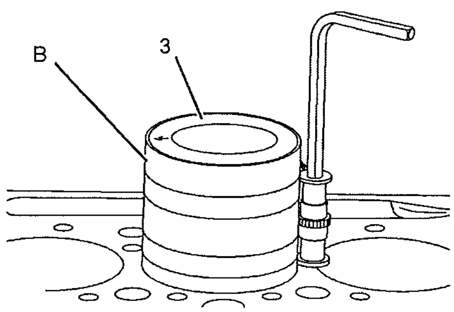

Illustration 288 g01253096

Typical example

4. Ensure that the gaps for the piston rings are at 120 degrees away from each other. Install Tooling (B) onto piston (3).

Note: Ensure that Tooling (B) is installed correctly and that the piston can easily slide from the tool. Ensure that the piston and the connecting rod assembly are installed in the correct cylinder. The arrow on the top of the piston must be toward the front of the engine.

5. Carefully push the piston and the connecting rod assembly into the cylinder bore and onto the crankshaft pin.

Note: Do not damage the finished surface of the crankshaft pin.

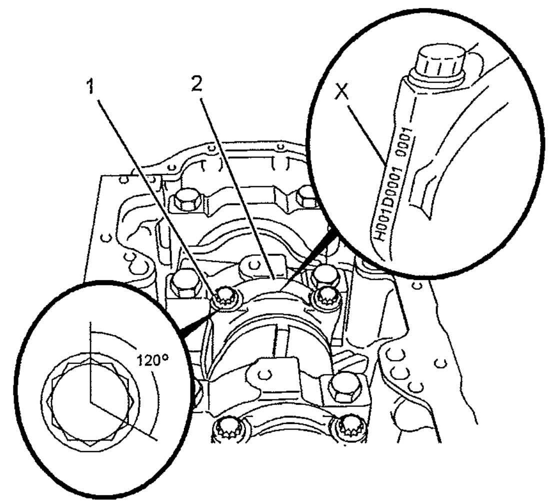

Illustration 289 g01479452

Typical example

6. Install connecting rod cap (2) onto the connecting rod.

Note: Ensure that etched Number (X) on the connecting rod cap matches the etched number on the connecting rod. Ensure the correct orientation of connecting rod cap (2).

7. Install new bolts (1) to the connecting rod. Tighten the bolts evenly to a torque of 18 N·m (13 lb ft).

8. Tighten the bolts evenly to a torque of 70 N·m (52 lb ft).

9. Use Tooling (B) to turn the bolts through an additional 120 degrees.

10. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

11. Repeat Step 2 through Step 10 in order to install the remaining pistons and connecting rods.

Note: If all pistons and connecting rods require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. **Ensure that both pairs of the pistons and connecting rods are installed before changing from one pair of cylinders to another pair of cylinders.**

12. Check the height of the pistons above the top face of the cylinder block. Refer to Systems Operation, Testing and Adjusting, "Piston Height - Inspect" for the correct procedure.

End By:

a. Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

c. Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

i02933597

Connecting Rod Bearings - Remove (Connecting rods in position)

Removal Procedure

Table 72

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Discard all used connecting rod bolts.

Note: If all connecting rod bearings require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. **Ensure that both pairs of the connecting rod bearings are installed before changing from one pair of cylinders to another pair of cylinders.**Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install".

1. Use Tooling (A) to rotate the crankshaft until the crank pin is at the bottom center position.

If necessary, remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

Note: Removal of the glow plugs aids removal of the connecting rod bearings. It is not essential.

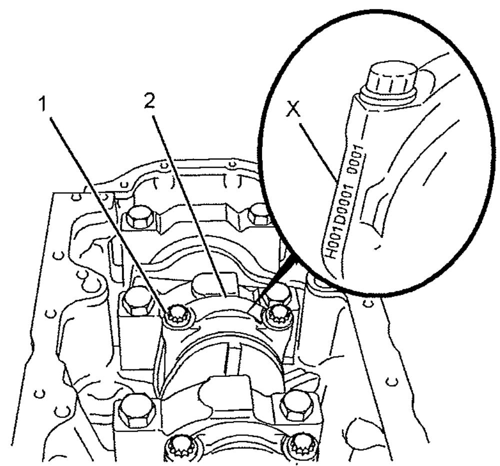

Illustration 290 g01479383

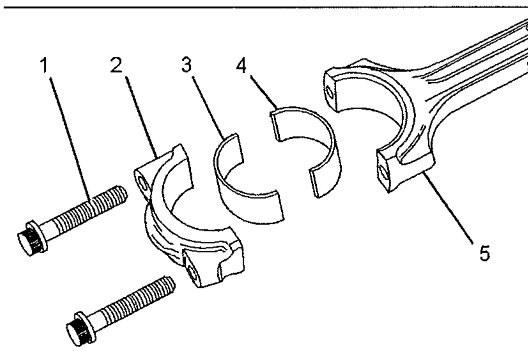

Illustration 291 g01253101

2. The connecting rod and the connecting rod cap should have an etched Number (X) on the side. The number on the connecting rod and the connecting rod cap must match. If necessary, make a temporary mark on connecting rod (5) and connecting rod cap (2) in order to identify the cylinder number.

Note: Do not punch identification marks onto fracture split connecting rods. Do not stamp identification marks onto fracture split connecting rods.

3. Remove bolts (1) and connecting rod cap (2) from connecting rod (5). Discard the bolts.

4. Remove the lower half of connecting rod bearing (3) from connecting rod cap (2). Keep the connecting rod bearing and the connecting rod cap together.

5. Carefully push the piston and connecting rod assembly into the cylinder bore until connecting rod (5) is clear of the crankshaft. Remove the upper half of connecting rod bearing (4) from connecting rod (5). Keep the bearings together.

Note: Do not push on the fracture split surfaces of the connecting rod as damage may result. Do not allow the connecting rod to contact the piston cooling jet.

Fracture split connecting rods should not be left without the connecting rod caps installed. After the removal procedure for the connecting rod bearings is complete, carry out the installation procedure as soon as possible. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install".

i02933596

Connecting Rod Bearings - Install (Connecting rods in position)

Installation Procedure

Table 73

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1
B	21825607	Angle Gauge	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Discard all used connecting rod bolts.

1. Inspect the pins of the crankshaft for damage. If the crankshaft is damaged, replace the crankshaft or recondition the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Remove" and Disassembly and Assembly, "Crankshaft - Install". Ensure that the connecting rod bearings are clean and free from wear or damage. If necessary, replace the connecting rod bearings.

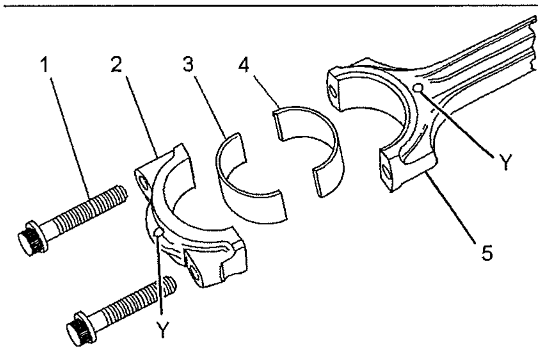

Illustration 292 g01260354

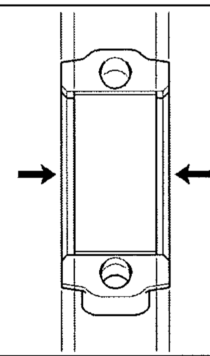

Illustration 293 g01001160

Aligning the bearing in the center of the connecting rod

Note: New connecting rod bearings are supplied with an alignment tool. If new bearings are installed, use the tool to align the bearing in the connecting rod.

2. Install the upper half of connecting rod bearing (4) to connecting rod (5). Ensure that the bearing is centralized in the connecting rod. Refer to Illustration 293.

   The ends of the bearing must be centered in the connecting rod. The ends of the bearing must be equally positioned in relation to the faces of the connecting rod.

3. Clean the connecting rod cap. Install lower connecting rod bearing (3) to connecting rod cap (2). Ensure that the connecting rod bearing is centralized in the connecting rod cap. Refer to Illustration 293.

   The ends of the lower connecting rod bearing must be centered in the connecting rod cap. The ends of the lower connecting rod bearing must be equally positioned in relation to the faces of the connecting rod cap.

4. Lubricate upper connecting rod bearing (4) with clean engine oil.

5. If necessary, use Tooling (A) in order to rotate the crankshaft until the crankshaft pin is at the bottom dead center position.

6. Carefully pull connecting rod (5) against the crankshaft pin.

Note: Do not allow the connecting rod to contact the piston cooling jet.

7. Lubricate the pin of the crankshaft and lubricate lower connecting rod bearing (3) with clean engine oil.

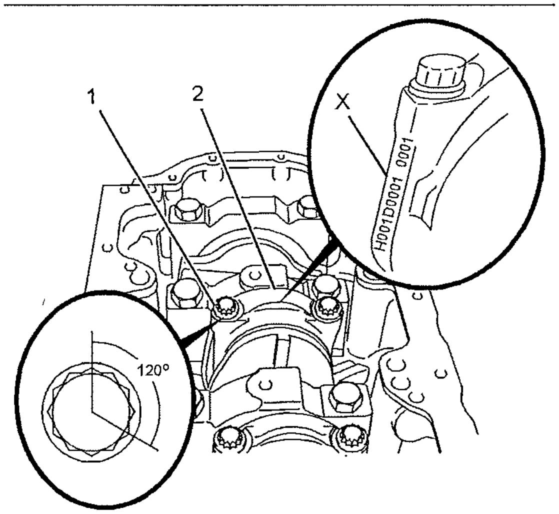

Illustration 294 g01479452

Typical example

8. Install connecting rod cap (2) to connecting rod (5).

Note: Ensure that etched Number (X) on connecting rod cap (2) matches etched Number (X) on connecting rod (5). Ensure the correct orientation of the connecting rod cap. The forged Marks (Y) on the connecting rod and the connecting rod cap should be on the same side. Refer to Illustration 292.

9. Install new bolts (1). Tighten the bolts evenly to a torque of 18 N·m (13 lb ft).

Note: Do not reuse the old bolts in order to secure the connecting rod cap.

10. Tighten the bolts evenly to a torque of 70 N·m (52 lb ft).

11. Use Tooling (B) to turn the bolts through an additional 120 degrees.

12. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

13. Repeat Step 2 through Step 12 for the remaining connecting rod bearings.

Note: If all connecting rod bearings require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. **Ensure that both pairs of the connecting rod bearings are installed before changing from one pair of cylinders to another pair of cylinders..**

14. If the glow plugs were removed, install the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Install".

End By:

a. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

i02933605

Crankshaft Main Bearings - Remove and Install (Crankshaft in position)

Removal Procedure

Table 74

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	21825576	Crankshaft Turning Tool	1
A(2)	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Start By:

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

b. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove".

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
This procedure must only be used to remove and install the main bearing shells with the crankshaft in position.

The removal procedure and the installation procedure must be completed for each pair of main bearing shells before the next pair of main bearing shells are removed.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

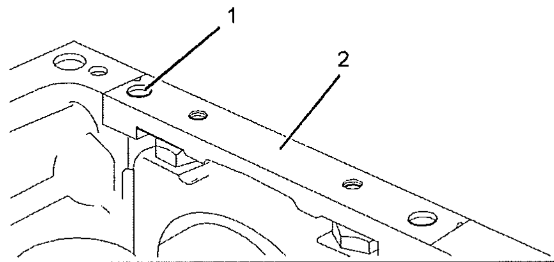

Illustration 295 g01490997
Typical example

1. Remove allen head screws (1). Remove bridge piece (2).

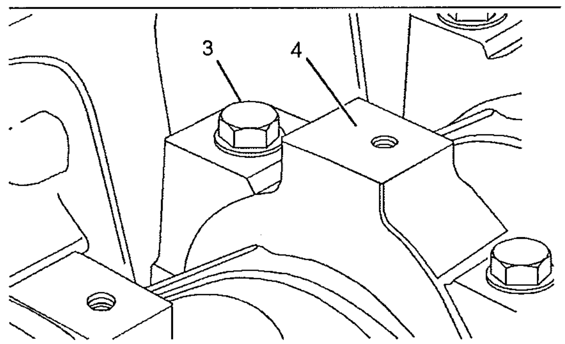

Illustration 296 g01253719
Typical example

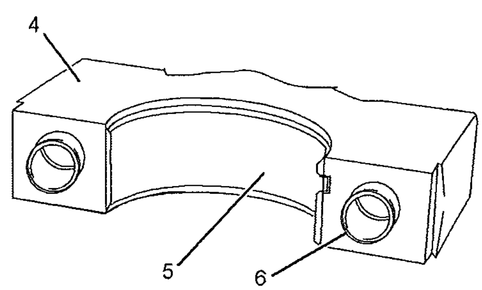

Illustration 297 g01253146
Typical example

2. Ensure that the main bearing cap is marked for the correct location and orientation.

3. Remove bolts (3). Remove main bearing cap (4) from the cylinder block.

4. Remove lower main bearing (5) from main bearing cap (4). Keep the main bearing and the main bearing cap together. Take care not to displace dowels (6).

Note: The lower main bearing is a plain bearing that has no oil holes. The dowels may remain in the main bearing cap or in the cylinder block.

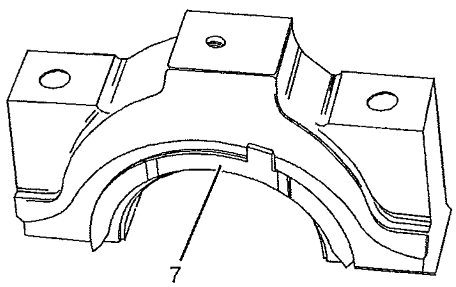

Illustration 298 g01253137

Typical example

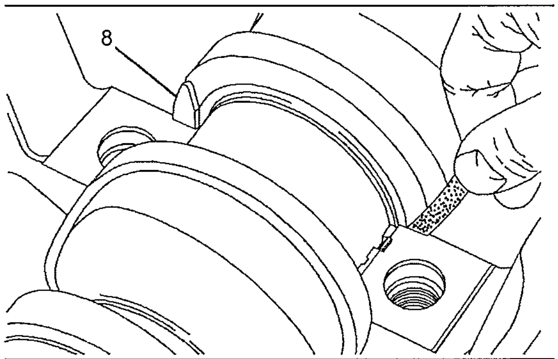

Illustration 299 g01253142

Typical example

5. For number three main bearing cap, remove thrust washers (7).

6. For number three main bearing, remove thrust washers (8) from the cylinder block. In order to remove the thrust washers, push the crankshaft toward the front of the engine or push the crankshaft toward the rear of the engine. Use Tooling (A) in order to rotate the crankshaft. If necessary, use a suitable tool to free the thrust washers.

Note: Do not damage the machined surfaces of the crankshaft during removal of the thrust washers.

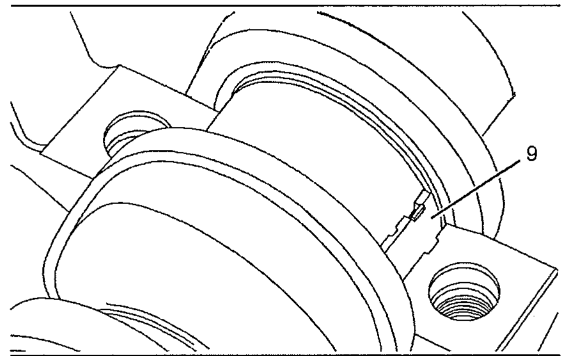

Illustration 300 g01253145

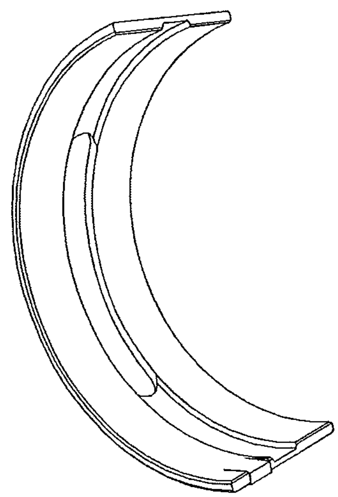

Illustration 301 g01889993

No. 1 Upper Main Bearing

7. Push out upper main bearing (9) with a suitable tool from the side opposite the locating tab. Carefully rotate the crankshaft while you push on the bearing . Remove upper main bearing (9) from the cylinder block. Keep the bearings together.

Note: Do not damage the machined surfaces of the crankshaft during removal of the upper main bearing. Number 1 upper main bearing has an oil slot. See Illustration 303. All other upper main bearings have a groove and two oil holes.

Installation Procedure

Table 75

Required Tools			
Tool	Part Number	Part Description	Qty
B	21825617	Dial Indicator Group	1
C	-	Straight Edge	1
D	-	5 mm Allen Socket	1
E	21826038	POWERPART Silicon Rubber Sealant	1

NOTICE
This procedure must only be used to remove and install the main bearing shells with the crankshaft in position.

The removal procedure and the installation procedure must be completed for each pair of main bearing shells before the next pair of main bearing shells are removed.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the main bearings are clean and free from wear or damage. If necessary, replace the main bearings.

2. Clean the journals of the crankshaft. Inspect the journals of the crankshaft for damage. If necessary, replace the crankshaft or recondition the crankshaft.

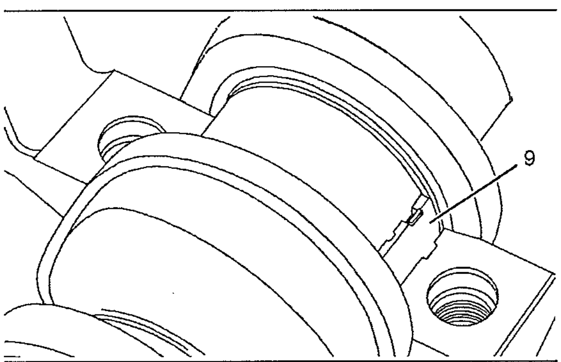

Illustration 302 g01253145

Typical example

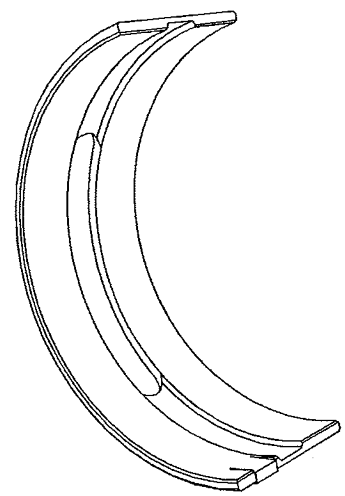

Illustration 303 g01889993

No. 1 Upper Main Bearing

3. Lubricate the crankshaft journal and upper main bearing (9) with clean engine oil. Slide upper main bearing (9) into position between the crankshaft journal and the cylinder block. Ensure that the locating tab for the upper main bearing is correctly seated in the slot in the cylinder block.

Note: Number 1 upper main bearing has an oil slot. See Illustration 303. All other upper main bearings have a groove and two oil holes.

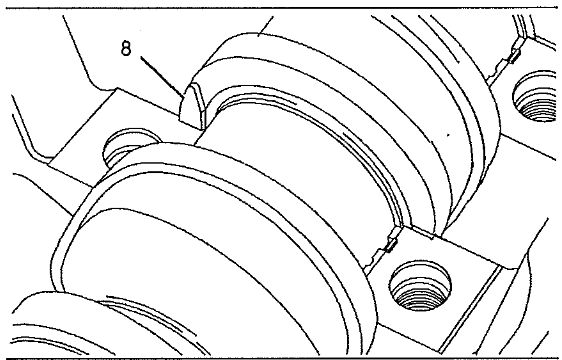

Illustration 304 g01261200

Typical example

4. For number three main bearing, ensure that thrust washers (8) are clean and free from wear or damage. If necessary, replace the thrust washers. Lubricate thrust washers (8) with clean engine oil. Slide the thrust washers into position between the crankshaft and the cylinder block. The grooves in the thrust washers must be located against the crankshaft.

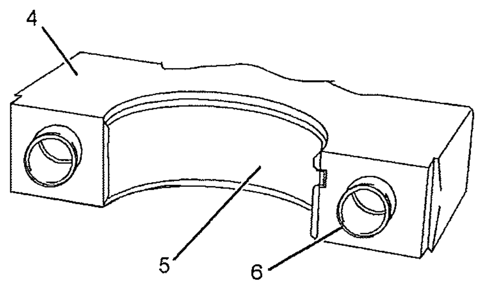

Illustration 305 g01253146

Typical example

5. Install lower main bearing (5) into main bearing cap (4). Ensure that the locating tab for the lower main bearing is correctly seated into the slot in the bearing cap.

Note: The lower main bearing is a plain bearing that has no oil holes.

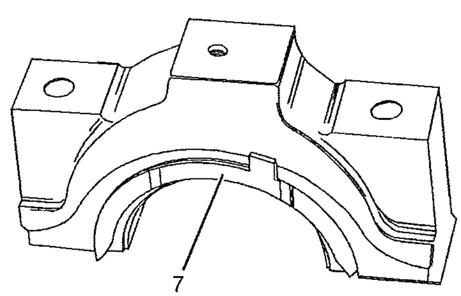

Illustration 306 g01253137

Typical example

6. For number three main bearing cap, ensure that thrust washers (7) are clean and free from wear or damage. If necessary, replace the thrust washers. Lubricate thrust washers (7) with clean engine oil. Place the thrust washers into position on the main bearing cap. Ensure that the locating tab is correctly seated in the main bearing cap.

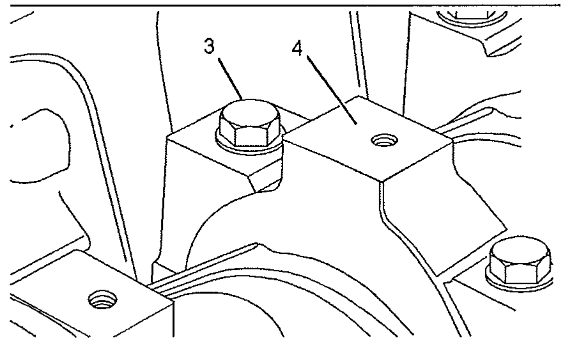

Illustration 307 g01253719

Typical example

7. Lubricate the crankshaft journal and the lower main bearing with clean engine oil. Install main bearing cap (4) to the cylinder block.

Note: Ensure the correct orientation of the main bearing cap. The locating tab for the upper and the lower bearing should be on the same side of the engine.

8. Lubricate the threads of bolts (3) with clean engine oil. Lubricate the underside of the heads of the bolts with clean engine oil.

9. Install bolts (3) to main bearing cap (4). Evenly tighten the bolts in order to pull cap (5) into position. Ensure that the cap is correctly seated.

Note: Do not tap the main bearing cap into position as the bearing may be dislodged.

10. Tighten bolts (3) to a torque of 245 N·m (180 lb ft).

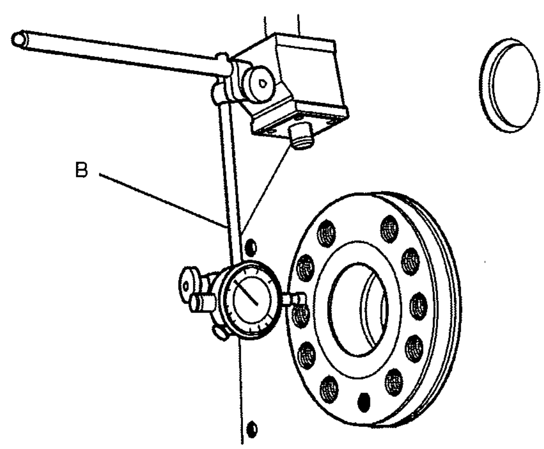

Illustration 308 g01253186

Typical example

11. Check the crankshaft end play. Push the crankshaft toward the front of the engine. Install Tooling (B) to the cylinder block and the rear face of the crankshaft. Push the crankshaft toward the rear of the engine. Use Tooling (B) to measure the crankshaft end play. The permissible crankshaft end play is 0.17 to 0.41 mm (0.007 to 0.016 inch).

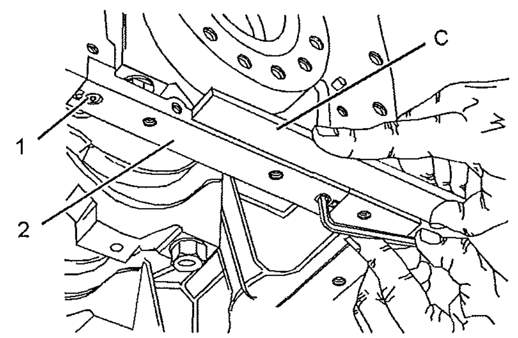

Illustration 309 g01253836

Typical example

12. Follow Step 12.a through Step 12.d in order to install the bridge piece.

a. Ensure that the recess in the cylinder block and the bridge piece are clean, dry and free from old sealant.

b. Install bridge piece (2) and allen head screws (1). Tighten the allen head screws finger tight.

c. Use Tooling (C) in order to align the rear face of the bridge piece with the rear face of the cylinder block.

d. Use Tooling (D) to tighten allen head screws (1) to a torque of 16 N·m (12 lb ft).

13. Install the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

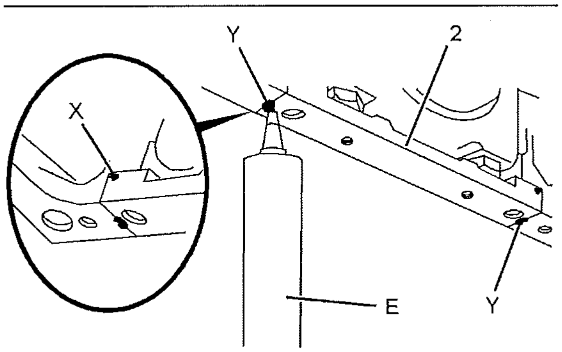

Illustration 310 g01344584

Typical example

14. Apply Tooling (E) to Cavities (Y) in bridge piece (2). Continue to apply Tooling (E) until sealant extrudes from Cavities (X).

Note: If the oil pan will not be installed immediately, ensure that the face of the bridge piece and the cylinder block are left free of sealant.

End By:

a. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

i02933602

Crankshaft - Remove

Removal Procedure

Table 76

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Lifting Strap	1

Start By:

a. Remove the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

b. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".

c. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove".

d. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

NOTICE

If the crankshaft has been reground or if the crankshaft has been replaced, the height of the piston above the cylinder block must be inspected. It is necessary to remove the cylinder head in order to inspect the height of the piston above the cylinder block.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. The engine should be mounted on a suitable stand and placed in the inverted position.

2. If necessary, remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove". Remove the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Remove".

   If the cylinder head, the pistons and the connecting rods have not been removed, remove the connecting rod caps. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Remove".

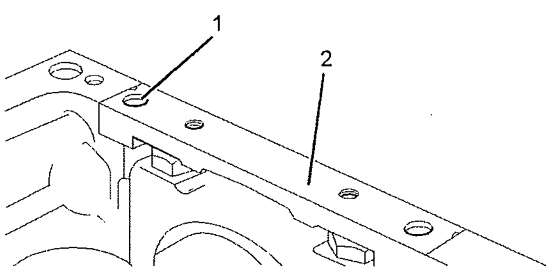

Illustration 311 g01439628

Typical example

3. Remove allen head screws (1). Remove bridge piece (2).

4. Ensure that the main bearing caps are marked for the location and orientation.

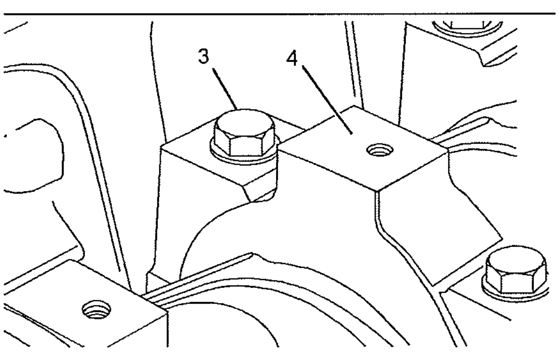

Illustration 312 g01253719

Typical example

5. Remove bolts (3) and main bearing caps (4) from the cylinder block.

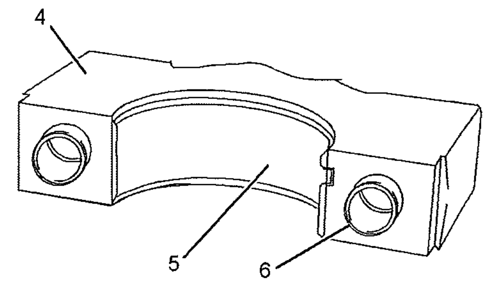

Illustration 313 g01253146

Typical example

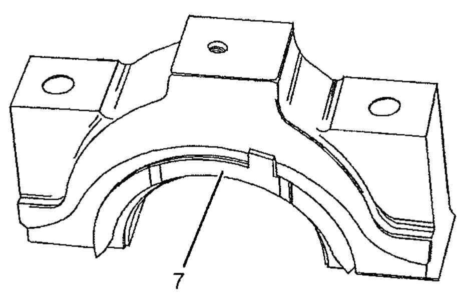

Illustration 314 g01253137

Typical example

6. Remove lower main bearings (5) from main bearing caps (4). Take care not to displace dowels (6). For number three main bearing cap, remove thrust washers (7). Keep the lower main bearings and the thrust washers with the respective main bearing caps.

Note: The lower main bearings are plain bearings that have no oil holes. The dowels may remain in the main bearing cap or in the cylinder block.

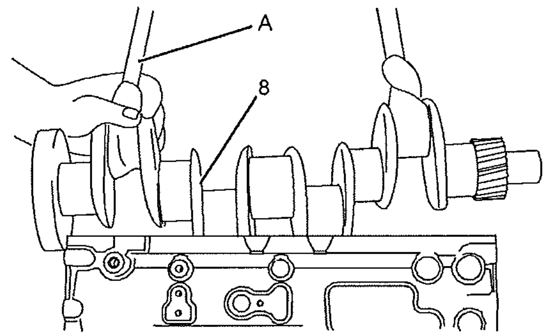

Illustration 315 g01254099

Typical example

7. Attach Tooling (A) and a suitable lifting device to crankshaft (8). Carefully lift the crankshaft out of the cylinder block. The weight of the crankshaft is approximately 30 kg (66 lb).

Note: Do not damage any of the finished surfaces on the crankshaft. When the crankshaft is removed from the engine, the crankshaft must be supported on a suitable stand in order to prevent damage to the crankshaft timing ring.

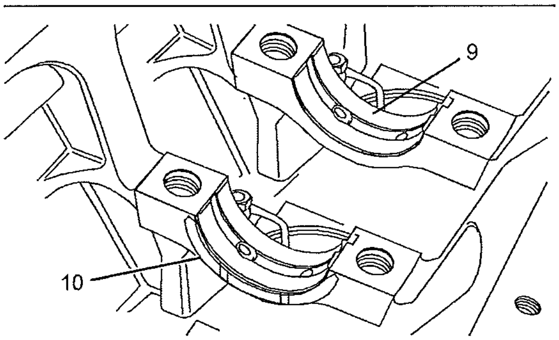

Illustration 316 g01254104

Typical example

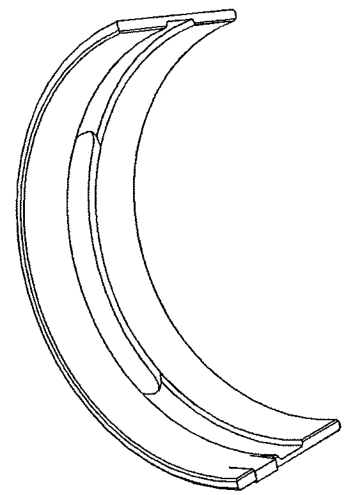

Illustration 317 g01889993

No. 1 Upper Main Bearing

8. Remove upper main bearings (9) from the cylinder block. Keep the upper main bearings with the respective main bearing caps.

Note: Number 1 upper main bearing has an oil slot. See Illustration 317. All other upper main bearings have a groove and two oil holes.

9. Remove thrust washers (10) from number three main bearing in the cylinder block.

10. If necessary, remove the crankshaft timing ring. Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install".

11. If necessary, remove the crankshaft gear. Refer to Disassembly and Assembly, "Crankshaft Gear - Remove and Install".

i02933601

Crankshaft - Install

Installation Procedure

Table 77

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Lifting Strap	1
B	21825617	Dial Indicator Group	1
C	-	Straight Edge	1
D	-	5 mm Allen Socket	1
E	21826038	POWERPART Silicon Rubber Sealant	-

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

If the crankshaft has been reground or if the crankshaft has been replaced, the height of the piston above the cylinder block must be inspected. It is necessary to remove the cylinder head in order to inspect the height of the piston above the cylinder block.

NOTICE

If the crankshaft has been reground or if the crankshaft has been replaced, ensure that the engine oil system is free from debris and contaminents.

1. Clean the crankshaft and inspect the crankshaft for wear or damage. Refer to Specifications, "Crankshaft" for more information. If necessary, replace the crankshaft or recondition the crankshaft.

2. If necessary, install the crankshaft gear. Refer to Disassembly and Assembly, "Crankshaft Gear - Remove and Install".

3. If necessary, install a new crankshaft timing ring. Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install".

Note: The engine should be mounted on a suitable stand and placed in the inverted position.

4. Ensure that the parent bores for the crankshaft bearings in the cylinder block are clean. Ensure that the threads for the bearing bolts in the cylinder block are clean and free from damage.

5. Clean the crankshaft bearings and the thrust washers. Inspect the bearings and the thrust washers for wear or damage. If necessary, replace the bearings and the thrust washers.

Note: If the crankshaft bearings are replaced, check whether oversize bearings were previously installed. If the thrust washers are replaced, check whether oversize thrust washers were previously installed.

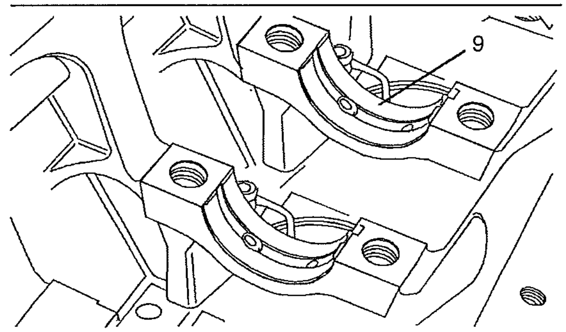

Illustration 318 g01253240

Typical example

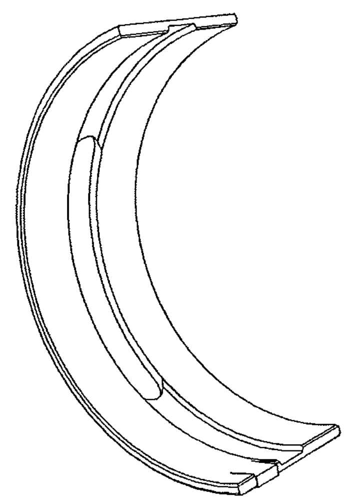

Illustration 319 g01889993

No. 1 Upper Main Bearing

6. Install upper bearings (9) to the cylinder block. Ensure that the locating tabs for the upper bearings are seated in the slots in the cylinder block.

Note: Number 1 upper main bearing has an oil slot. See Illustration 319. All other upper bearings have a groove and two oil holes.

7. Lubricate upper bearings (9) with clean engine oil.

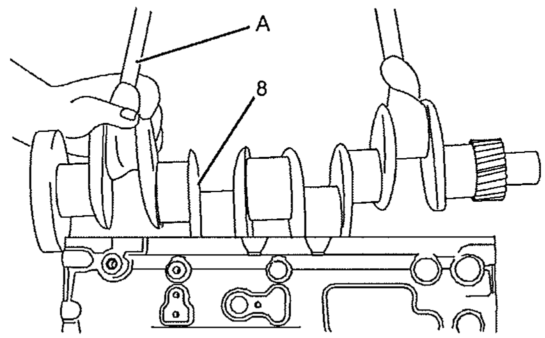

Illustration 320 g01254099

Typical example

8. Attach Tooling (A) and a suitable lifting device to crankshaft (8). Carefully lift the crankshaft into the cylinder block. The weight of the crankshaft is approximately 30 kg (66 lb). Remove Tooling (A).

Note: Do not damage any of the finished surfaces on the crankshaft. Do not damage the bearing.

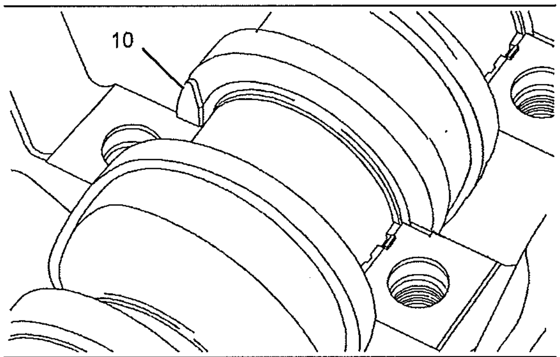

Illustration 321 g01254100

Typical example

9. For number three bearing, ensure that thrust washers (10) are clean and free from wear or damage. If necessary, replace the thrust washers. Lubricate thrust washers (10) with clean engine oil. Slide the thrust washers into position between the crankshaft and the cylinder block.

Note: The grooves in the thrust washers must be located against the crankshaft.

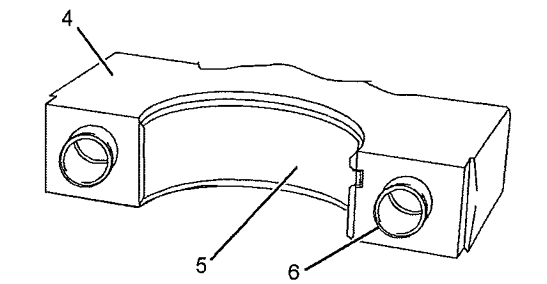

Illustration 322 g01253146

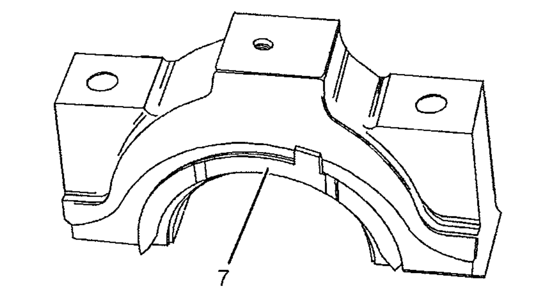

Illustration 323 g01253137

10. Install lower bearings (5) into bearing caps (4). Ensure that the locating tabs for the lower bearings are correctly seated into the slots in the bearing caps. For number three bearing cap, ensure that thrust washers (7) are clean and free from wear or damage. If necessary, replace both the thrust washers. Lubricate thrust washers (7) with clean engine oil. Place the thrust washers into position on the bearing cap. Ensure that the locating tab is correctly seated in the bearing cap.

Note: The lower bearing is a plain bearing that has no oil holes.

11. Lubricate lower bearings (5) and lubricate the journals of crankshaft (8) with clean engine oil. Install bearing caps (4) to the cylinder block.

Note: Ensure the correct location and orientation of the bearing caps. The locating tabs for the upper and the lower bearings should be on the same side of the engine.

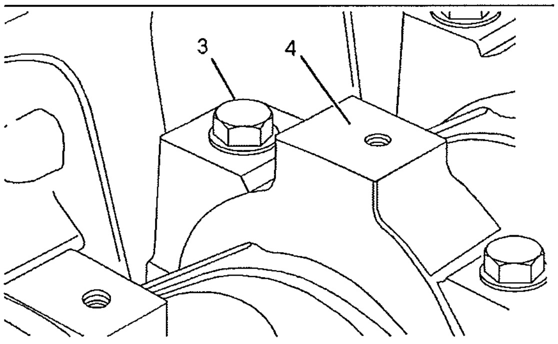

Illustration 324 g01253719

12. Lubricate the threads of bolts (3) with clean engine oil. Lubricate the underside of the heads of the bolts with clean engine oil.

13. Install bolts (3) to bearing caps (4). Evenly tighten the bolts in order to pull the caps into position. Ensure that the caps are correctly seated.

Note: Do not tap the bearing caps into position as the bearing may be dislodged.

14. Tighten bolts (3) to a torque of 245 N·m (180 lb ft).

15. Rotate the crankshaft in order to ensure that there is no binding.

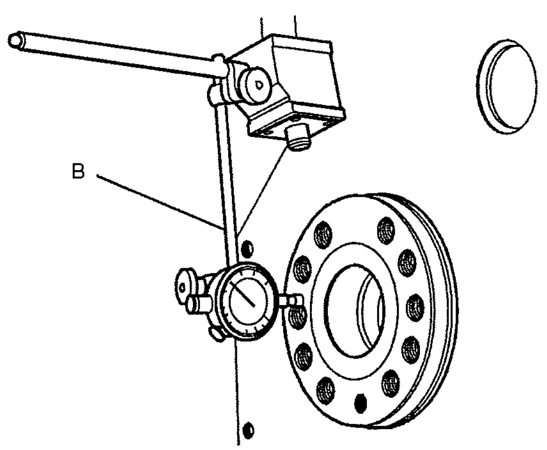

Illustration 325 g01253186

Typical example

16. Check the crankshaft end play. Push the crankshaft toward the front of the engine. Install Tooling (B) to the cylinder block and the rear face of the crankshaft. Push the crankshaft toward the rear of the engine. Use Tooling (B) to measure the crankshaft end play. The permissible crankshaft end play is 0.17 to 0.41 mm (0.007 to 0.016 inch).

17. If the crankshaft has been replaced or the crankshaft has been reconditioned, inspect the height of the piston above the cylinder block. Refer to Systems Operation, Testing and Adjusting, "Piston Height - Inspect" for more information.

If the crankshaft has not been replaced or the crankshaft has not been reconditioned, install the connecting rod caps. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install".

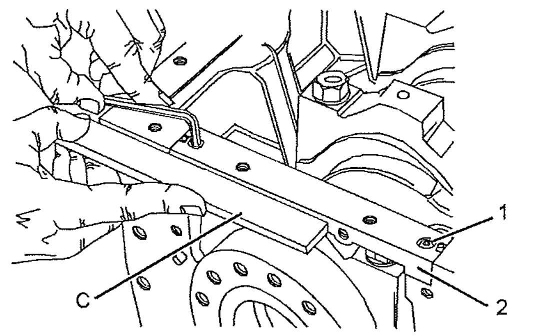

Illustration 326 g01254102

Typical example

18. Follow Step 18.a through Step18.d in order to install the bridge piece.

a. Ensure that the cylinder block and the bridge piece are clean, dry and free from old sealant.

b. Install bridge piece (2) and allen head screws (1). Tighten the allen head screws finger tight.

c. Use Tooling (C) in order to align the rear face of the bridge piece with the rear face of the cylinder block.

d. Use Tooling (D) in order to tighten the allen head screws to a torque of 16 N·m (12 lb ft).

19. Install the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

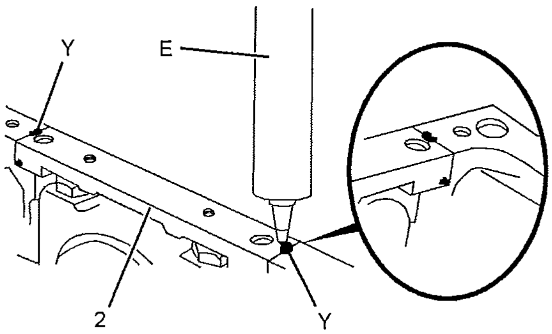

Illustration 327 g01344593

Typical example

20. Apply Tooling (E) to Cavities (Y) in the bridge piece (2). Continue to apply Tooling (E) until sealant extrudes from Cavities (X).

Note: If the oil pan will not be installed immediately, ensure that the face of the bridge piece and the cylinder block are left free of sealant.

End By:

a. If necessary, install the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Install".

b. If the engine has a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine does not have a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

c. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

d. If necessary, install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

e. Install the rockershaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and PushRod - Install".

i02933611

Crankshaft Timing Ring - Remove and Install

Removal Procedure

Start By:

a. Remove the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Remove ".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

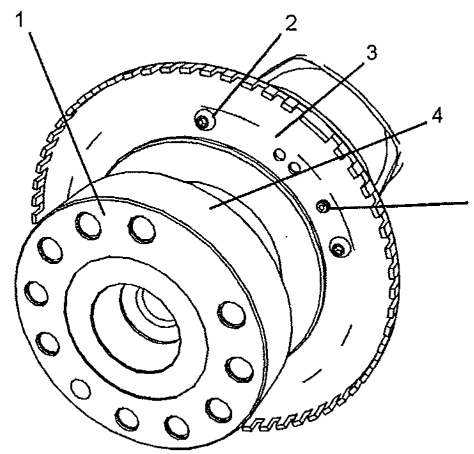

Illustration 328 g01254108

1. Support crankshaft (1) on a suitable stand.

2. Remove allen head screws (2) from crankshaft timing ring (3). Do not reuse the allen head screws.

3. Carefully remove crankshaft timing ring (3) from crankshaft (1). Do not reuse the crankshaft timing ring.

Note: Ensure that seal surface (4) of the crankshaft is not damaged when the crankshaft timing ring is removed.

Note: Do not remove dowel (5) from crankshaft (1) unless the dowel is damaged.

Installation Procedure

Table 78

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	4 mm Allen Socket	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Support crankshaft (1) on a suitable stand.
2. Ensure that the flange for the crankshaft timing ring on the crankshaft is clean and free from damage.

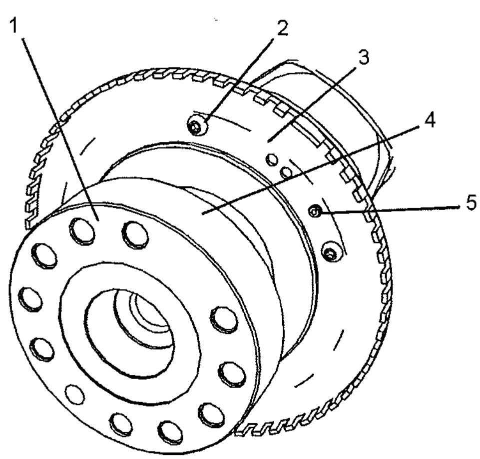

Illustration 329 g01254108

3. If dowel (5) was removed, install a new dowel to crankshaft (1).
4. Position crankshaft timing ring (3) onto the crankshaft with the teeth toward rear seal surface (4). Align the hole in crankshaft timing ring (3) with dowel (5). Carefully install crankshaft timing ring (3) to crankshaft (1).

Note: Ensure that seal surface (4) on the crankshaft is not damaged when the crankshaft timing ring is installed.

5. Use Tooling (A) to install new allen head screws (2). Tighten the allen head screws to a torque of 9 N·m (80 lb in).

End By:

a. Install the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Install ".

i02933604

Crankshaft Gear - Remove and Install

Removal Procedure

Table 79

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bearing Puller	1
	-	Puller	1
	-	Crossblock	1
	-	Puller Leg	2

Start By:

a. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".

b. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The crankshaft gear may be a sliding fit on the crankshaft or an interference fit on the crankshaft.

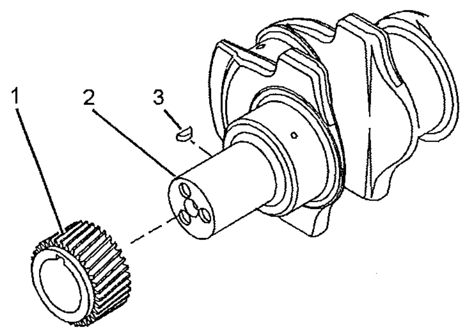

Illustration 330 g01367358

Typical example

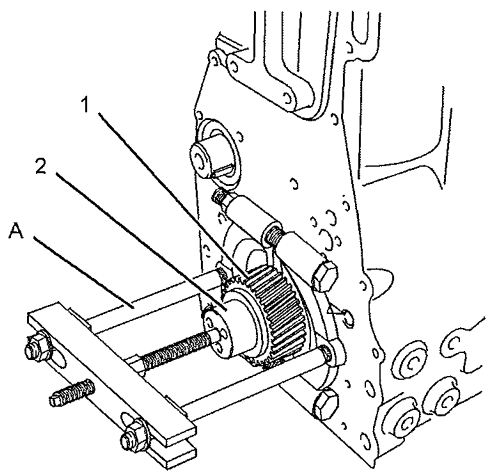

Illustration 331 g01270549

Typical example

1. If the crankshaft gear is a sliding fit on the crankshaft, remove crankshaft gear (1) from crankshaft (2).

   If the crankshaft gear is an interference fit on the crankshaft, use Tooling (A) in order to remove crankshaft gear (1) from crankshaft (2).

2. If necessary, remove key (3) from crankshaft (2).

Note: Do not remove the key from the crankshaft unless the key is damaged.

Installation Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.

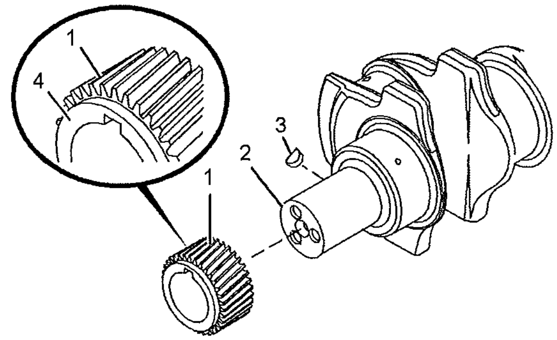

Illustration 332 g01367359

Typical example

2. If necessary, install a new key (3) to crankshaft (2).

Note: The crankshaft gear may be a sliding fit on the crankshaft or an interference fit on the crankshaft.

⚠ WARNING

Hot parts or hot components can cause burns or personal injury. Do not allow hot parts or components to contact your skin. Use protective clothing or protective equipment to protect your skin.

3. If the crankshaft gear is a sliding fit on the crankshaft, align the keyway in crankshaft gear (1) with key (3) in the crankshaft. Install crankshaft gear (1) to crankshaft (2).

   If the crankshaft gear is an interference fit on the crankshaft, heat crankshaft gear (1) in an oven to 150° ± 50°C (302° ± 90°F). Align the keyway in crankshaft gear (1) with key (3) in the crankshaft. Install crankshaft gear (1) to crankshaft (2).

   Ensure that shoulder (4) on crankshaft gear (1) is toward the front of the engine.

End By:

a. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

i02748526

Bearing Clearance - Check

Measurement Procedure

Table 80

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Plastic Gauge (Green) 0.025 to 0.076 mm (0.001 to 0.003 inch)	1
	-	Plastic Gauge (Red) 0.051 to 0.152 mm (0.002 to 0.006 inch)	1
	-	Plastic Gauge (Blue) 0.102 to 0.229 mm (0.004 to 0.009 inch)	1
	-	Plastic Gauge (Yellow) 0.230 to 0.510 mm (0.009 to 0.020 inch)	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Perkins does not recommend the checking of the actual clearances of the bearing shells particularly on small engines. This is because of the possibility of obtaining inaccurate results and of damaging the bearing shell or the journal surfaces. Each Perkins bearing shell is quality checked for specific wall thickness.

Note: The measurements should be within specifications and the correct bearings should be used. If the crankshaft journals and the bores for the block and the rods were measured during disassembly, no further checks are necessary. However, if the technician still wants to measure the bearing clearances, Tooling (A) is an acceptable method. Tooling (A) is less accurate on journals with small diameters if clearances are less than 0.10 mm (0.004 inch).

NOTICE
Lead wire, shim stock or a dial bore gauge can damage the bearing surfaces.

The technician must be very careful to use Tooling (A) correctly. The following points must be remembered:

- Ensure that the backs of the bearings and the bores are clean and dry.
- Ensure that the bearing locking tabs are properly seated in the tab grooves.
- The crankshaft must be free of oil at the contact points of Tooling (A).

1. Put a piece of Tooling (A) on the crown of the bearing that is in the cap.

Note: Do not allow Tooling (A) to extend over the edge of the bearing.

2. Use the correct torque-turn specifications in order to install the bearing cap. Do not use an impact wrench. Be careful not to dislodge the bearing when the cap is installed.

Note: Do not turn the crankshaft when Tooling (A) is installed.

3. Carefully remove the cap, but do not remove Tooling (A). Measure the width of Tooling (A) while Tooling (A) is in the bearing cap or on the crankshaft journal. Refer to Illustration 333.

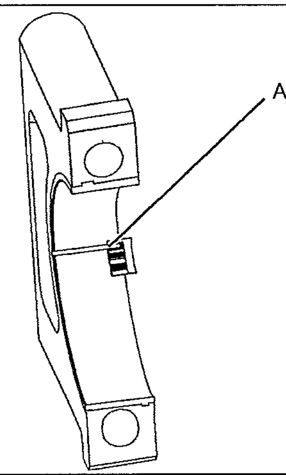

Illustration 333 g01152855

Typical Example

4. Remove all of Tooling (A) before you install the bearing cap.

Note: When Tooling (A) is used, the readings can sometimes be unclear. For example, all parts of Tooling (A) are not the same width. Measure the major width in order to ensure that the parts are within the specification range. Refer to Specifications Manual, "Connecting Rod Bearing Journal" and Specifications Manual, "Main Bearing Journal" for the correct clearances.

i02933606

Crankshaft Position Sensor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

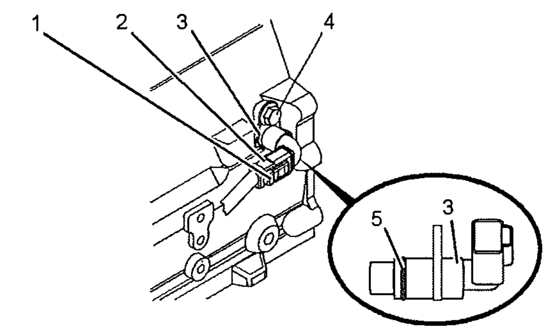

Illustration 334 g01479572

Typical example

1. Slide locking tab (1) into the unlocked position.
2. Disconnect harness assembly (2) from position sensor (3).
3. Remove bolt (4).
4. Carefully remove position sensor (3) from the cylinder block.

Note: Do not use a lever to remove the position sensor from the cylinder block.

5. Remove O-ring seal (5) from position sensor (3).

Installation Procedure

Table 81

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21820221	POWERPART Rubber Grease	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

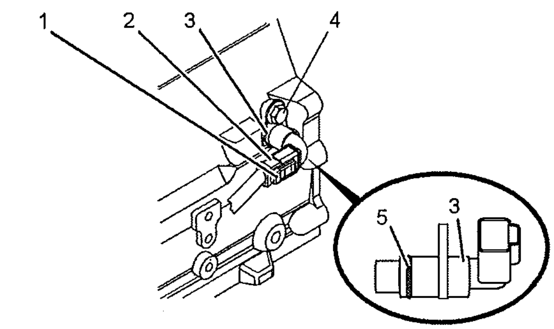

Illustration 335 g01479572

Typical example

1. Install a new O-ring seal (5) to the groove in position sensor (3). Lubricate the new O-ring seal with Tooling (A).
2. Align the hole in position sensor (3) with the hole in the cylinder block. Install the position sensor to the cylinder block.

Note: Do not use bolt (4) to pull the position sensor into position against the cylinder block.

3. Install bolt (4). Tighten the bolt to a torque of 22 N·m (16 lb ft).
4. Connect harness assembly (2) to position sensor (3).
5. Slide locking tab (1) into the locked position.

i02933668

Position Sensor (Fuel Injection Pump) - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

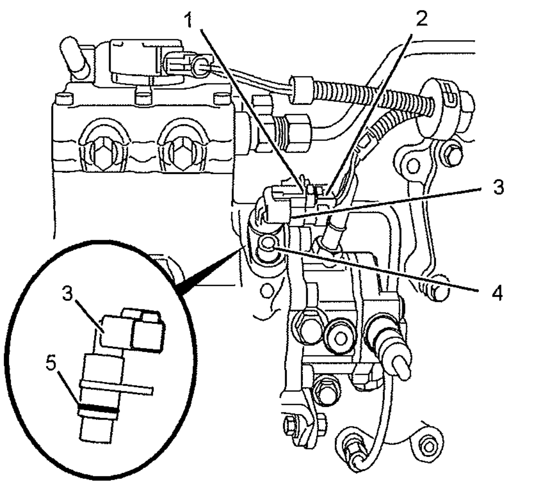

Illustration 336 g01480052

Typical example

1. Slide locking tab (1) into the unlocked position.
2. Disconnect harness assembly (2) from position sensor (3).
3. Remove bolt (4).
4. Carefully remove position sensor (3) from the fuel injection pump.

Note: Do not use a lever to remove the position sensor from the fuel injection pump.

5. Plug the hole for the position sensor in the fuel injection pump with a new plug.
6. Remove O-ring seal (5) from position sensor (3).

Installation Procedure

Table 82

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820221	POWERPART Rubber Grease	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

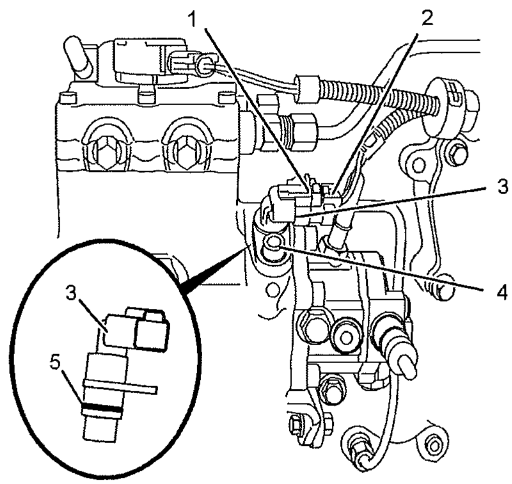

Illustration 337 g01480052

Typical example

1. Install a new O-ring seal (5) to the groove in position sensor (3). Lubricate the new O-ring seal with Tooling (A).
2. Remove the plug from the hole in the fuel injection pump for the position sensor.
3. Align the hole in position sensor (3) with the hole in the fuel injection pump. Install the position sensor to the fuel injection pump.

Note: Do not use bolt (4) to pull the position sensor into position against the fuel injection pump.

4. Install bolt (4). Tighten the bolt to a torque of 22 N·m (16 lb ft).
5. Connect harness assembly (2) to position sensor (3).
6. Slide locking tab (1) into the locked position.

i02933598

Coolant Temperature Sensor - Remove and Install

Removal Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system, to a level below the coolant temperature sensor, into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

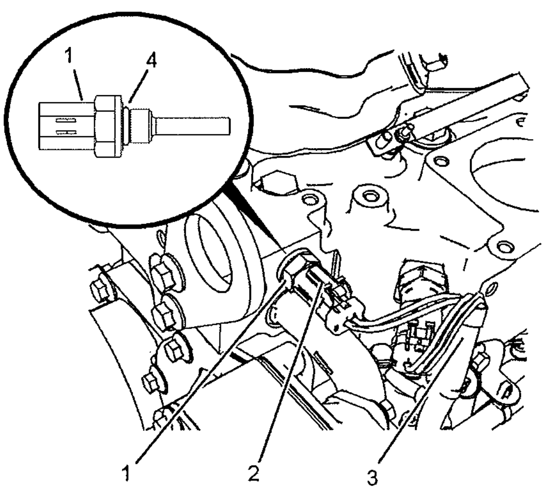

Illustration 338 g01480094

Typical example

2. Slide locking tab (2) into the unlocked position.
3. Disconnect harness assembly (3) from coolant temperature sensor (1).

Note: The coolant temperature sensor has a two-wire plug.

4. Use a deep socket to remove coolant temperature sensor (1) from the cylinder head.

Note: If necessary, remove the bracket for the harness assembly from the bypass tube.

5. Remove O-ring seal (4) from coolant temperature sensor (1).

Installation Procedure

Table 83

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820221	POWERPART Rubber Grease	1

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

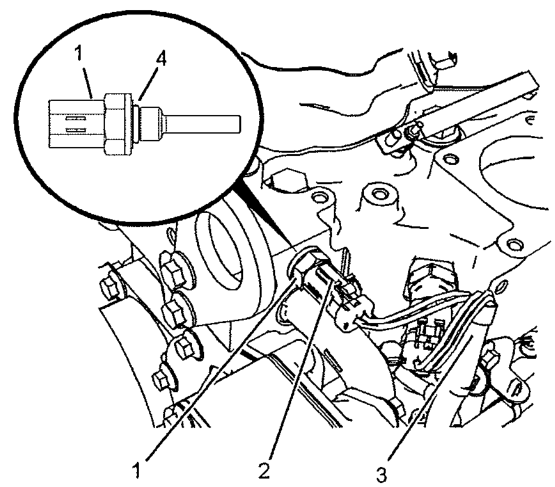

Illustration 339 g01480094

Typical example

1. Install a new O-ring seal (4) to the groove in coolant temperature sensor (1). Lubricate the new O-ring seal with Tooling (A).
2. Use a deep socket in order to install coolant temperature sensor (1) to the cylinder head. Tighten the coolant temperature sensor to a torque of 20 N·m (15 lb ft).
3. Connect harness assembly (3) to coolant temperature sensor (1).

Note: If necessary, install the bracket for the harness assembly to the bypass tube.

4. Slide locking tab (2) into the locked position.
5. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check" and refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.

i02933624

Engine Oil Pressure Sensor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: The engine oil pressure sensor may be located in the cylinder block, on a plate or in the engine oil filter base. Ensure that the engine oil pressure sensor is installed in the correct position.

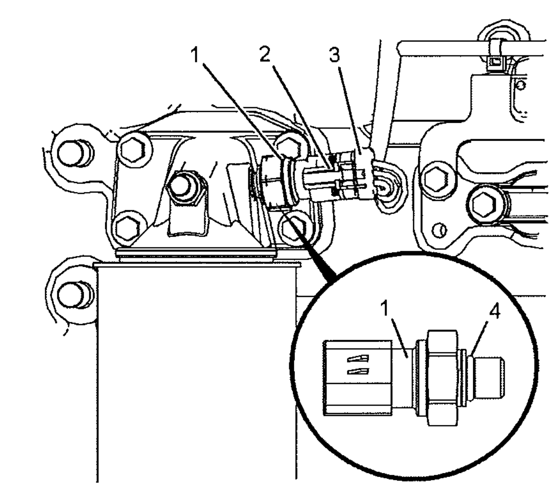

Illustration 340 g01480133

Typical example

1. Slide locking tab (2) into the unlocked position.

2. Disconnect harness assembly (3) from engine oil pressure sensor (1).

3. If necessary, remove the engine oil filter in order to gain access to engine oil pressure sensor (1). Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

4. If necessary, remove the dipstick tube in order to gain access to engine oil pressure sensor (1). Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

5. Use a deep socket to remove engine oil pressure sensor (1).

6. Remove O-ring seal (4) from engine oil pressure sensor (1).

Installation Procedure

Table 84

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820221	POWERPART Rubber Grease	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The engine oil pressure sensor may be located in the cylinder block, on a blanking plate or in the engine oil filter base. Ensure that the engine oil pressure sensor is installed in the correct position.

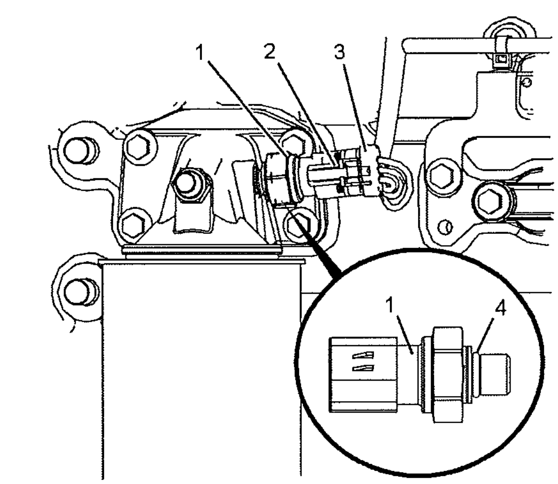

Illustration 341 g01480133

Typical example

1. Install a new O-ring seal (4) to the groove in engine oil pressure sensor (1). Lubricate the new O-ring seal with Tooling (A).
2. Use a deep socket to install engine oil pressure sensor (1). Tighten the engine oil pressure sensor to a torque of 10 N·m (89 lb in).
3. If necessary, install the engine oil filter. Refer to Operation and Maintenance Manual, "Engine Oil and Filter Change".
4. If necessary, install the dipstick tube. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".
5. Connect harness assembly (3) to engine oil pressure sensor (1).
6. Slide locking tab (2) into the locked position.
7. If necessary, fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check".

i02933645

Fuel Pressure Sensor - Remove and Install

Removal Procedure

Table 85

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Seal Pick	1

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

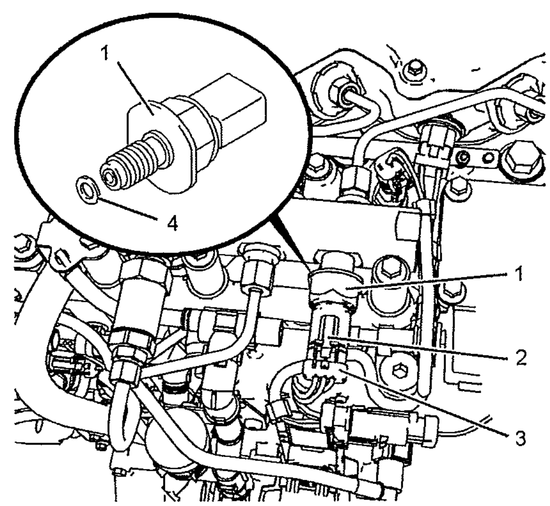

Illustration 342
g01459748

Typical example

1. Slide locking tab (2) into the unlocked position.
2. Disconnect harness assembly (3) from fuel pressure sensor (1).
3. Use a deep socket to remove fuel pressure sensor (1) from the fuel manifold.

Note: After the engine has stopped, allow the pressure to dissipate for 60 seconds before removing the fuel pressure sensor.

4. If necessary, use Tooling (A) in order to remove sealing washer (4) from the fuel manifold.

Note: Do not damage the seat for the washer in the fuel manifold. Ensure that no debris enters the fuel manifold during the removal of the sealing washer.

5. Plug the open port in the fuel manifold immediately with a new plug.

Installation Procedure

Table 86

Required Tools			
Tool	Part Number	Part Description	Qty
B	21825607	Angle gauge	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

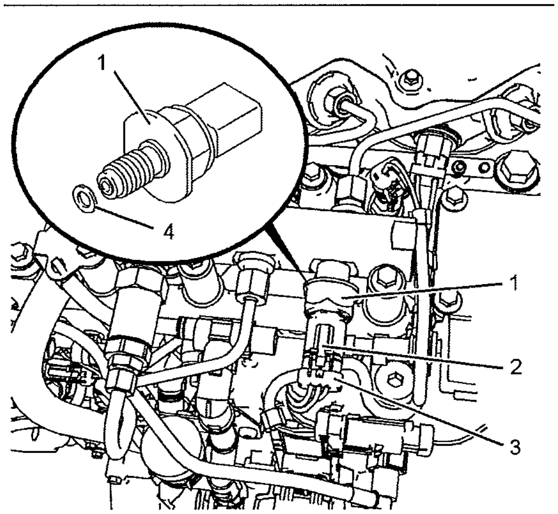

Illustration 343 g01459748

Typical example

1. Position a new sealing washer (4) onto fuel pressure sensor (1).

2. Remove the plug from the fuel manifold.

3. Install fuel pressure sensor (1) to the fuel manifold. Use a deep socket to tighten the fuel pressure sensor to a torque of 5 N·m (44 lb in). Use Tooling (B) to turn the fuel pressure sensor through an additional 120 degrees.

4. Connect harness assembly (3) to fuel pressure sensor (1).

5. Slide locking tab (2) into the locked position.

6. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933592

Boost Pressure Sensor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The boost pressure sensor may be located on the secondary fuel filter base or in the cylinder head.

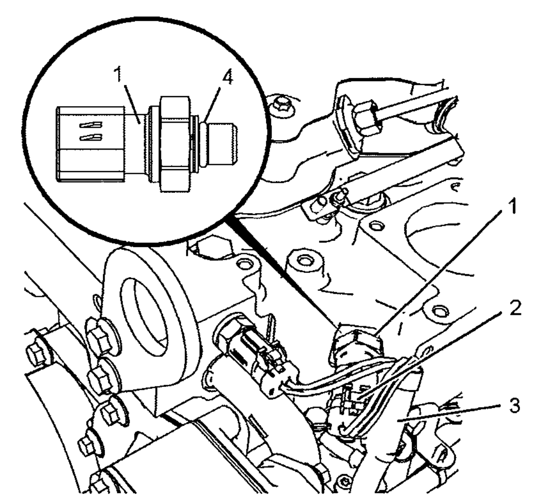

Illustration 344 g01480192

Typical example

1. Slide locking tab (2) into the unlocked position.

2. Disconnect harness assembly (3) from boost pressure sensor (1).

Note: The boost pressure sensor has a three-wire plug.

3. Use a deep socket to remove boost pressure sensor (1).

Note: If necessary, remove the bracket for the harness assembly from the bypass tube.

4. Remove O-ring seal (4) from boost pressure sensor (1).

Installation Procedure

Table 87

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820221	POWERPART Rubber Grease	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The boost pressure sensor may be located on the secondary fuel filter base or in the cylinder head.

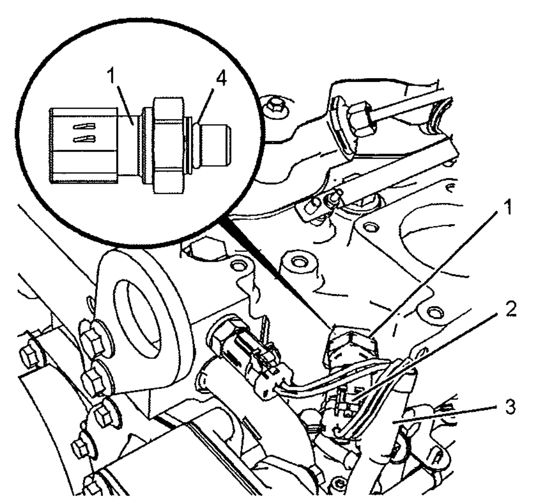

Illustration 345 g01480192

Typical example

1. Install a new O-ring seal (4) to the groove in boost pressure sensor (1). Lubricate the new O-ring seal with Tooling (A).

2. Use a deep socket to install boost pressure sensor (1). Tighten the boost pressure sensor to a torque of 10 N·m (89 lb in).

Note: If necessary, install the bracket for the harness assembly to the bypass tube.

3. Connect harness assembly (3) to boost pressure sensor (1).

4. Slide locking tab (2) into the locked position.

i02933659

Inlet Air Temperature Sensor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

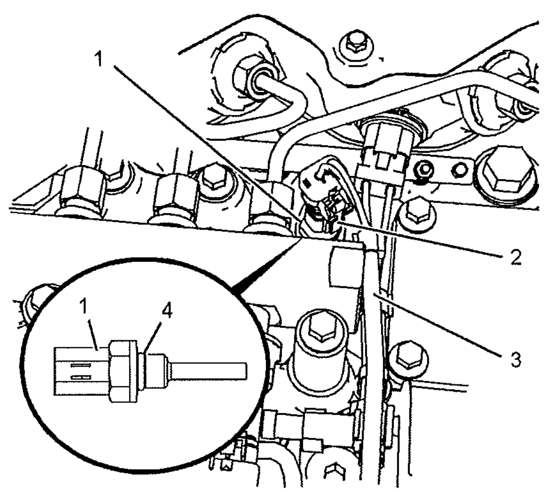

Illustration 346 g01480292

Typical example

1. Slide locking tab (2) into the unlocked position.

2. Disconnect harness assembly (3) from inlet air pressure sensor (1).

Note: The inlet air temperature sensor has a two wire plug.

3. Use a deep socket in order to remove inlet air temperature sensor (1) from the cylinder head.

4. Remove O-ring seal (4) from inlet air temperature sensor (1).

Installation Procedure

Table 88

Required Tools			
Tool	Part Number	Part Description	Qty
A	21820221	POWERPART Rubber Grease	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

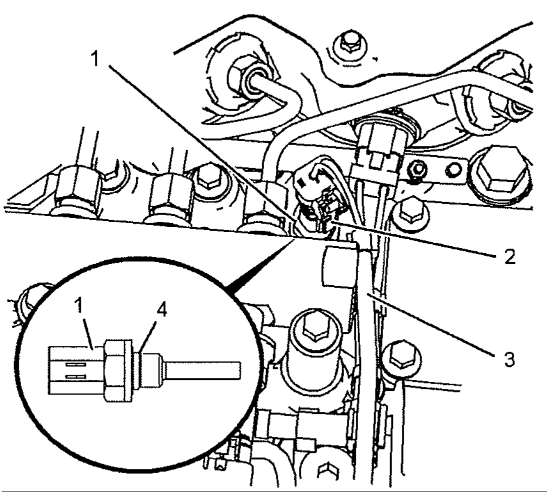

Illustration 347 g01480292

Typical example

1. Install a new O-ring seal (4) to the groove in inlet air temperature sensor (1). Lubricate the new O-ring seal with Tooling (A).
2. Install inlet air temperature sensor (1) to the cylinder head. Use a deep socket in order to tighten the inlet air temperature sensor to a torque of 20 N·m (15 lb ft).
3. Connect harness assembly (3) to inlet air temperature sensor (1).
4. Slide locking tab (2) into the locked position.

i02933653

Glow Plugs - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the battery disconnect switch to the OFF position.

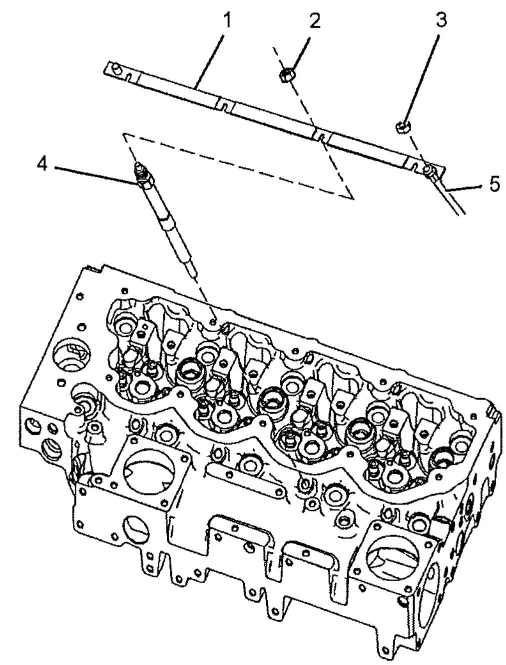

Illustration 348 g01245944

Typical example

2. Remove nut (3) and disconnect wire (5) from bus bar (1).

Note: The wire may be connected to either end of the bus bar. Note the position of the wire.

3. Remove nuts (2) that secure bus bar (1) to glow plugs (4).
4. Remove bus bar (1) from glow plugs (4).
5. Remove glow plugs (4) from the cylinder head.

Installation Procedure

Table 89

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610296	Torque Wrench	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the threads of the glow plugs are clean and free from damage. Replace any damaged glow plugs.

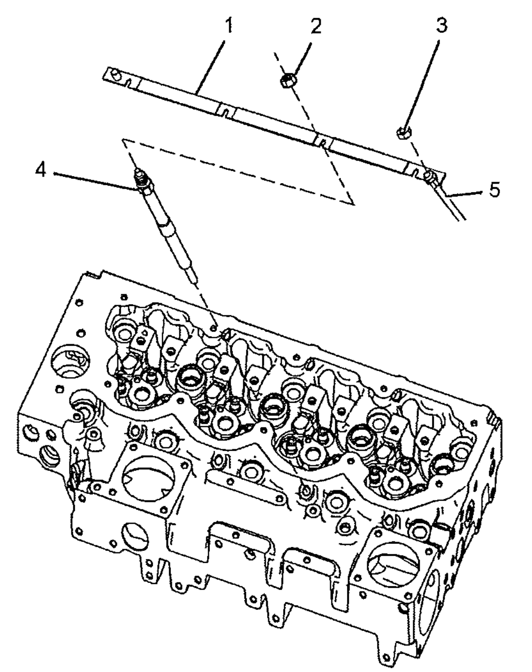

Illustration 349 g01245944

Typical example

2. Install glow plugs (4) into the cylinder head. Tighten the glow plugs to a torque of 15 N·m (132 lb in).

3. Position bus bar (1) onto glow plugs (4). Install nuts (2) onto the glow plugs. Use Tooling (A) in order to tighten the nuts to a torque of 2 N·m (17 lb in).

4. Connect wire (5) to the stud on bus bar (1).

Note: The wire may be connected to either end of the bus bar. Ensure that the wire is installed in the correct position.

5. Install nut (3) to the stud on bus bar (1). Tighten the nut to a torque of 6 N·m (53 lb in).

6. Turn the battery disconnect switch to the ON position.

i02933675

V-Belts - Remove and Install (Engines Without an Automatic Belt Tensioner)

Removal Procedure

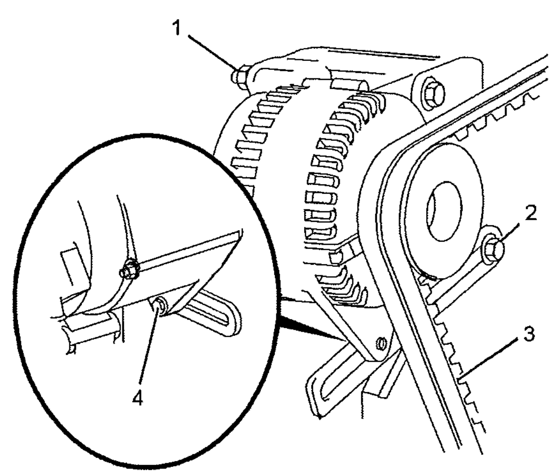

Illustration 350 g01401773

Typical example

1. If the engine is equipped with fan guards, remove the fan guards.

2. Loosen nut (1), bolt (2) and bolt (4). Slide the alternator toward the engine.

3. Remove V-belts (3).

Note: Mark the position and direction of rotation if the V-belts will be reused. Never replace single V-belts. Always replace V-belts as a pair.

Installation Procedure

Table 90

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Belt Tension Gauge	1

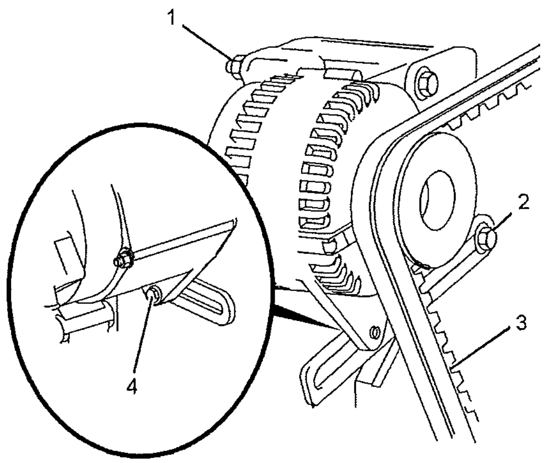

Illustration 351 g01401773

Typical example

1. Install V-belts (3) onto the correct pulleys.

Note: Used V-belts should be installed in the original position and direction of rotation.

2. Adjust the tension on the V-belts by moving the alternator away from the engine. Use Tooling (A) in order to achieve the correct belt tension. Refer to Specifications, "Belt Tension Chart" for more information. Tighten bolt (4) to a torque of 22 N·m (16 lb ft).
3. Tighten bolt (2) to a torque of 44 N·m (32 lb ft).
4. Tighten nut (1) to a torque of 22 N·m (16 lb ft).
5. If the engine is equipped with fan guards, install the fan guards.

i02933589

Alternator Belt - Remove and Install (Engines With an Automatic Belt Tensioner)

Removal Procedure

Table 91

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Locking Pin Ø 8mm by 85 mm	1

1. If the engine is equipped with fan guards, remove the fan guards.

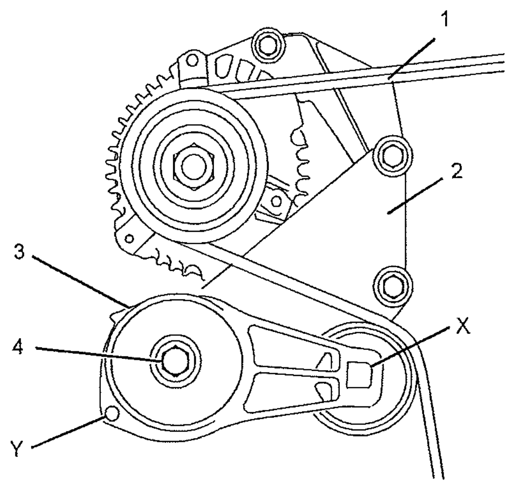

Illustration 352 g01260739

Typical example

2. Install a suitable square drive tool into Hole (X) in tensioner (3). From the front of the engine, turn the tool in a clockwise direction.
3. Insert Tooling (A) into Hole (Y). Release the pressure on the square drive tool.
4. Remove alternator belt (1).

Note: Mark the direction of rotation if the belt will be reused.

5. From the front of the engine, turn the square drive tool in a clockwise direction. Release the pressure on Tooling (A). Remove Tooling (A) from Hole (Y).

6. Release the pressure on the square drive tool and remove the tool from Hole (X).

7. If necessary, follow Step 7.a and Step 7.b in order to remove tensioner (3) from mounting bracket (2).

   a. Remove bolt (4) that secures tensioner (3) to mounting bracket (2).

   b. Remove tensioner (3) from mounting bracket (2).

Installation Procedure

Table 92

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Locking Pin Ø 8mm by 85 mm	1

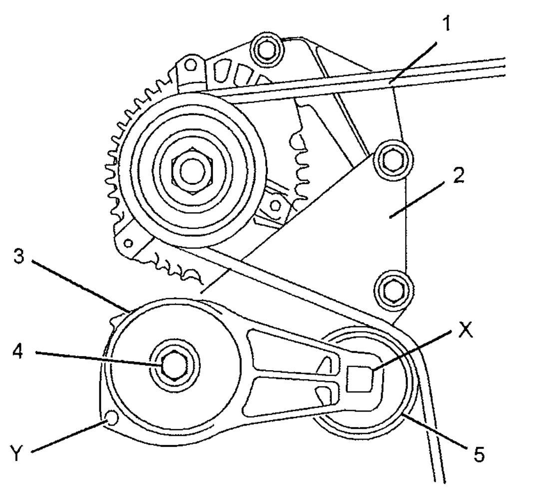

Illustration 353 g01270907

Typical example

1. If the tensioner was previously removed, follow Step 1.a through Step 1.c in order to install the tensioner.

   a. Align the dowel in the back of tensioner (3) with the hole in mounting bracket (2).

   b. Install tensioner (3) to mounting bracket (2).

   c. Install bolt (4). Tighten the bolt to a torque of 44 N·m (32 lb ft).

2. Install a suitable square drive tool into Hole (X) in tensioner (1). From the front of the engine, turn the tool in a clockwise direction.

3. Insert Tooling (A) into Hole (Y). Release the pressure on the square drive tool.

4. Install alternator belt (1). Ensure that the alternator belt is centered on pulley (5). A used alternator belt should be installed in the original direction of rotation.

Note: The ribs on the alternator belt must be located into the ribs of all pulleys.

5. From the front of the engine, turn the square drive tool in a clockwise direction. Release the pressure on Tooling (A). Remove Tooling (A) from Hole (Y).

6. Release the pressure on the square drive tool until the alternator belt is tensioned. Remove the tool from Hole (X).

Note: The tensioner should be at the nominal position.

7. If the engine is equipped with fan guards, install the fan guards.

i02933630

Fan - Remove and Install

Removal Procedure

Start By:

a. If the engine is equipped with an automatic belt tensioner, remove the Alternator Belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install". If the engine is not equipped with an automatic belt tensioner, remove the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

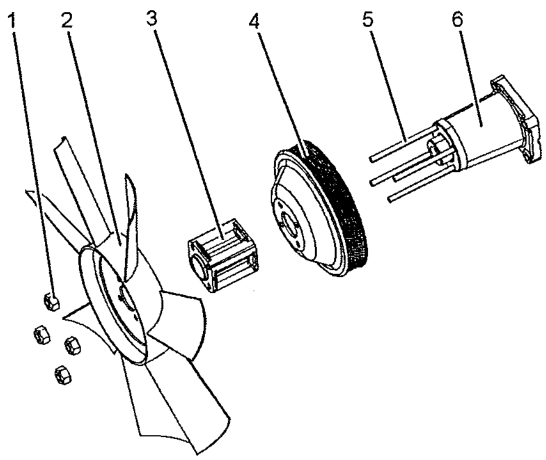

Illustration 354 g01270917

Typical example

1. Remove locking nuts (1).
2. Remove fan (2).

Note: Note the orientation of the fan.

3. Remove fan adapter (3).
4. Remove fan pulley (4).
5. If necessary, remove studs (5) from fan drive (6).

Installation Procedure

1. Ensure that all the components are free from wear or damage. If necessary, replace any components that are worn or damaged.

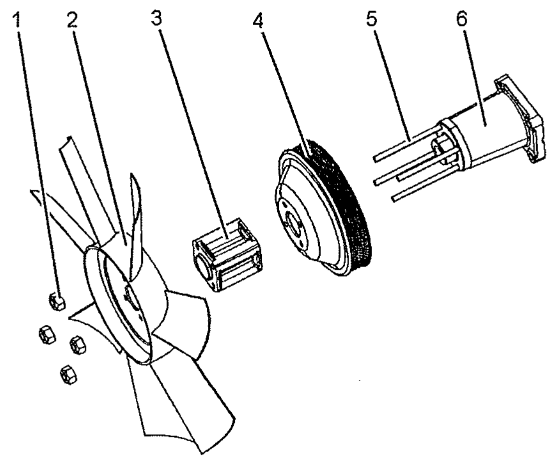

Illustration 355 g01270917

Typical example

2. If necessary, install studs (5) to fan drive (6).
3. Install fan pulley (4).
4. Install fan adapter (3).
5. Install fan (2).

Note: Ensure that the fan is correctly oriented.

6. Inspect the condition of locking nuts (1). If necessary, replace the locking nuts. Install locking nuts (1) and tighten to a torque of 22 N·m (16 lb ft).

End By:

a. If the engine is equipped with an automatic belt tensioner, install the Alternator Belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install". If the engine is not equipped with an automatic belt tensioner, install the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

i02933631

Fan Drive - Remove and Install

Removal Procedure

Start By:

a. Remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

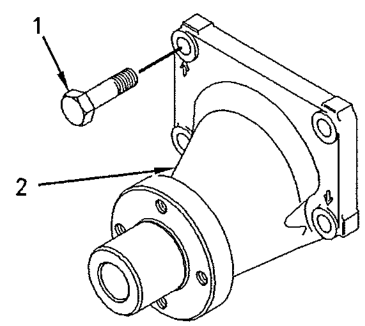

Illustration 356 g00944500

Typical example

1. Remove bolts (1) from fan drive (2).

Note: Identify the orientation and the position of the fan drive.

2. Remove fan drive (2).

Installation Procedure

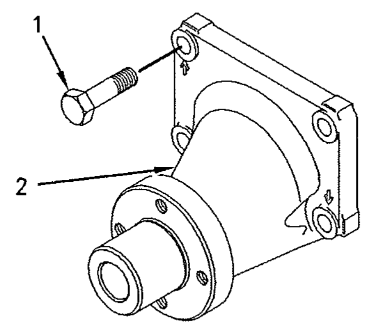

Illustration 357 g00944500

Typical example

1. Check the fan drive for wear or damage. The fan drive is not a serviceable item. If the fan drive is worn or damaged, replace the fan drive.

2. Install fan drive (2).

Note: Ensure the correct orientation of the fan drive.

3. Install bolts (1). Tighten the bolts to a torque of 44 N·m (32 lb ft).

End By:

a. Install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933616

Electronic Control Module - Remove and Install

Removal Procedure

NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

Note: Some engines do not have a fuel supply to the electronic control module.

1. Turn the battery disconnect switch to the OFF position.

2. If the electronic control module is equipped with a fuel supply, turn the fuel supply to the OFF position.

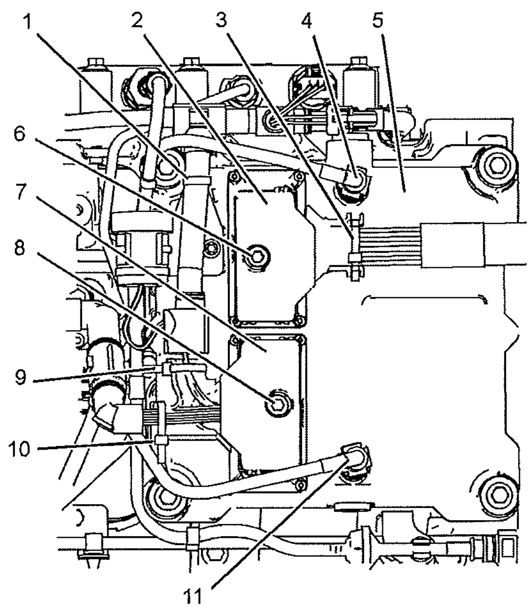

Illustration 358 g01271315

Typical example

3. Cut cable strap (3). Unscrew bolt (6) that secures machine wiring harness (2) to electronic control module (5). Disconnect the machine wiring harness from the electronic control module.

4. Cut cable straps (1), (9) and (10). Unscrew bolt (8) that secures engine harness (7) to electronic control module (5). Disconnect the engine harness from the electronic control module.

5. If the electronic control module is equipped with a fuel supply, disconnect plastic tube assembly (4) and plastic tube assembly (11).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are plugged.

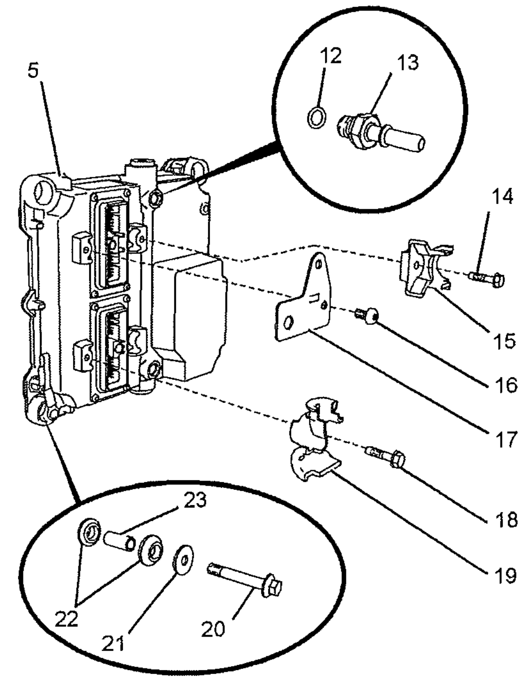

Illustration 359 g01807973

Typical example

6. Remove bolts (20) and remove the assembly of the electronic control module. Note the position of any brackets that are secured by bolts (20). Note the orientation of the electronic control module.

7. Remove bolts (20) and remove washers (18) from electronic control module (5). Note the position of the ground strap for the electronic control module.

8. If necessary, follow Step 8.a through Step 8.e in order to disassemble the electronic control module.

    a. Remove isolation mounts (22) and spacers (23).

    b. Remove connectors (13). Remove O-ring seals (12) from the connectors.

    c. Remove bolt (18) and remove bracket (19) for the engine wiring harness. Note the orientation of the bracket.

    d. Loosen bolt (16) and remove bracket (17) from the engine wiring harness. Note the orientation of the bracket.

    e. Remove bolt (14) and remove bracket (15) for the machine wiring harness. Note the orientation of the bracket.

Installation Procedure

Table 93

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610296	Torque Wrench	1

1. If a replacement electronic control module is installed, the module must be programmed with the correct information. Refer to Troubleshooting, "Replacing the ECM" and refer to Troubleshooting, "Flash Programming" for the correct procedure.

2. Ensure that the electronic control module is clean and free from damage. If necessary, replace the electronic control module.

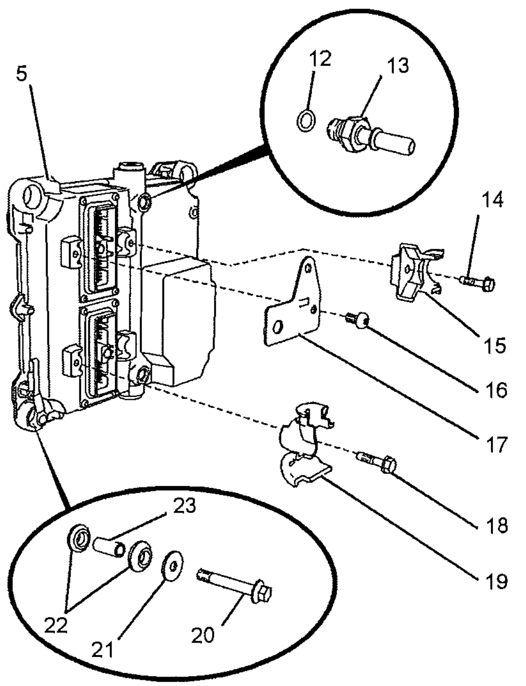

Illustration 360 g01807973

Typical example

3. If necessary, follow Step 3.a through Step 3.e in order to assemble the electronic control module.

   a. Install new O-ring seals (12) to connectors (13). Install connectors (13) to electronic control module (5). Tighten the connectors to a torque of 18 N·m (13 lb ft).

   b. Position bracket (17) on electronic control module (5). Ensure that the bracket is correctly oriented. Install torx screw (16). Tighten the torx screw to a torque of 7 N·m (62 lb in).

   c. Position bracket (19) on electronic control module (5). Ensure that the bracket is correctly oriented. Install bolt (18). Tighten the bolt to a torque of 9 N·m (80 lb in).

   d. Position bracket (15) for the machine wiring harness on electronic control module (5). Ensure that the bracket is correctly oriented and install bolt (14). Tighten the bolt to a torque of 9 N·m (80 lb in).

   e. Install isolation mounts (22) and spacers (23) to electronic control module (5).

4. Install washers (21) and bolts (20) to electronic control module (5).

Note: Ensure that the ground strap for the electronic control module is clamped between the washer and the appropriate bolt.

5. Install the assembly of the electronic control module to the mounting bracket . Ensure that any brackets that are secured by bolts (20) are installed in the correct position. Tighten bolts (20) to a torque of 22 N·m (16 lb ft).

Note: Ensure that the electronic control module is correctly oriented. Ensure that the ground strap is not strained as the bolt is tightened.

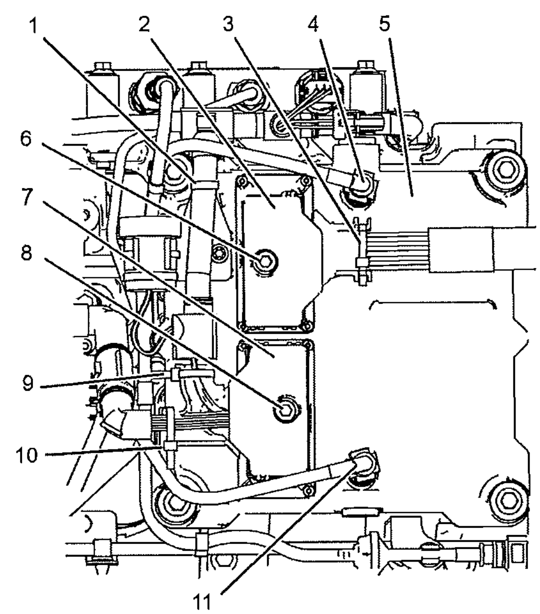

Illustration 361 g01271315

Typical example

6. If the electronic control module is equipped with a fuel supply, connect plastic tube assembly (4) and tube assembly (11) to electronic control module (5).

Note: If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are connected.

7. Connect engine wiring harness (7) to electronic control module (5). Use Tooling (A) to tighten bolt (8) to a torque of 5 N·m (44 lb in). If the engine is equipped with a diagnostic connection, install the diagnostic connection to the support clip.

Note: Care must be taken in order to avoid damage to the connector pins during installation of the harness.

8. Position the assembly of the engine wiring harness onto bracket (15), bracket (17) and bracket (19). Use new cable straps (1), (9) and (10) in order to secure the harness assembly to the brackets.

9. Connect machine wiring harness (2) to electronic control module (5). Use Tooling (A) to tighten bolt (6) to a torque of 5 N·m (44 lb in).

Note: Care must be taken in order to avoid damage to the connector pins during installation of the harness.

10. Use a new cable strap (3) in order to secure the machine wiring harness (2).

11. If the electronic control module is equipped with a fuel supply, turn the fuel supply to ON position.

12. Turn the battery disconnect switch to the ON position.

13. If the electronic control module is equipped with a fuel supply, remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933614

ECM Mounting Bracket - Remove and Install

Removal Procedure

Start By:

a. Remove the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

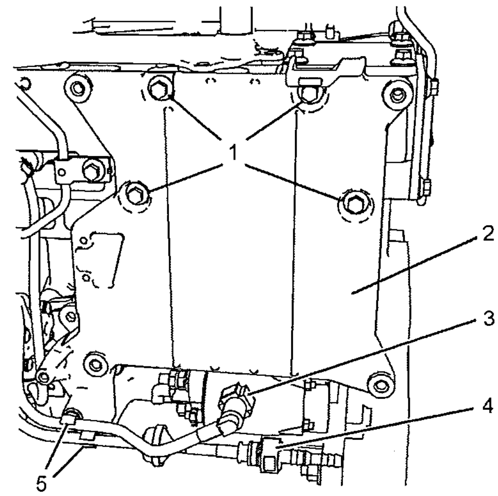

Illustration 362 g01254468

Typical example

1. Remove plastic tube assembly (3) and assembly (4) from clips (5).

2. Cut the cable strap and position the engine wiring harness away from mounting bracket (2).

3. Remove bolts (1) and remove mounting bracket (2) from the cylinder head.

4. If necessary, remove clips (5) from mounting bracket (2).

Installation Procedure

1. Ensure that the mounting bracket for the electronic control module is clean and free from damage. If necessary, replace the mounting bracket.

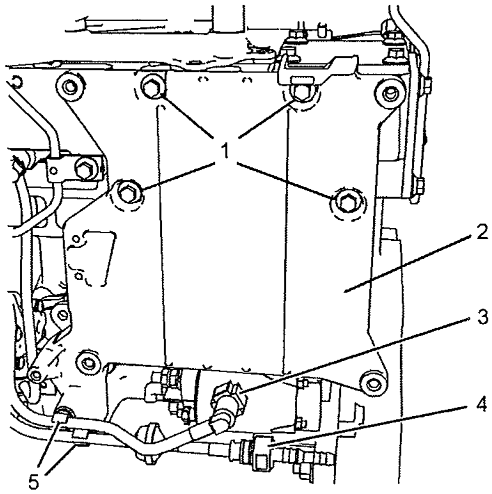

Illustration 363 g01254468

Typical example

2. If necessary, install clips (5) to mounting bracket (2).

3. Position mounting bracket (2) against the cylinder head. Install bolts (1). Tighten the bolts to a torque of 22 N·m (16 lb ft).

4. Position the engine wiring harness against mounting bracket (2). Secure the engine wiring harness with a new cable strap.

5. Install plastic tube assembly (3) and assembly (4) to clips (5).

End By:

a. Install the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

i02933588

Alternator - Remove (Engines Without an Automatic Belt Tensioner)

Removal Procedure

Start By:

a. Remove the V-belts. Refer to Disassembly and Assembly, "V-belts - Remove and Install".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the battery disconnect switch to the OFF position.

2. Make temporary identification marks on the connections of the harness assembly.

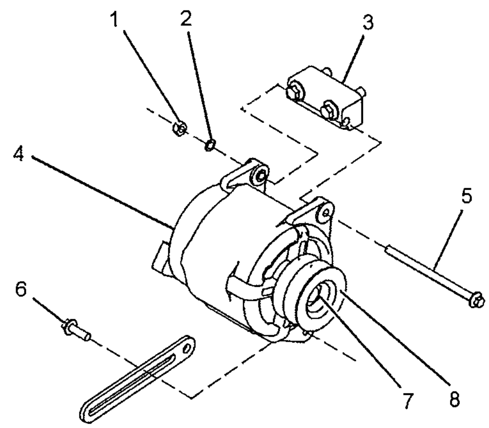

Illustration 364 g01255718

Typical Example

3. Disconnect the harness assembly from alternator (4).

4. Remove bolt (6) from alternator (4).

5. Remove nut (1) and washer (2). Remove bolt (5) from alternator (4). Remove alternator (4) from alternator bracket (3).

6. If necessary, remove pulley (8) from alternator (4). Follow Step 6.a and Step 6.b for the method in order to remove the pulley from the alternator.

Note: This method may not be suitable for some configurations of pulley.

   a. Hold the shaft of alternator (4) with an allen wrench. Use a cranked ring spanner (box wrench) in order to loosen nut (7).

   b. Remove nut (7) and pulley (8) from alternator (4).

i02933586

Alternator - Remove (Engines With an Automatic Belt Tensioner)

Removal Procedure

Start By:

a. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the battery disconnect switch to the OFF position.
2. Make temporary identification marks on the connections of the harness assembly.

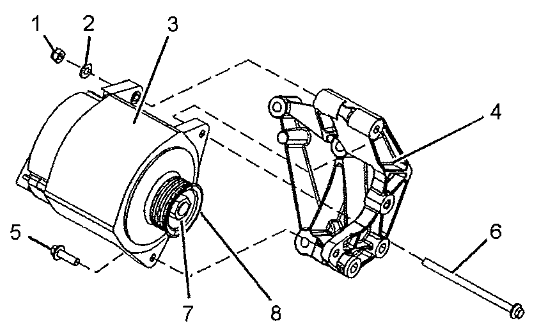

Illustration 365 g01271317

Typical example

3. Disconnect the harness assembly from alternator (3).
4. Remove bolt (5) from alternator (3).
5. Remove nut (1) and washer (2). Remove bolt (6) from alternator (3). Remove the alternator from alternator bracket (4).
6. If necessary, follow Step 6.a and Step 6.b in order to remove pulley (8) from alternator (1).

    a. Hold the shaft of alternator (3) with an allen wrench. Use a cranked ring spanner (box wrench) in order to loosen nut (7).

    b. Remove nut (7) and pulley (8) from alternator (3).

i02933587

Alternator - Install (Engines Without an Automatic Belt Tensioner)

Installation Procedure

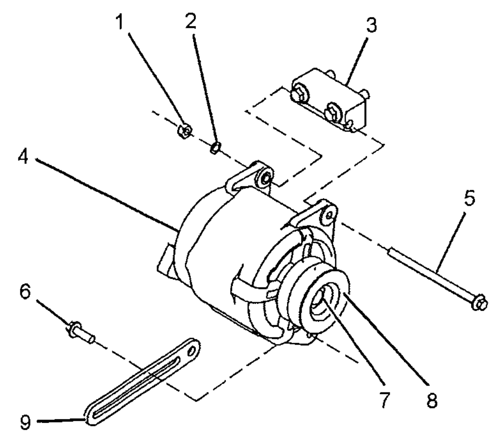

Illustration 366 g01263045

Typical example

1. If necessary, install the pulley to the alternator. Follow Step 1.a and Step 1.b in order to install the pulley to the alternator.

Note: This method may not be suitable for some configurations of pulley.

    a. Install pulley (8) and nut (7) to the shaft of alternator (4).

    b. Hold the shaft of the alternator with an allen wrench. Use a cranked ring spanner (box wrench) in order to tighten nut (7). Tighten the nut to a torque of 80 N·m (59 lb ft).

2. Install alternator (4) to bracket (3) and install bolt (5) to alternator (4).
3. Install washer (2) and nut (1) to bolt (5) finger tight.
4. Install bolt (6) through adjusting link (9) to alternator (4) finger tight.

5. Install the V-belts. Refer to Disassembly and assembly, "V-belts - Remove and Install" for the correct procedure.

6. Tighten nut (1) and bolt (6) to a torque of 22 N·m (16 lb ft).

7. Connect the wiring harness assembly to alternator (4).

8. Turn the battery disconnect switch to the ON position.

i02933585

Alternator - Install (Engines With an Automatic Belt Tensioner)

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

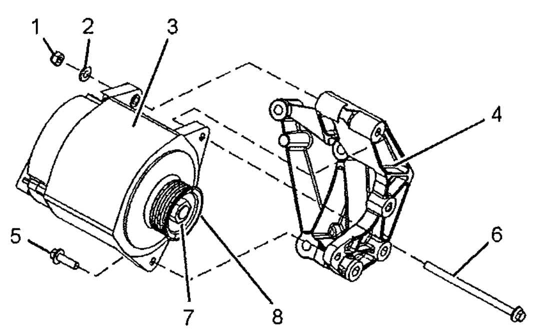

Illustration 367 g01271317

Typical example

1. If necessary, install pulley (8) and nut (7) to alternator (3). Hold the shaft of the alternator with an allen wrench. Use a cranked ring spanner (box wrench) in order to tighten nut (7).

Note: Different types of alternator have different sizes of nut. Ensure that the correct torque value is used for the nut.

Tighten M16 and M17 nuts to a torque of 80 N·m (59 lb ft). Tighten 5/8 inch - 18 UNF nuts to a torque of 102 N·m (75 lb ft).

2. Position alternator (3) on alternator mounting bracket (4).

3. Install bolt (6) to alternator (3). Install washer (2) and nut (1) to bolt (6).

4. Install bolt (5) to alternator (3).

5. Tighten nut (1) and bolt (5) to a torque of 22 N·m (16 lb ft).

6. Connect the wiring harness assembly to alternator (3).

7. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

8. Turn the battery disconnect switch to the ON position.

i02933615

Electric Starting Motor - Remove and Install

Removal Procedure

WARNING

Accidental engine starting can cause injury or death to personnel working on the equipment.

To avoid accidental engine starting, disconnect the battery cable from the negative (−) battery terminal. Completely tape all metal surfaces of the disconnected battery cable end in order to prevent contact with other metal surfaces which could activate the engine electrical system.

Place a Do Not Operate tag at the Start/Stop switch location to inform personnel that the equipment is being worked on.

1. Turn the battery disconnect switch to the OFF position.

2. If necessary, remove the hose for the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

3. Make temporary identification marks on the harness assemblies that are connected to the electric starting motor and to the solenoid.

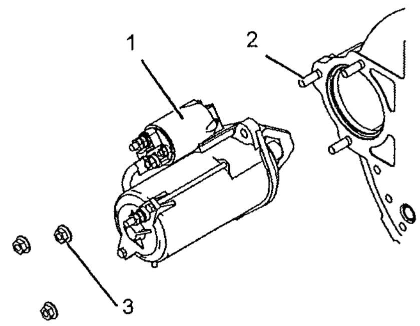

Illustration 368 g01261155

Typical example

4. Disconnect the harness assemblies from the electric starting motor and from the solenoid.

5. Remove nuts (3) from electric starting motor (1).

Note: Support the weight of the electric starting motor as the nuts are removed.

6. Remove electric starting motor (1).

7. If necessary, remove studs (2).

Installation Procedure

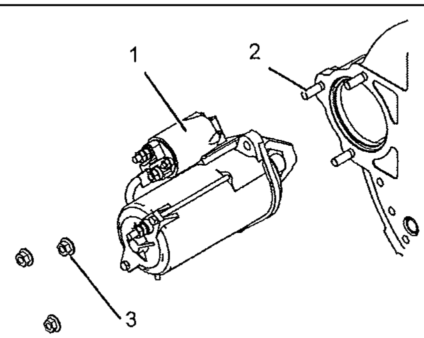

Illustration 369 g01261155

Typical example

1. If necessary, install studs (2).

2. Align electric starting motor (1) to studs (2). Install the electric starting motor.

3. Install nuts (3).

   Tighten M10 nuts to a torque of 44 N·m (32 lb ft).

   Tighten M12 nuts to a torque of 78 N·m (57 lb ft).

4. Connect the harness assemblies to the electric starting motor and the solenoid.

5. If necessary, install the hose for the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

6. Turn the battery disconnect switch to the ON position.

i02933584

Air Compressor - Remove and Install

Removal Procedure

Table 94

Required Tools			
Tool	Part Number	Part Description	Qty
A[1]	21825576	Crankshaft Turning Tool	1
A[2]	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610211	Crankshaft Timing Pin	1
C	-	Puller (Three Leg)	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Put identification marks on all hoses, on all hose assemblies and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

⚠ WARNING

Do not disconnect the air lines until the air pressure in the system is at zero. If hose is disconnected under pressure it can cause personal injury.

1. Release the pressure from the air system.

2. Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

3. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

4. If the engine is equipped with a hydraulic pump on the rear of the air compressor, remove the hydraulic pump.

5. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

Note: The air compressor must be timed with the engine in order to minimize engine vibration.

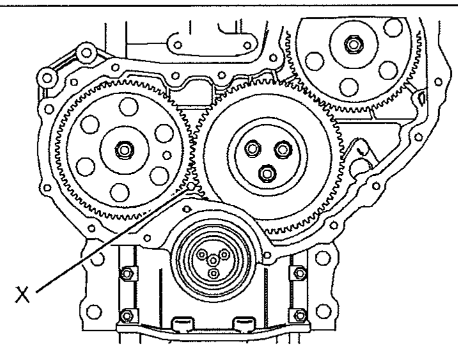

Illustration 370 g01272266

Typical example

6. Install Tooling (B) through Hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft.

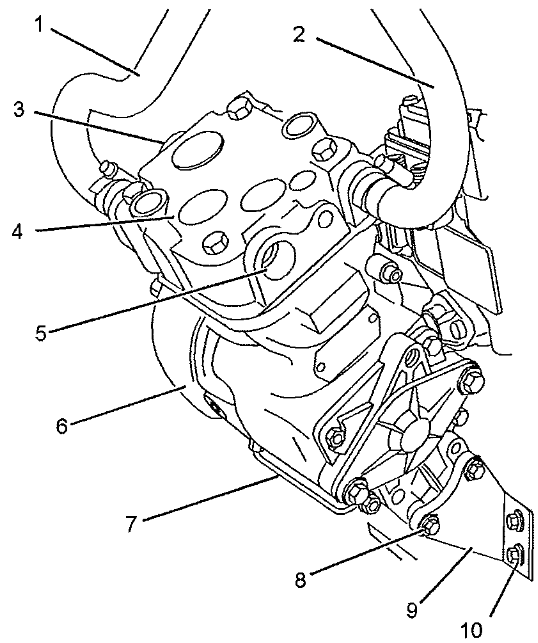

Illustration 371 g01250794

Typical example

7. Disconnect coolant hoses (1) and (2) from air compressor (4).

8. Disconnect the air lines from ports (3) and (5).

9. Remove tube assembly (7) from air compressor (4) and from the cylinder block.

10. Remove bolts (8) and (10) from support bracket (9) and remove the support bracket.

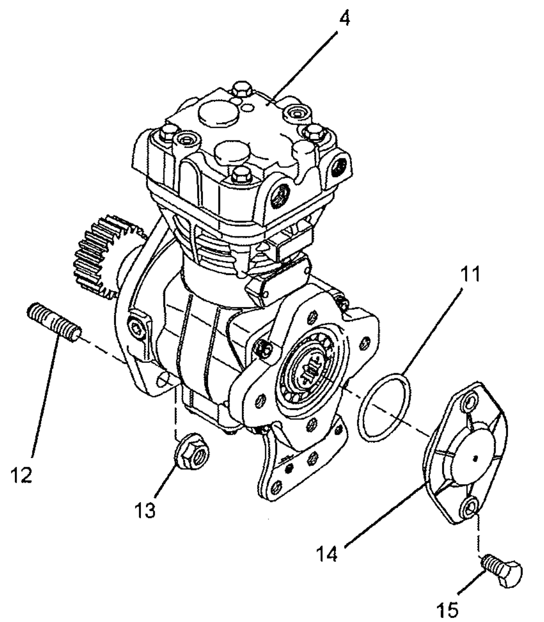

Illustration 372 g01250816

Typical example

11. Support air compressor (4). Remove nuts (13) and remove the air compressor from front housing (6).

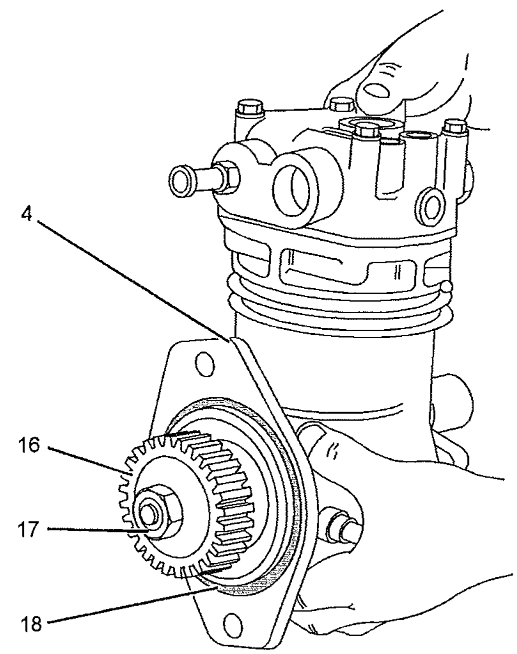

Illustration 373 g01250889

Typical example

12. Remove O-ring seal (18) from air compressor (4).

13. If necessary, remove bolts (15) and remove plate (14). Remove O-ring seal (11) from plate (14). Refer to Illustration 372.

14. If necessary, remove nut (17) and remove the spring washer. Use Tooling (C) in order to remove gear (16) from the crankshaft of the air compressor.

Installation Procedure

Table 95

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610211	Crankshaft Timing Pin	1
D	21826051	POWERPART High Strength Retainer	-
E	21820221	POWERPART Rubber Grease	-

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

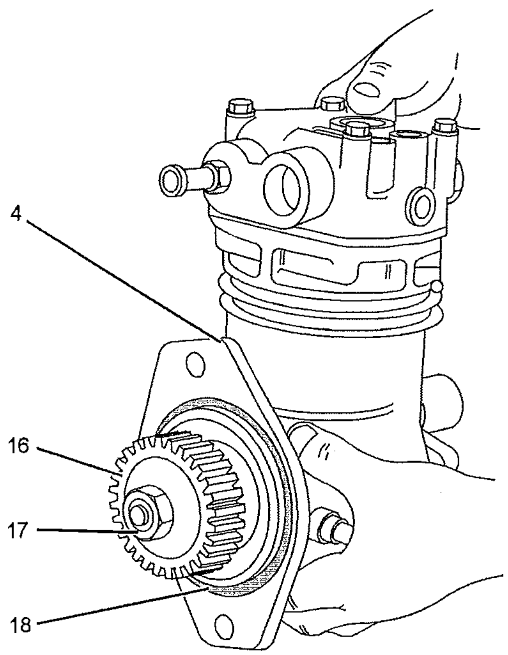

Illustration 374 g01250889

Typical example

1. If necessary, follow Step 1.a through Step 1.b in order to install the gear to the air compressor.

    a. Ensure that the shaft of air compressor (4) is clean and dry. Ensure that gear (16) is clean and free from damage.

    b. Install gear (16) and a new spring washer to the shaft of the air compressor.

    c. Apply Tooling (D) to the threads of the shaft. Install nut (17) to the shaft of air compressor (4). Tighten the nut to a torque of 120 N·m (89 lb ft).

2. Install the O-ring seal to air compressor (4). Use Tooling (E) in order to lubricate the O-ring seal.

3. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

Note: The air compressor must be timed with the engine in order to minimize engine vibration.

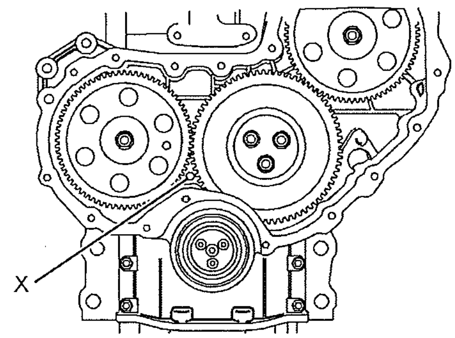

Illustration 375 g01272266

Typical example

4. Ensure that Tooling (B) is installed in Hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

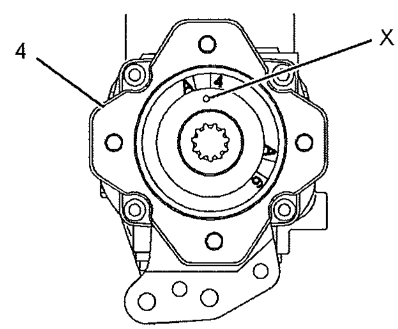

Illustration 376 g01250968

Typical air compressor with a SAE drive

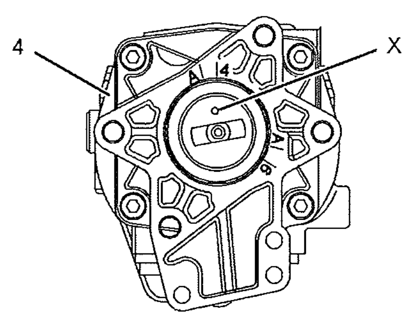

Illustration 377 g01251223

Typical air compressor with a DIN drive

5. Rotate the crankshaft of the air compressor until timing Mark (X) is aligned with timing mark A4 on the rear face of air compressor (4). Refer to Illustration 376 for air compressors with a SAE drive. Refer to Illustration 377 for air compressors with a DIN drive.

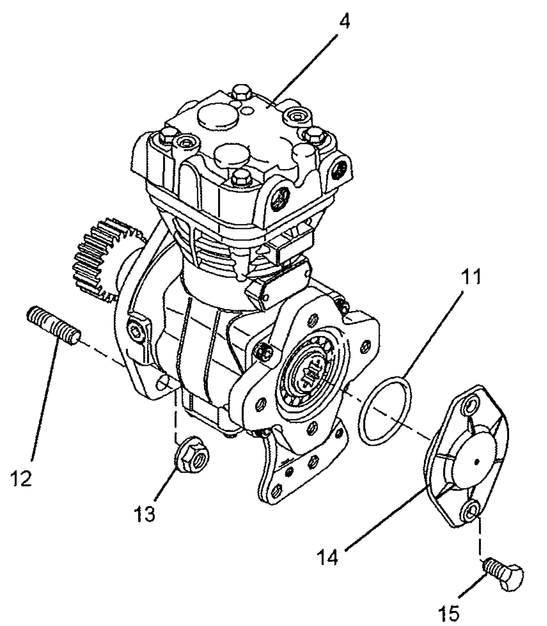

Illustration 378 g01250816

Typical example

6. Align air compressor (4) with studs (12). Install the air compressor to the front housing. If necessary, rotate the crankshaft of the air compressor in a clockwise direction in order to align the gears.

Note: Ensure that timing Mark (X) is aligned with timing mark A4. Refer to Illustration 376 for air compressors with a SAE drive. Refer to Illustration 377 for air compressors with a DIN drive.

7. Install nuts (13). Tighten the nuts to a torque of 78 N·m (58 lb ft).

8. If necessary, follow Step 8.a through Step 8.c in order to install cover (14).

   a. Install a new O-ring seal (11) to cover (14). Use Tooling (E) in order to lubricate the O-ring seal.

   b. Install cover (14) to air compressor (4).

   c. Install bolts (15). Tighten the bolts to a torque of 13 N·m (9.5 lb ft).

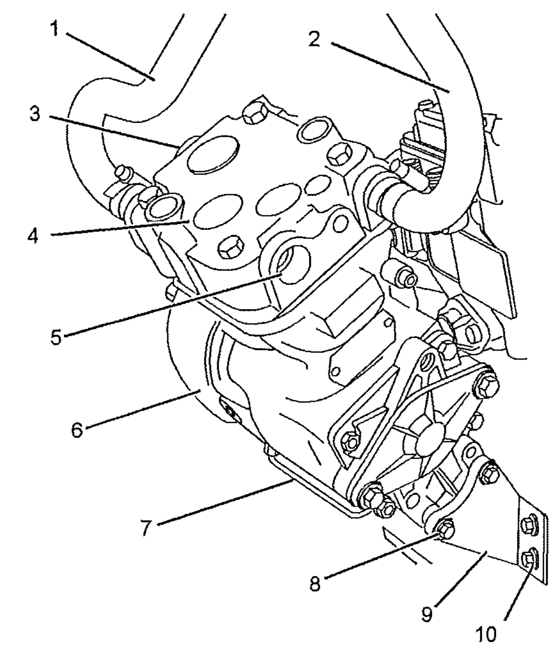

Illustration 379 g01250794

Typical example

9. Position support bracket (9) onto air compressor (4). Install bolts (8) finger tight.

10. Install bolts (10) finger tight.

11. Tighten bolts (8) to a torque of 22 N·m (16 lb ft). Tighten bolts (10) to a torque 22 N·m (16 lb ft).

Note: Ensure that the air compressor is not stressed as the bolts are tightened.

12. Install tube assembly (7) to air compressor (4) and to the cylinder block. Tighten the nuts to a torque of 9 N·m (80 lb in).

13. Remove Tooling (B) from Hole (X) in the front housing.

14. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

15. If the engine is equipped with a hydraulic pump on the rear of the air compressor, install the hydraulic pump.

16. Connect the air lines to ports (3) and (5) in the air compressor.

17. Connect coolant hoses (1) and (2) to air compressor (4).

18. Fill the cooling system with coolant to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

i02933676

Vacuum Pump - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Put identification marks on all hoses, on all hose assemblies and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

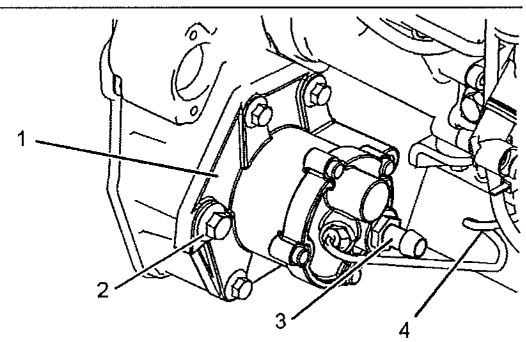

Illustration 380 g01254510

Typical example

1. Remove tube assembly (4) from vacuum pump (1) and from the cylinder block.
2. Disconnect the vacuum line from connector (3) on the vacuum pump.
3. Remove bolts (2). Remove vacuum pump (1) from the front housing.
4. Remove the gasket.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

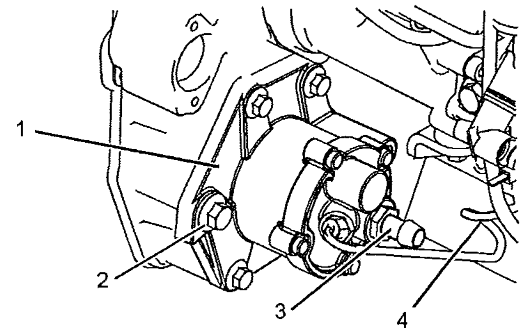

Illustration 381 g01254510

Typical example

1. Ensure that the vacuum pump is clean and free from damage. If necessary, replace the vacuum pump.
2. Clean the surfaces on the front housing.
3. Install a new gasket to vacuum pump (1).
4. Install vacuum pump (1) to the front housing. If necessary, rotate the shaft of the vacuum pump in order to align the gears.
5. Install bolts (2).

   Tighten M8 bolts to a torque of 22 N·m (16 lb ft).

   Tighten M10 bolts to a torque of 44 N·m (32 lb ft).
6. Connect the vacuum line to connector (3).
7. Install tube assembly (4) to vacuum pump (1) and to the cylinder block. Tighten the nuts on the tube assembly to a torque of 9 N·m (80 lb in).

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Perkins®

SEBU8172-02
July 2012

Operation and Maintenance Manual

1104D Industrial Engine

NH (Engine)
NJ (Engine)

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the “Safety Alert Symbol” and followed by a “Signal Word” such as “DANGER”, “WARNING” or “CAUTION”. The Safety Alert “WARNING” label is shown below.

WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

Perkins cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Perkins is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Perkins dealers or Perkins distributors have the most current information available.

WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

Table of Contents

Foreword

Literature Information

This manual contains safety, operation instructions, lubrication and maintenance information. This manual should be stored in or near the engine area in a literature holder or literature storage area. Read, study and keep it with the literature and engine information.

English is the primary language for all Perkins publications. The English used facilitates translation and consistency in electronic media delivery.

Some photographs or illustrations in this manual show details or attachments that may be different from your engine. Guards and covers may have been removed for illustrative purposes. Continuing improvement and advancement of product design may have caused changes to your engine which are not included in this manual. Whenever a question arises regarding your engine, or this manual, please consult with your Perkins dealer for the latest available information.

Safety

This safety section lists basic safety precautions. In addition, this section identifies hazardous, warning situations. Read and understand the basic precautions listed in the safety section before operating or performing lubrication, maintenance and repair on this product.

Operation

Operating techniques outlined in this manual are basic. They assist with developing the skills and techniques required to operate the engine more efficiently and economically. Skill and techniques develop as the operator gains knowledge of the engine and its capabilities.

The operation section is a reference for operators. Photographs and illustrations guide the operator through procedures of inspecting, starting, operating and stopping the engine. This section also includes a discussion of electronic diagnostic information.

Maintenance

The maintenance section is a guide to engine care. The illustrated, step-by-step instructions are grouped by fuel consumption, service hours and/or calendar time maintenance intervals. Items in the maintenance schedule are referenced to detailed instructions that follow.

Use fuel consumption or service hours to determine intervals. Calendar intervals shown (daily, annually, etc.) may be used instead of service meter intervals if they provide more convenient schedules and approximate the indicated service meter reading.

Recommended service should be performed at the appropriate intervals as indicated in the Maintenance Interval Schedule. The actual operating environment of the engine also governs the Maintenance Interval Schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

The maintenance schedule items are organized for a preventive maintenance management program. If the preventive maintenance program is followed, a periodic tune-up is not required. The implementation of a preventive maintenance management program should minimize operating costs through cost avoidances resulting from reductions in unscheduled downtime and failures.

Maintenance Intervals

Perform maintenance on items at multiples of the original requirement. Each level and/or individual items in each level should be shifted ahead or back depending upon your specific maintenance practices, operation and application. We recommend that the maintenance schedules be reproduced and displayed near the engine as a convenient reminder. We also recommend that a maintenance record be maintained as part of the engine's permanent record.

See the section in the Operation and Maintenance Manual, “Maintenance Records” for information regarding documents that are generally accepted as proof of maintenance or repair. Your authorized Perkins dealer can assist you in adjusting your maintenance schedule to meet the needs of your operating environment.

Overhaul

Major engine overhaul details are not covered in the Operation and Maintenance Manual except for the interval and the maintenance items in that interval. Major repairs are best left to trained personnel or an authorized Perkins dealer. Your Perkins dealer offers a variety of options regarding overhaul programs. If you experience a major engine failure, there are also numerous after failure overhaul options available from your Perkins dealer. Consult with your dealer for information regarding these options.

California Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

Battery posts, terminals and related accessories contain lead and lead compounds. **Wash hands after handling.**

Safety Section

i02864025

Safety Messages

There may be several specific warning signs on your engine. The exact location and a description of the warning signs are reviewed in this section. Please become familiar with all warning signs.

Ensure that all of the warning signs are legible. Clean the warning signs or replace the warning signs if the words cannot be read or if the illustrations are not visible. Use a cloth, water, and soap to clean the warning signs. Do not use solvents, gasoline, or other harsh chemicals. Solvents, gasoline, or harsh chemicals could loosen the adhesive that secures the warning signs. The warning signs that are loosened could drop off of the engine.

Replace any warning sign that is damaged or missing. If a warning sign is attached to a part of the engine that is replaced, install a new warning sign on the replacement part. Your Perkins dealer or your distributor can provide new warning signs.

(1) Universal Warning

WARNING

Do not operate or work on this equipment unless you have read and understand the instructions and warnings in the Operation and Maintenance Manuals. Failure to follow the instructions or heed the warnings could result in serious injury or death.

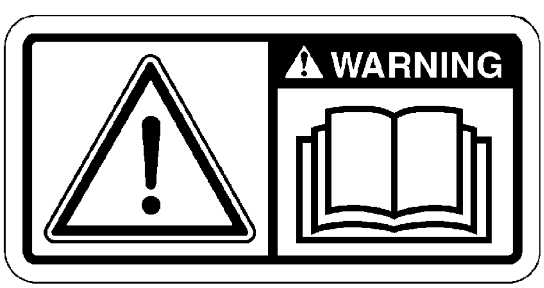

Illustration 1 g01154807

Typical example

The Universal Warning label (1) is located on both sides of the valve mechanism cover base. Refer to illustration 1.

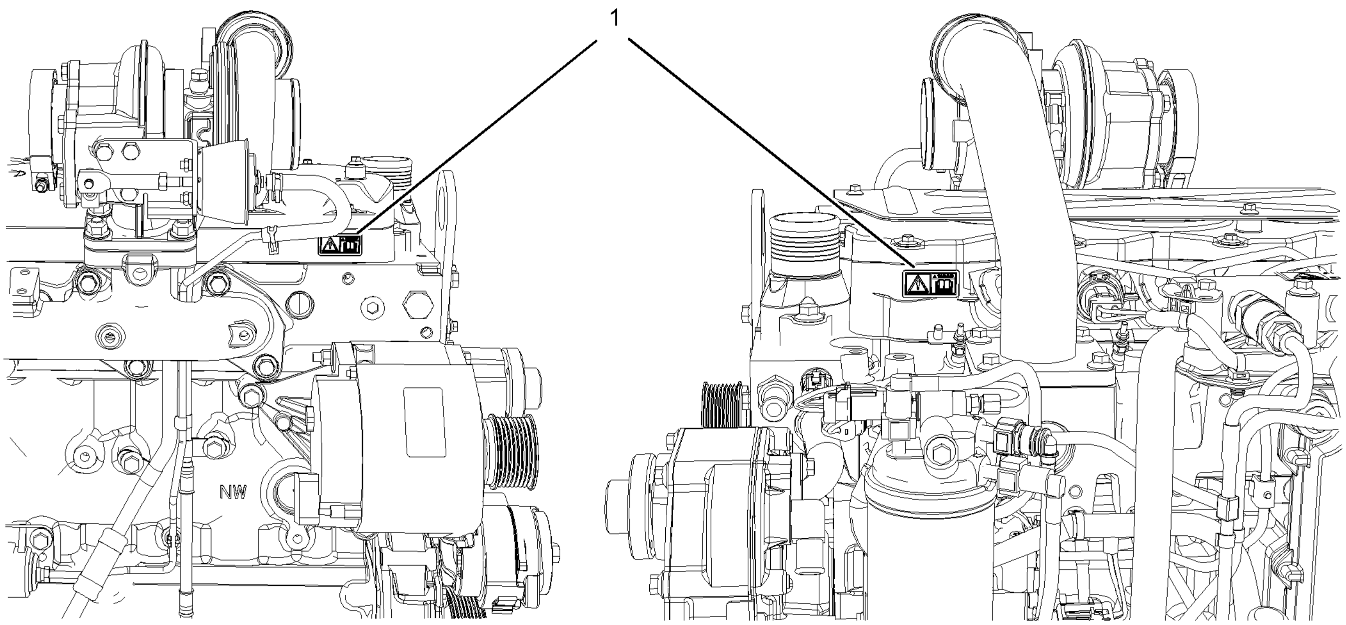

Illustration 2 g01268960

(1) Universal warning

(2) Hand (High Pressure)

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

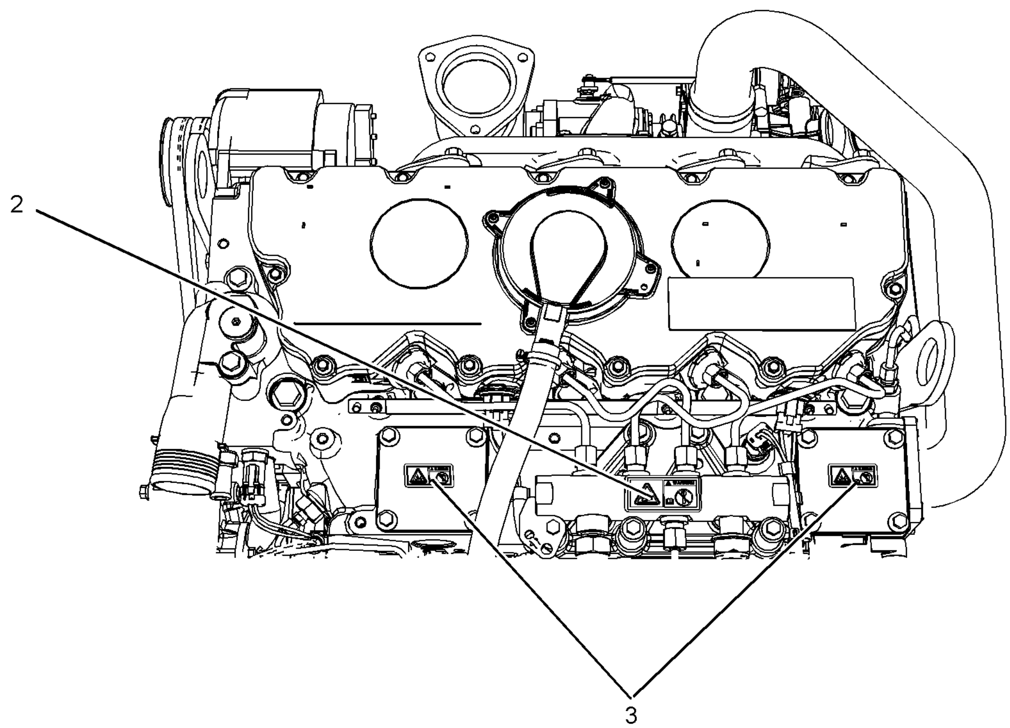

Illustration 3 g01426636

(2) Hand (High Pressure)
(3) Ether

Illustration 4 g01154858

Typical example

The warning label for the Hand (High Pressure) (2) is located on the top of the fuel manifold. Refer to illustration 4.

(3) Ether

WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

Illustration 5 g01154809

Typical example

The ether warning label (3) is located on the cover of the inlet manifold. Refer to illustration 4.

Note: The location of this label will depend on the application of the engine.

i02328435

General Hazard Information

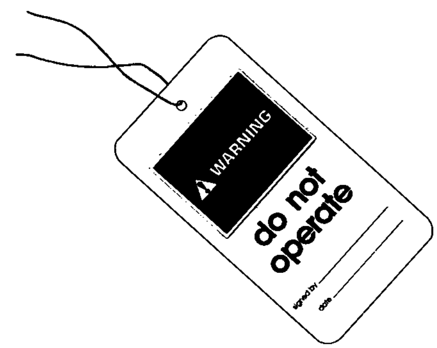

Illustration 6 g00104545

Attach a “Do Not Operate” warning tag or a similar warning tag to the start switch or to the controls before you service the equipment or before you repair the equipment.

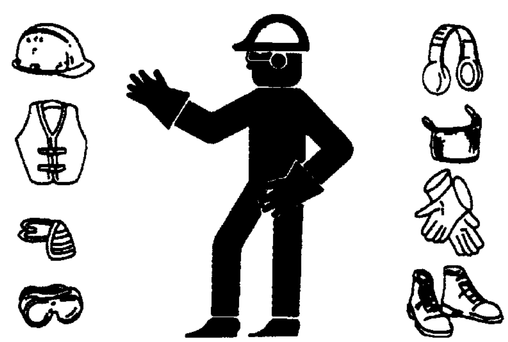

Illustration 7 g00702020

Wear a hard hat, protective glasses, and other protective equipment, as required.

Do not wear loose clothing or jewelry that can snag on controls or on other parts of the engine.

Make sure that all protective guards and all covers are secured in place on the engine.

Keep the engine free from foreign material. Remove debris, oil, tools, and other items from the deck, from walkways, and from steps.

Never put maintenance fluids into glass containers. Drain all liquids into a suitable container.

Obey all local regulations for the disposal of liquids.

Use all cleaning solutions with care.

Report all necessary repairs.

Do not allow unauthorized personnel on the equipment.

Ensure that the power supply is disconnected before you work on the bus bar or the glow plugs.

Perform maintenance on the engine with the equipment in the servicing position. Refer to the OEM information for the procedure for placing the equipment in the servicing position.

Pressure Air and Water

Pressurized air and/or water can cause debris and/or hot water to be blown out. This could result in personal injury.

The direct application of pressurized air or pressurized water to the body could result in personal injury.

When pressurized air and/or water is used for cleaning, wear protective clothing, protective shoes, and eye protection. Eye protection includes goggles or a protective face shield.

The maximum air pressure for cleaning purposes must be below 205 kPa (30 psi). The maximum water pressure for cleaning purposes must be below 275 kPa (40 psi).

Fluid Penetration

Pressure can be trapped in the hydraulic circuit long after the engine has been stopped. The pressure can cause hydraulic fluid or items such as pipe plugs to escape rapidly if the pressure is not relieved correctly.

Do not remove any hydraulic components or parts until pressure has been relieved or personal injury may occur. Do not disassemble any hydraulic components or parts until pressure has been relieved or personal injury may occur. Refer to the OEM information for any procedures that are required to relieve the hydraulic pressure.

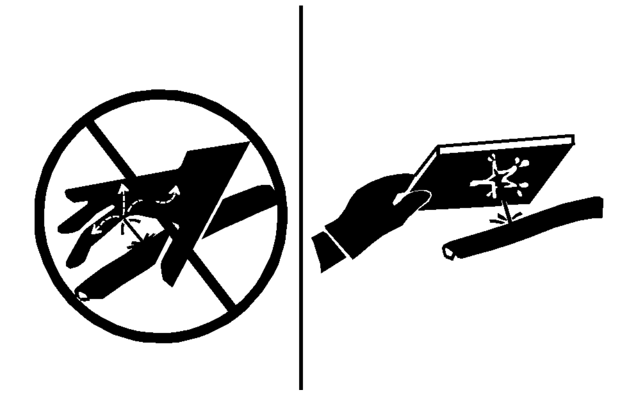

Illustration 8 g00687600

Always use a board or cardboard when you check for a leak. Leaking fluid that is under pressure can penetrate body tissue. Fluid penetration can cause serious injury and possible death. A pin hole leak can cause severe injury. If fluid is injected into your skin, you must get treatment immediately. Seek treatment from a doctor that is familiar with this type of injury.

Containing Fluid Spillage

Care must be taken in order to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the engine. Make provision to collect the fluid with a suitable container before any compartment is opened or before any component is disassembled.

- Only use the tools that are suitable for collecting fluids and equipment that is suitable for collecting fluids.

- Only use the tools that are suitable for containing fluids and equipment that is suitable for containing fluids.

Obey all local regulations for the disposal of liquids.

i02334785

Burn Prevention

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine.

⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines.

Allow the pressure to be purged in the air system, in the hydraulic system, in the lubrication system, or in the cooling system before any lines, fittings or related items are disconnected.

Coolant

When the engine is at operating temperature, the engine coolant is hot. The coolant is also under pressure. The radiator and all lines to the heaters or to the engine contain hot coolant.

Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained.

Check the coolant level after the engine has stopped and the engine has been allowed to cool.

Ensure that the filler cap is cool before removing the filler cap. The filler cap must be cool enough to touch with a bare hand. Remove the filler cap slowly in order to relieve pressure.

Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

Oils

Hot oil and hot lubricating components can cause personal injury. Do not allow hot oil to contact the skin. Also, do not allow hot components to contact the skin.

Batteries

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes. Always wear protective glasses for servicing batteries. Wash hands after touching the batteries and connectors. Use of gloves is recommended.

i04823662

Fire Prevention and Explosion Prevention

Illustration 9 g00704000

All fuels, most lubricants, and some coolant mixtures are flammable.

Flammable fluids that are leaking or spilled onto hot surfaces or onto electrical components can cause a fire. Fire may cause personal injury and property damage.

After the emergency stop button is operated, ensure that you allow 15 minutes, before the engine covers are removed.

Determine whether the engine will be operated in an environment that allows combustible gases to be drawn into the air inlet system. These gases could cause the engine to overspeed. Personal injury, property damage, or engine damage could result.

If the application involves the presence of combustible gases, consult your Perkins dealer and/or your Perkins distributor for additional information about suitable protection devices.

Remove all flammable combustible materials or conductive materials such as fuel, oil, and debris from the engine. Do not allow any flammable combustible materials or conductive materials to accumulate on the engine.

Store fuels and lubricants in correctly marked containers away from unauthorized persons. Store oily rags and any flammable materials in protective containers. Do not smoke in areas that are used for storing flammable materials.

Do not expose the engine to any flame.

Exhaust shields (if equipped) protect hot exhaust components from oil or fuel spray in a line, a tube, or a seal failure. Exhaust shields must be installed correctly.

Do not weld on lines or tanks that contain flammable fluids. Do not flame cut lines or tanks that contain flammable fluid. Clean any such lines or tanks thoroughly with a nonflammable solvent prior to welding or flame cutting.

Wiring must be kept in good condition. Ensure that all electrical wires are correctly routed and securely attached. Check all electrical wires daily. Repair any wires that are loose or frayed before you operate the engine. Clean all electrical connections and tighten all electrical connections.

Eliminate all wiring that is unattached or unnecessary. Do not use any wires or cables that are smaller than the recommended gauge. Do not bypass any fuses and/or circuit breakers.

Arcing or sparking could cause a fire. Secure connections, recommended wiring, and correctly maintained battery cables will help to prevent arcing or sparking.

⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

After the engine has stopped, wait for 60 seconds in order to allow the fuel pressure to be purged from the high-pressure fuel lines before any service or repair is performed on the engine fuel lines.

Ensure that the engine is stopped. Inspect all lines and hoses for wear or for deterioration. Properly route all hoses. The lines and hoses must have adequate support and secure clamps.

Properly install oil filters and fuel filters. The filter housings must be tightened to the correct torque. Refer to the Disassembly and Assembly manual for more information.

Illustration 10 g00704059

Use caution when you are refueling an engine. Do not smoke while you are refueling an engine. Do not refuel an engine near open flames or sparks. Always stop the engine before refueling.

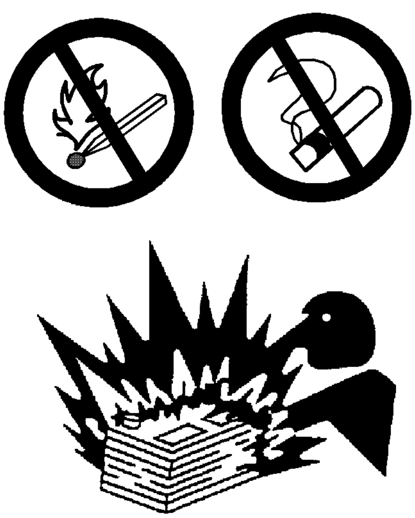

Illustration 11 g02298225

Gases from a battery can explode. Keep any open flames or sparks away from the top of a battery. Do not smoke in battery charging areas.

Never check the battery charge by placing a metal object across the terminal posts. Use a voltmeter or a hydrometer.

Incorrect jumper cable connections can cause an explosion that can result in injury. Refer to the Operation Section of this manual for specific instructions.

Do not charge a frozen battery.Charging a frozen battery may cause an explosion.

The batteries must be kept clean. The covers (if equipped) must be kept on the cells. Use the recommended cables, connections, and battery box covers when the engine is operated.

Fire Extinguisher

Make sure that a fire extinguisher is available. Be familiar with the operation of the fire extinguisher. Inspect the fire extinguisher and service the fire extinguisher regularly. Obey the recommendations on the instruction plate.

Lines, Tubes, and Hoses

Do not bend high-pressure lines. Do not strike high-pressure lines. Do not install any lines that are damaged.

Leaks can cause fires. Consult your Perkins dealer or your Perkins distributor for replacement parts.

Replace the parts if any of the following conditions are present:

- High-pressure fuel line or lines are removed.
- End fittings are damaged or leaking.
- Outer coverings are chafed or cut.
- Wires are exposed.
- Outer coverings are ballooning.
- Flexible parts of the hoses are kinked.
- Outer covers have embedded armoring.
- End fittings are displaced.

Make sure that all clamps, guards, and heat shields are installed correctly in order to prevent vibration, rubbing against other parts, and excessive heat.

i02143194

Crushing Prevention and Cutting Prevention

Support the component correctly when work beneath the component is performed.

Unless other maintenance instructions are provided, never attempt adjustments while the engine is running.

Stay clear of all rotating parts and of all moving parts. Leave the guards in place until maintenance is performed. After the maintenance is performed, reinstall the guards.

Keep objects away from moving fan blades. The fan blades will throw objects or cut objects.

When objects are struck, wear protective glasses in order to avoid injury to the eyes.

Chips or other debris may fly off objects when objects are struck. Before objects are struck, ensure that no one will be injured by flying debris.

i02235492

Mounting and Dismounting

Inspect the steps, the handholds, and the work area before mounting the engine. Keep these items clean and keep these items in good repair.

Mount the engine and dismount the engine only at locations that have steps and/or handholds. Do not climb on the engine, and do not jump off the engine.

Face the engine in order to mount the engine or dismount the engine. Maintain a three-point contact with the steps and handholds. Use two feet and one hand or use one foot and two hands. Do not use any controls as handholds.

Do not stand on components which cannot support your weight. Use an adequate ladder or use a work platform. Secure the climbing equipment so that the equipment will not move.

Do not carry tools or supplies when you mount the engine or when you dismount the engine. Use a hand line to raise and lower tools or supplies.

i02861106

High Pressure Fuel Lines

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

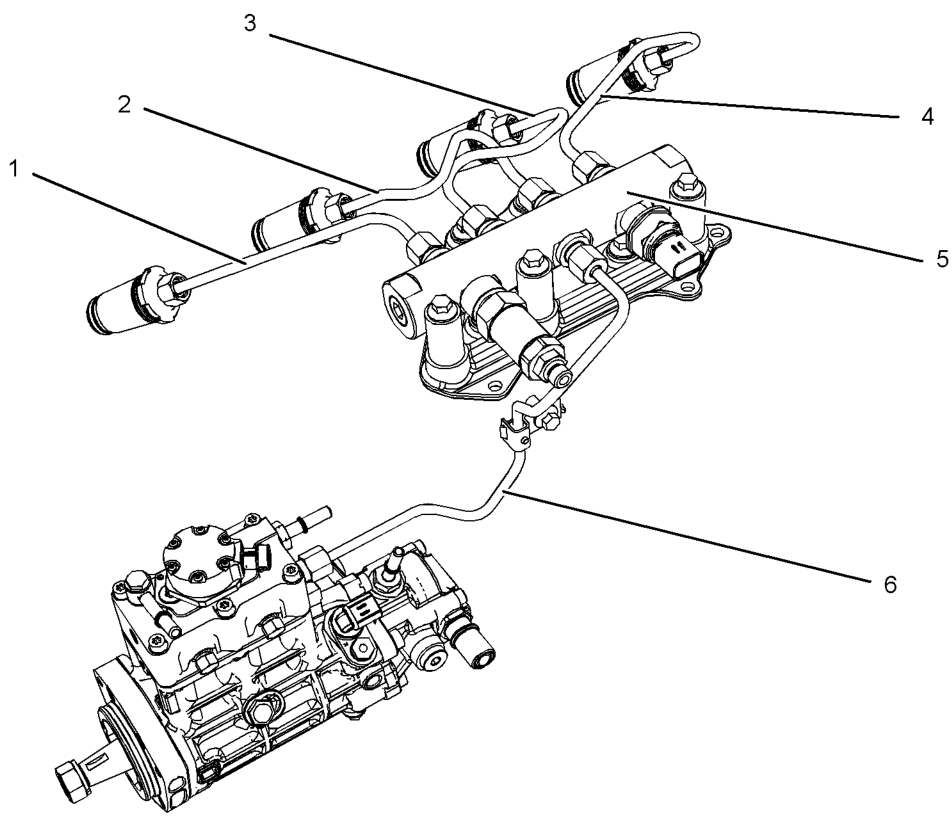

Illustration 12
g01425090

(1) High pressure line
(2) High pressure line
(3) High pressure line
(4) High pressure line
(5) High pressure fuel manifold (rail)
(6) High pressure line

The high pressure fuel lines are the fuel lines that are between the high pressure fuel pump and the high pressure fuel manifold and the fuel lines that are between the fuel manifold and cylinder head. These fuel lines are different from fuel lines on other fuel systems.

This is because of the following differences:

- The high pressure fuel lines are constantly charged with high pressure.
- The internal pressures of the high pressure fuel lines are higher than other types of fuel system.
- The high pressure fuel lines are formed to shape and then strengthened by a special process.

Do not step on the high pressure fuel lines. Do not deflect the high pressure fuel lines. Do not bend or strike the high pressure fuel lines. Deformation or damage of the high pressure fuel lines may cause a point of weakness and potential failure.

Do not check the high pressure fuel lines with the engine or the starting motor in operation. After the engine has stopped allow 60 seconds to pass in order to allow the pressure to be purged before any service or repair is performed on the engine fuel lines.

Do not loosen the high pressure fuel lines in order to remove air from the fuel system. This procedure is not required.

Visually inspect the high pressure fuel lines before the engine is started. This inspection should be each day.

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General Hazard Information”.

- Inspect the high pressure for the following: damage, deformation, a nick, a cut, a crease, or a dent

- Do not operate the engine with a fuel leak. If there is a leak do not tighten the connection in order to stop the leak. The connection must only be tightened to the recommended torque. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Remove and Fuel Injection Lines - Install”.

- If the high pressure fuel lines are torqued correctly and the high pressure fuel lines are leaking the high pressure fuel lines must be replaced.

- Ensure that all clips on the high pressure fuel lines are in place. Do not operate the engine with clips that are damaged, missing or clips that are loose.

- Do not attach any other item to the high pressure fuel lines.

- Loosened high pressure fuel lines must be replaced. Also removed high pressure fuel lines must be replaced. Refer to Disassembly and Assembly Manual, “ Fuel Injection Lines - Install”.

i02813489

Before Starting Engine

Before the initial start-up of an engine that is new, serviced or repaired, make provision to shut the engine off, in order to stop an overspeed. This may be accomplished by shutting off the air and/or fuel supply to the engine.

Overspeed shutdown should occur automatically for engines that are controlled electronically. If automatic shutdown does not occur, press the emergency stop button in order to cut the fuel and/or air to the engine.

Inspect the engine for potential hazards.

Before starting the engine, ensure that no one is on, underneath, or close to the engine. Ensure that the area is free of personnel.

If equipped, ensure that the lighting system for the engine is suitable for the conditions. Ensure that all lights work correctly, if equipped.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Do not bypass the automatic shutoff circuits. Do not disable the automatic shutoff circuits. The circuits are provided in order to help prevent personal injury. The circuits are also provided in order to help prevent engine damage.

See the Service Manual for repairs and for adjustments.

i02251260

Engine Starting

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

If a warning tag is attached to the engine start switch or to the controls DO NOT start the engine or move the controls. Consult with the person that attached the warning tag before the engine is started.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Start the engine from the operator's compartment or from the engine start switch.

Always start the engine according to the procedure that is described in the Operation and Maintenance Manual, “Engine Starting” topic in the Operation Section. Knowing the correct procedure will help to prevent major damage to the engine components. Knowing the procedure will also help to prevent personal injury.

To ensure that the jacket water heater (if equipped) and/or the lube oil heater (if equipped) is working correctly, check the water temperature gauge and/or the oil temperature gauge during the heater operation.

Engine exhaust contains products of combustion which can be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is started in an enclosed area, vent the engine exhaust to the outside.

Note: The engine is equipped with a device for cold starting. If the engine will be operated in very cold conditions, then an extra cold starting aid may be required. Normally, the engine will be equipped with the correct type of starting aid for your region of operation.

These engines are equipped with a glow plug starting aid in each individual cylinder that heats the intake air in order to improve starting.

i02234873

Engine Stopping

Stop the engine according to the procedure in the Operation and Maintenance Manual, “Engine Stopping (Operation Section)” in order to avoid overheating of the engine and accelerated wear of the engine components.

Use the Emergency Stop Button (if equipped) ONLY in an emergency situation. Do not use the Emergency Stop Button for normal engine stopping. After an emergency stop, DO NOT start the engine until the problem that caused the emergency stop has been corrected.

Stop the engine if an overspeed condition occurs during the initial start-up of a new engine or an engine that has been overhauled.

To stop an electronically controlled engine, cut the power to the engine and/or shutting off the air supply to the engine.

i02234878

Electrical System

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause the combustible gases that are produced by some batteries to ignite.

To help prevent sparks from igniting combustible gases that are produced by some batteries, the negative “−” cable should be connected last from the external power source to the negative “−” terminal of the starting motor. If the starting motor is not equipped with a negative “−” terminal, connect the cable to the engine block.

Check the electrical wires daily for wires that are loose or frayed. Tighten all loose electrical connections before the engine is started. Repair all frayed electrical wires before the engine is started. See the Operation and Maintenance Manual for specific starting instructions.

Grounding Practices

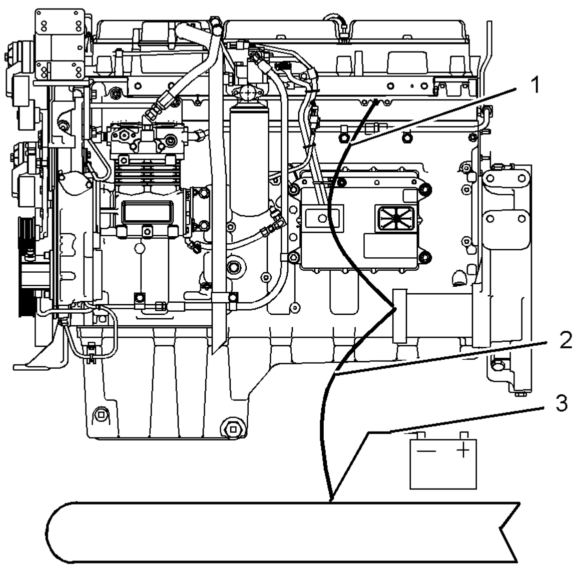

Illustration 13 g01162916

Typical example

(1) Starting motor to engine block
(2) Ground to starting motor
(3) Ground to battery

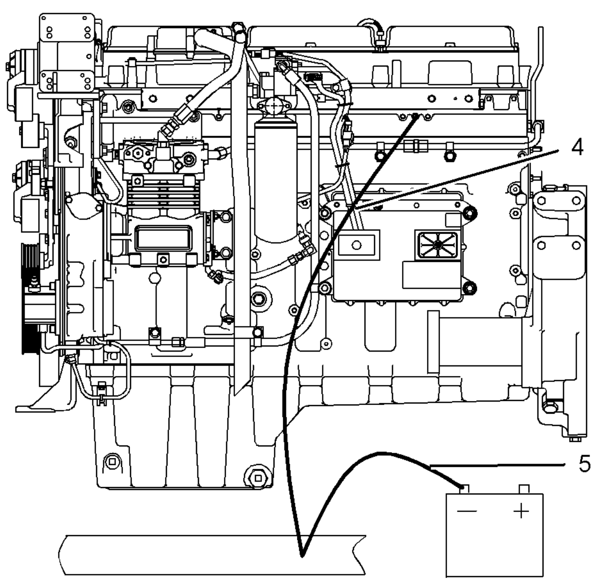

Illustration 14 g01162918

Typical example

(4) Ground to engine
(5) Ground to battery

Correct grounding for the engine electrical system is necessary for optimum engine performance and reliability. Incorrect grounding will result in uncontrolled electrical circuit paths and in unreliable electrical circuit paths.

Uncontrolled electrical circuit paths can result in damage to the crankshaft bearing journal surfaces and to aluminum components.

Engines that are installed without engine-to-frame ground straps can be damaged by electrical discharge.

To ensure that the engine and the engine electrical systems function correctly, an engine-to-frame ground strap with a direct path to the battery must be used. This path may be provided by way of a direct engine ground to the frame.

The connections for the grounds should be tight and free of corrosion. The engine alternator must be grounded to the negative "-" battery terminal with a wire that is adequate to handle the full charging current of the alternator.

The power supply connections and the ground connections for the engine electronics should always be from the isolator to the battery.

i02650954

Engine Electronics

WARNING

Tampering with the electronic system installation or the OEM wiring installation can be dangerous and could result in personal injury or death and/or engine damage.

WARNING

Electrical Shock Hazard. The electronic unit injectors use DC voltage. The ECM sends this voltage to the electronic unit injectors. Do not come in contact with the harness connector for the electronic unit injectors while the engine is operating. Failure to follow this instruction could result in personal injury or death.

This engine has a comprehensive, programmable Engine Monitoring System. The Electronic Control Module (ECM) has the ability to monitor the engine operating conditions. If any of the engine parameters extend outside an allowable range, the ECM will initiate an immediate action.

The following actions are available for engine monitoring control:

- Warning
- Derate
- Shutdown

The following monitored engine operating conditions have the ability to limit engine speed and/or the engine power:

- Engine Coolant Temperature
- Engine Oil Pressure
- Engine Speed/Timing
- Intake Manifold Air Temperature

The Engine Monitoring package can vary for different engine models and different engine applications. However, the monitoring system and the engine monitoring control will be similar for all engines.

Note: Many of the engine control systems and display modules that are available for Perkins Engines will work in unison with the Engine Monitoring System. Together, the two controls will provide the engine monitoring function for the specific engine application. Refer to Troubleshooting for more information on the Engine Monitoring System.

Product Information Section

Model Views

i02861104

Model View Illustrations

The following model views show typical features of the engine. Due to individual applications, your engine may appear different from the illustrations.

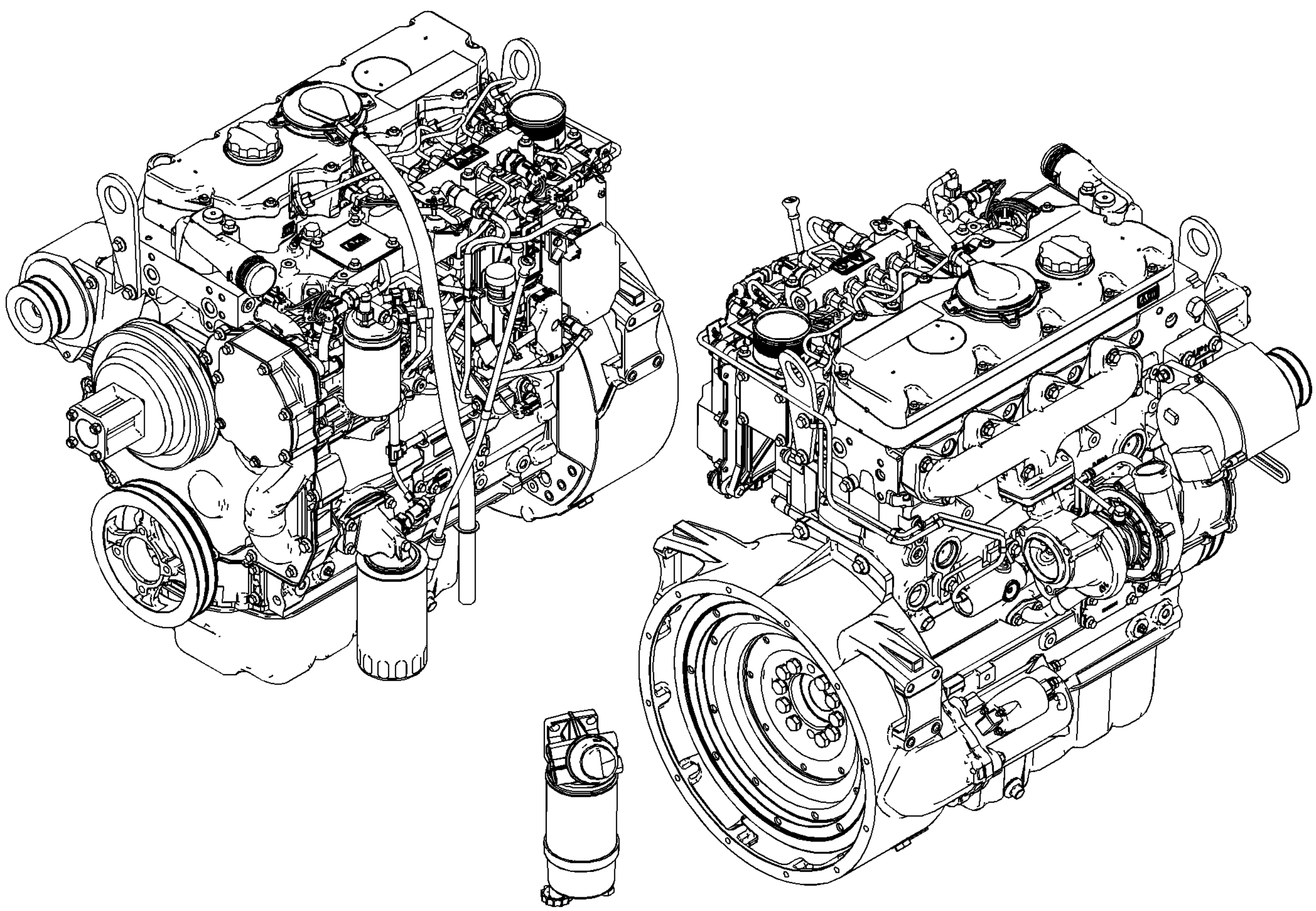

Illustration 15 g01425089

The 1104D NJ engine is turbocharged and aftercooled.

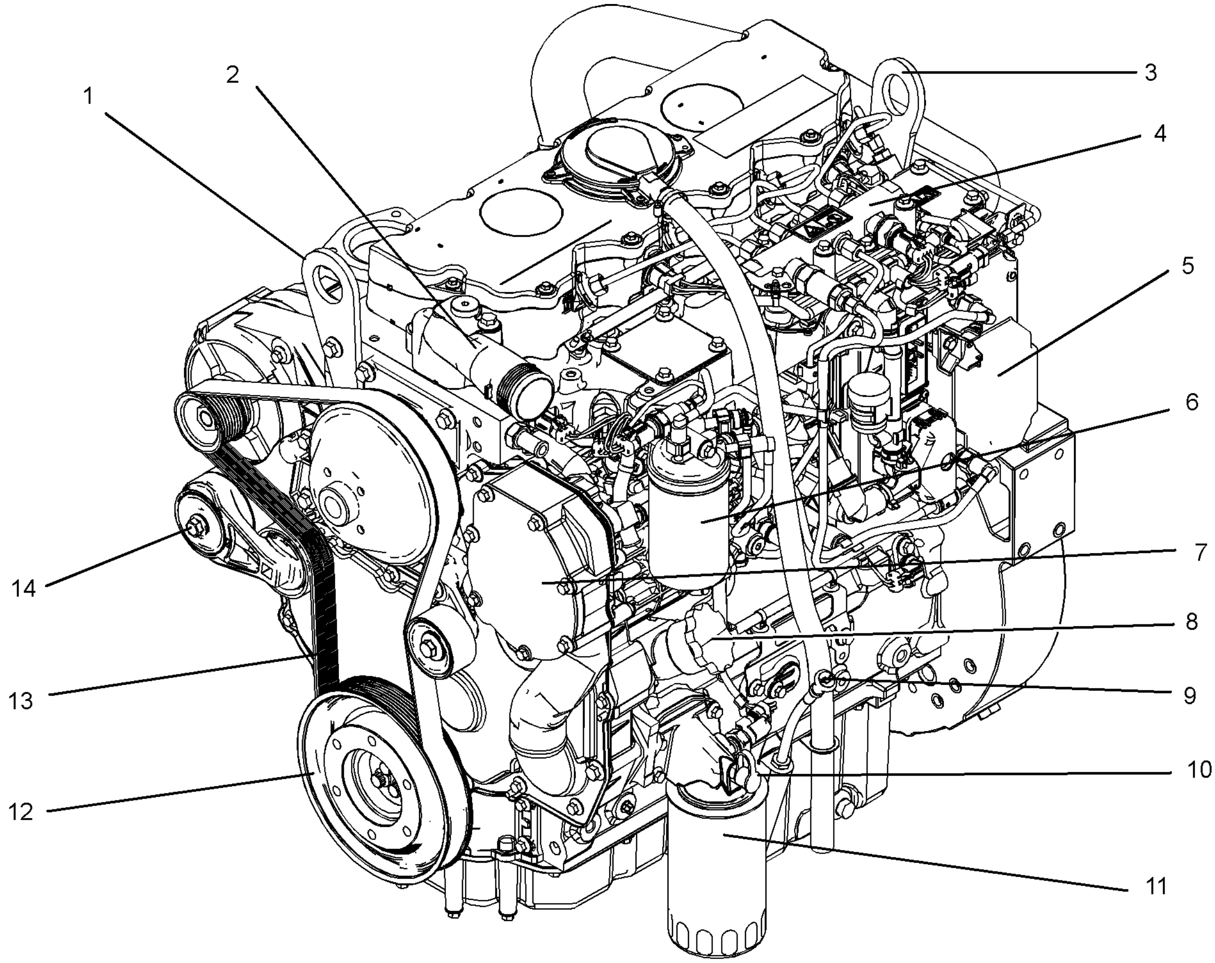

Illustration 16 g01428165

The 1104D NH engine is turbocharged.

Front left engine view

(1) Front lifting eye
(2) Water outlet
(3) Rear lifting eye
(4) Fuel manifold (rail)
(5) Electronic control module
(6) Secondary fuel filter
(7) Water pump
(8) Oil Filler
(9) Oil gauge
(10) Oil sampling valve
(11) Oil filter
(12) Crankshaft pulley
(13) Drive Belt
(14) Belt tensioner

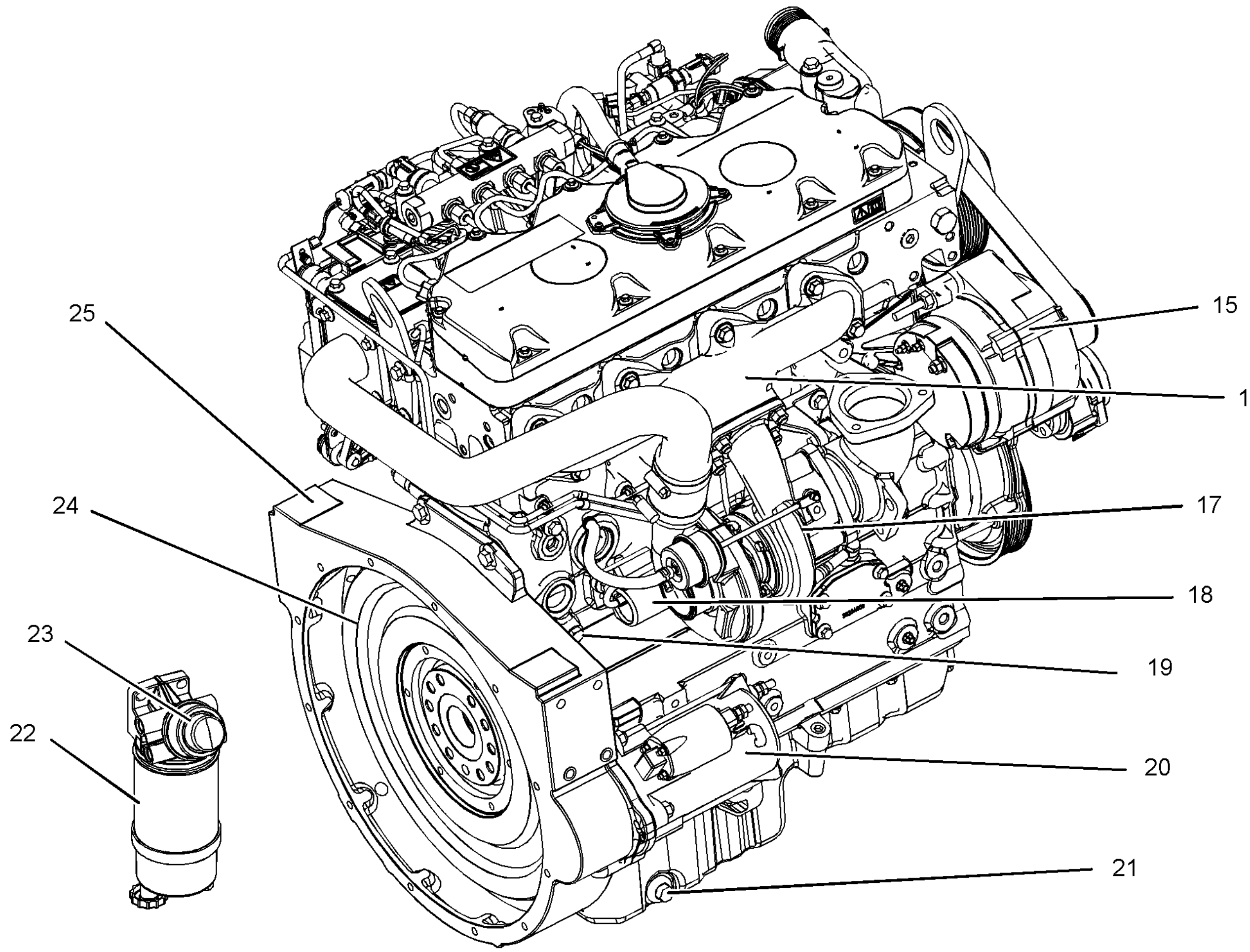

Illustration 17 g01428176

Rear right engine view

(15) Alternator
(16) Exhaust manifold
(17) Turbocharger
(18) Wastegate solenoid
(19) Drain plug or coolant sampling valve
(20) Starting Motor
(21) Oil drain plug
(22) Primary fuel filter
(23) Hand fuel priming pump
(24) Flywheel
(25) Flywheel housing

Note: The primary fuel filter may be mounted off the engine.

i04925801

Engine Description

The 1104 Electronic Engine models NH and NJ are designed for the following applications: machine and industrial mobile equipment. The engine is available in the following type of aspiration:

- Turbocharged
- Turbocharged aftercooled
- In-line 4 cylinder

Engine Specifications

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right sides of the engine are determined from the flywheel end. The number 1 cylinder is the front cylinder.

Emissions Control Systems

NH - Direct Diesel Injection, Turbocharger, and Engine Control Module

NJ - Direct Diesel Injection, Turbocharger with Air to Air Charge Cooler and Engine Control Module

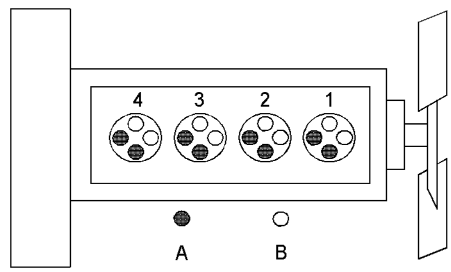

Illustration 18 g01187485

(A) Exhaust valves
(B) Inlet valves

Table 1

1104 Electronic Engine Specifications	
Operating Range (rpm)	750 to 2640(1)
Number of Cylinders	4 In-Line
Bore	105 mm (4.13 inch)
Stroke	127 mm (5.0 inch)
Aspiration	NH Turbocharged engine NJ Turbocharged engine that is aftercooled
Compression Ratio	16.2:1
Displacement	4.4 L (269 in^3)
Firing Order	1,3,4,2
Rotation (flywheel end)	Counterclockwise
Valve Lash Setting (Inlet)	0.35 mm (0.013 inch)
Valve Lash Setting (Exhaust)	0.35 mm (0.013 inch)

(1) The operating rpm is dependent on the engine rating, the application, and the configuration of the throttle.

Electronic Engine Features

The engine operating conditions are monitored. The Electronic Control Module (ECM) controls the response of the engine to these conditions and to the demands of the operator. These conditions and operator demands determine the precise control of fuel injection by the ECM. The electronic engine control system provides the following features:

- Engine monitoring
- Engine speed governing
- Control of the injection pressure
- Cold start strategy
- Automatic air/fuel ratio control
- Torque rise shaping
- Injection timing control
- System diagnostics

For more information on electronic engine features, refer to the Operation and Maintenance Manual, "Features and Controls" topic (Operation Section).

Engine Diagnostics

The engine has built-in diagnostics in order to ensure that the engine systems are functioning correctly. The operator will be alerted to the condition by a "Stop or Warning" lamp. Under certain conditions, the engine horsepower and the vehicle speed may be limited. The electronic service tool may be used to display the diagnostic codes.

There are three types of diagnostic codes: active, logged, and event.

Most of the diagnostic codes are logged and stored in the ECM. For additional information, refer to the Operation and Maintenance Manual, "Engine Diagnostics" topic (Operation Section).

The ECM provides an electronic governor that controls the injector output in order to maintain the desired engine rpm.

Engine Cooling and Lubrication

The cooling system consists of the following components:

- Gear-driven centrifugal water pump
- Water temperature regulator which regulates the engine coolant temperature
- Gear-driven rotor type oil pump
- Oil cooler

The engine lubricating oil is supplied by a rotor type oil pump. The engine lubricating oil is cooled and the engine lubricating oil is filtered. The bypass valves can provide unrestricted flow of lubrication oil to the engine if the oil filter element should become plugged.

Engine efficiency, efficiency of emission controls, and engine performance depend on adherence to proper operation and maintenance recommendations. Engine performance and efficiency also depend on the use of recommended fuels, lubrication oils, and coolants. Refer to this Operation and Maintenance Manual, “Maintenance Interval Schedule” for more information on maintenance items.

Product Identification Information

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Plate Locations and Film Locations

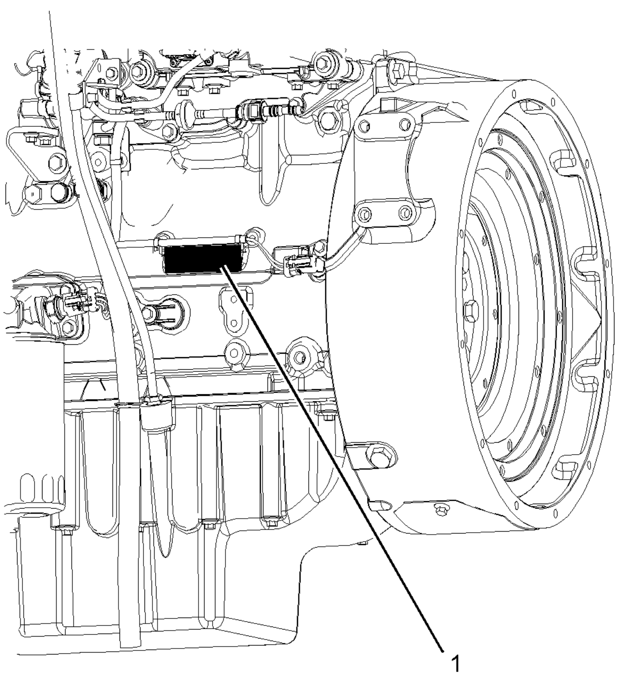

Illustration 19 g01248563

Location of the serial number plate

Perkins engines are identified by an engine serial number.

An example of an engine number is NH*****U000001J.

***** _______________The list number for the engine

NH _____________________________Type of engine

U ____________________Built in the United Kingdom

000001 ___________________Engine Serial Number

J __________________________Year of Manufacture

Perkins dealers or Perkins distributors need all of these numbers in order to determine the components that were included with the engine. This permits accurate identification of replacement part numbers.

The numbers for fuel setting information for electronic engines are stored within the personality module. These numbers can be read by using the Electronic Service Tool.

Serial Number Plate (1)

The engine serial number plate is located on the left side of the cylinder block to the rear of the engine.

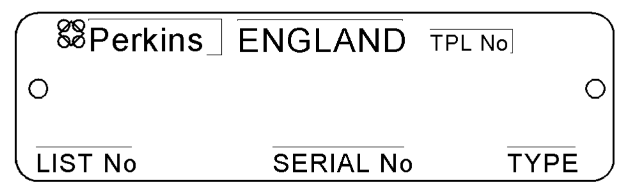

Illustration 20 g01094203

Serial number plate

i02164876

Reference Numbers

Information for the following items may be needed to order parts. Locate the information for your engine. Record the information in the appropriate space. Make a copy of this list for a record. Keep the information for future reference.

Record for Reference

Engine Model _________________________________

Engine Serial number __________________________

Engine Low Idle rpm ___________________________

Engine Full Load rpm ___________________________

Primary Fuel Filter _____________________________

Water Separator Element _______________________

Secondary Fuel Filter Element __________________

Lubrication Oil Filter Element ___________________

Auxiliary Oil Filter Element ______________________

Total Lubrication System Capacity _______________

Total Cooling System Capacity _________________

Air Cleaner Element ___________________________

Fan Drive Belt _______________________________

Alternator Belt _______________________________

i02861254

Emissions Certification Film

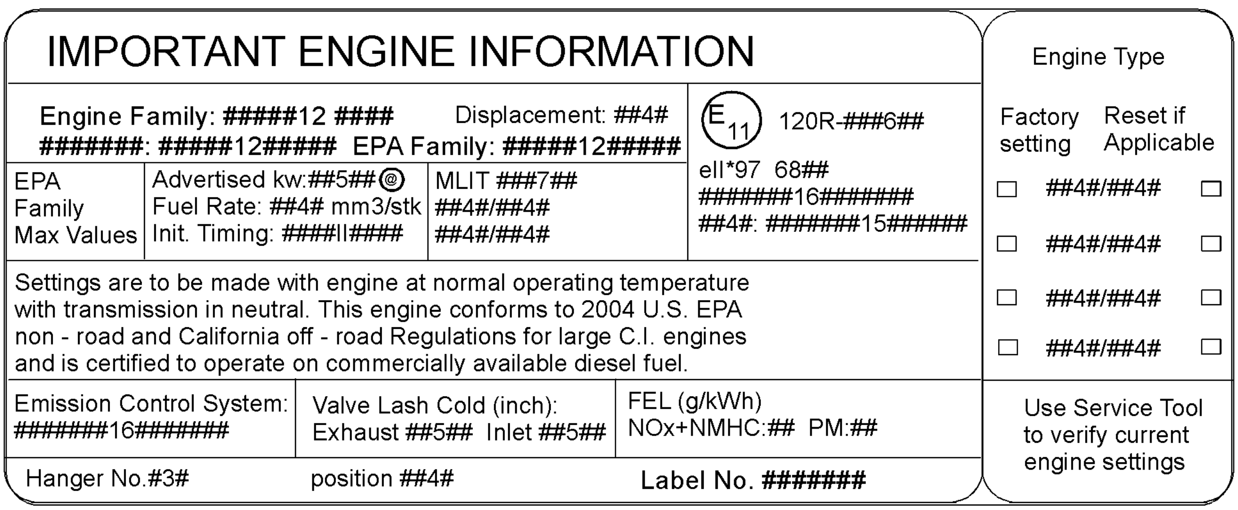

Illustration 21 g01440937

Typical example

Operation Section

Lifting and Storage

i02164186

Engine Lifting

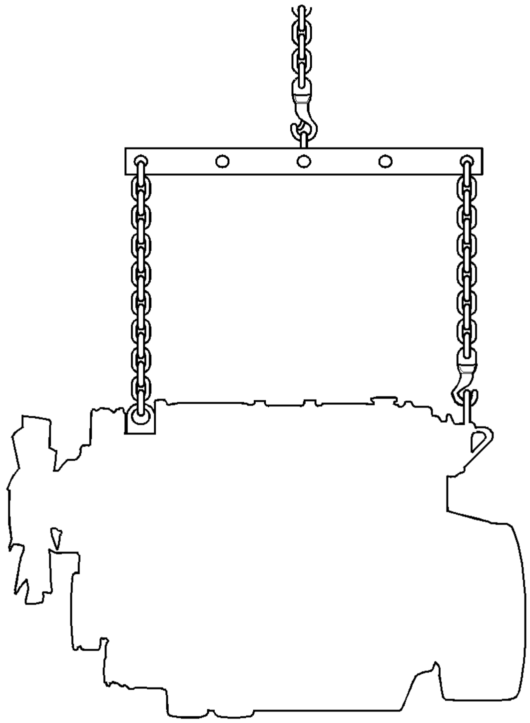

Illustration 22 g01097527

NOTICE
Never bend the eyebolts and the brackets. Only load the eyebolts and the brackets under tension. Remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90 degrees.

When it is necessary to remove a component at an angle, only use a link bracket that is properly rated for the weight.

Use a hoist to remove heavy components. Use an adjustable lifting beam to lift the engine. All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted.

Some removals require lifting the fixtures in order to obtain correct balance and safety.

To remove the engine ONLY, use the lifting eyes that are on the engine.

Lifting eyes are designed and installed for specific engine arrangements. Alterations to the lifting eyes and/or the engine make the lifting eyes and the lifting fixtures obsolete. If alterations are made, ensure that correct lifting devices are provided. Consult your Perkins dealer or your Perkins distributor for information regarding fixtures for correct engine lifting.

i02308881

Engine Storage

If the engine is not started for a month or longer the lubricating oil will drain from the cylinder walls and from the piston rings. Rust can form on the cylinder walls. Rust on the cylinder walls will cause increased engine wear and a reduction in engine service life.

Perkins are not responsible for damage which may occur when an engine is in storage after a period in service.

Your Perkins dealer or your Perkins distributor can assist in preparing the engine for extended storage periods.

If an engine is out of operation and if use of the engine is not planned for more than one month, a complete protection procedure is recommended.

To help prevent excessive engine wear and corrosion to the engine, use the following guidelines:

1. Completely clean the outside of the engine.

2. Ensure that the vehicle is on level ground.

3. Drain the fuel system completely and refill the system with preservative fuel. 1772204 POWERPART Lay-Up 1 can be mixed with the normal fuel in order to change the fuel into preservative fuel.

   If preservative fuel is not available, the fuel system can be filled with normal fuel. This fuel must be discarded at the end of the storage period together with the fuel filter elements.

WARNING

Personal injury can result from hot coolant. Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained.

4. Drain and refill the cooling system. Refer to this Operation and Maintenance Manual, "Cooling System coolant (Commercial Heavy Duty - Change or Cooling System coolant (ELC) - Change" for information on draining, flushing and refilling the cooling system.

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

5. Operate the engine until the engine reaches normal operating temperature. Stop the engine. After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

6. Drain the lubricating oil from the oil pan.

   Renew the canister(s) of the lubricating oil filter.

   Fill the oil pan to the Full Mark on the engine oil level gauge with new, clean lubricating oil. Add 1762811 POWERPART Lay-Up 2 to the oil in order to protect the engine against corrosion. If 1762811 POWERPART Lay-Up 2 is not available, use a preservative of the correct specification instead of the lubricating oil. If a preservative is used, this must be drained completely at the end of the storage period and the oil pan must be refilled to the correct level with normal lubricating oil.

7. Operate the engine in order to circulate engine oil.

8. Disconnect the battery. Ensure that the battery is in a fully charged condition. Protect the terminals against corrosion. 1734115 POWERPART Lay-Up 3 can be used on the terminals. Put the battery into safe storage.

9. If equipped, replace the crankcase breather element. Seal the end of the breather pipe.

10. Remove the valve mechanism cover. Spray 1762811 POWERPART Lay-Up 2 around the rocker shaft assembly.

11. Remove the glow plugs. Slowly rotate the crankshaft. By checking the valves, position the piston at BDC. Spray 1762811 POWERPART Lay-Up 2 for two seconds into the cylinder bore. This procedure must be carried out on each cylinder.

12. Install the glow plugs. Install the valve mechanism cover.

13. Remove the pipes that are installed between the air filter assembly and the turbocharger. Spray 1762811 POWERPART Lay-Up 2 into the turbocharger. The duration of the spray is printed on the container. Seal the turbocharger with waterproof tape.

14. Remove the exhaust pipe from the output side of the turbocharger. Spray 1762811 POWERPART Lay-Up 2 into the turbocharger. The duration of the spray is printed on the container. Seal the turbocharger with waterproof tape.

15. Seal the vent of the fuel tank or the fuel filler cap with waterproof tape.

16. Remove the alternator drive belt and put the drive belt into storage.

17. In order to prevent corrosion to the outside of the engine, spray the engine with 1734115 POWERPART Lay-Up 3. Do not spray the area inside the alternator.

Gauges and Indicators

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Gauges and Indicators

Your engine may not have the same gauges or all of the gauges that are described. For more information about the gauge package, see the OEM information.

Gauges provide indications of engine performance. Ensure that the gauges are in good working order. Determine the normal operating range by observing the gauges over a period of time.

Noticeable changes in gauge readings indicate potential gauge or engine problems. Problems may also be indicated by gauge readings that change even if the readings are within specifications. Determine and correct the cause of any significant change in the readings. Consult your Perkins dealer or your Perkins distributor for assistance.

Some engine applications are equipped with Indicator Lamps. Indicator lamps can be used as a diagnostic aid. There are two lamps. One lamp has an orange lens and the other lamp has a red lens.

These indicator lamps can be used in two ways:

- The indicator lamps can be used to identify the current operational status of the engine. The indicator lamps can also indicate that the engine has a fault. This system is automatically operated via the ignition switch.
- The indicator lamps can be used to identify active diagnostic codes. This system is activated by pressing the Flash Code button.

Refer to the Troubleshooting Guide, “Indicator Lamps” for further information.

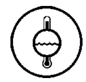
NOTICE

If no oil pressure is indicated, STOP the engine. If maximum coolant temperature is exceeded, STOP the engine. Engine damage can result.

Engine Oil Pressure – The oil pressure should be greatest after a cold engine is started. The typical engine oil pressure with SAE10W40 is 350 to 450 kPa (50 to 65 psi) at rated rpm.

A lower oil pressure is normal at low idle. If the load is stable and the gauge reading changes, perform the following procedure:

1. Remove the load.
2. Stop the engine.
3. Check and maintain the oil level.



Jacket Water Coolant Temperature – Typical temperature range is 83° to 95°C (181.4° to 171°F). The maximum allowable temperature at sea level with the pressurized cooling system at 48 kPa (7 psi) is 103 °C (217.4 °F). Higher temperatures may occur under certain conditions. The water temperature reading may vary according to load. The temperature reading should never exceed 7 °C (44.6 °F) below the boiling point for the pressurized system that is being used.

A 100 kPa (14.5 psi) radiator cap may be installed on the cooling system. The temperature of this cooling system must not exceed 112 °C (233.6 °F).

If the engine is operating above the normal range and steam becomes apparent, perform the following procedure:

1. Reduce the load and the engine rpm.
2. Determine if the engine must be shut down immediately or if the engine can be cooled by reducing the load.
3. Inspect the cooling system for leaks.

Tachometer – This gauge indicates engine speed (rpm). When the throttle control lever is moved to the full throttle position without load, the engine is running at high idle. The engine is running at the full load rpm when the throttle control lever is at the full throttle position with maximum rated load.

NOTICE

To help prevent engine damage, never exceed the high idle rpm. Overspeeding can result in serious damage to the engine. Operation at speeds exceeding high idle rpm should be kept to a minimum.

Ammeter – This gauge indicates the amount of charge or discharge in the battery charging circuit. Operation of the indicator should be to the “+” side of “0” (zero).

Fuel Level – This gauge indicates the fuel level in the fuel tank. The fuel level gauge operates when the “START/STOP” switch is in the “on” position.

Service Hour Meter – The gauge indicates total operating hours of the engine.

Features and Controls

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Monitoring System

⚠ WARNING

If the Shutdown mode has been selected and the warning indicator activates, engine shutdown may take as little as 20 seconds from the time the warning indicator is activated. Depending on the application, special precautions should be taken to avoid personal injury. The engine can be restarted following shutdown for emergency maneuvers, if necessary.

NOTICE

The Engine Monitoring System is not a guarantee against catastrophic failures. Programmed delays and derate schedules are designed to minimize false alarms and provide time for the operator to stop the engine.

The following parameters are monitored:

- Coolant temperature
- Intake air temperature
- Engine intake manifold pressure
- Engine Oil pressure
- Pressure in the fuel rail
- Engine speed/timing

Programmable Options and Systems Operation

⚠ WARNING

If the Warning/Derate/Shutdown mode has been selected and the warning indicator activates, bring the engine to a stop whenever possible. Depending on the application, special precautions should be taken to avoid personal injury.

The engine can be programmed to the following modes:

"Warning"

The "Warning" lamp and the warning signal (orange lamp) turn "ON" and the warning signal is activated continuously in order to alert the operator that one or more of the engine parameters is not within normal operating range.

"Warning/Derate"

The "Diagnostic" lamp turns "ON" and the warning signal (red lamp) is activated. After the warning, the engine power will be derated. The warning lamp will begin to flash when the derating occurs.

The engine will be derated if the engine exceeds preset operational limits. The engine derate is achieved by restricting the amount of fuel that is available for each injection. The amount of this reduction of fuel is dependent on the severity of the fault that has caused the engine derate, typically up to a limit of 50%. This reduction in fuel results in a predetermined reduction in engine power.

"Warning/Derate/Shutdown"

The "Diagnostic" lamp turns "ON" and the warning signal (red lamp) is activated. After the warning, the engine power will be derated. The engine will continue at the rpm of the set derate until a shutdown of the engine occurs. The engine can be restarted after a shutdown for use in an emergency.

A shutdown of the engine may occur in as little as 20 seconds. The engine can be restarted after a shutdown for use in an emergency. However, the cause of the initial shutdown may still exist. The engine may shut down again in as little as 20 seconds.

If there is a signal for low oil pressure or for coolant temperature, there will be a two second delay in order to verify the condition.

For each of the programmed modes, refer to Troubleshooting , "Indicator Lamps" for more information on Indicator Lamps.

For more information or assistance for repairs, consult your Perkins dealer or your Perkins distributor.

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Monitoring System

Table 2

Warning Lamp	Shutdown Lamp	Lamp Status	Description of lamp status	Engine Status
ON	**ON**	Lamp check	When the engine start switch is turned to the "ON" position both lamps will illuminate for 2 seconds only.	The engine has not been started.
OFF	**OFF**	No faults	There are no active diagnostic faults.	The engine is running normally.
ON	**OFF**	Active diagnostic fault	An active diagnostic fault has been detected.	The engine is running normally.
ON	**FLASHING**	Active diagnostic fault	A serious active diagnostic fault has been detected and an engine derate has been invoked.	The engine is running but the engine has been derated.
FLASHING	**OFF**	Warning	One or more of the engine protection values has been exceeded.	The engine is running normally.
FLASHING	**FLASHING**	Derate and warning	One or more of the engine protection values has been exceeded.	The engine is running but the engine has been derated.
ON	**ON**	Engine shutdown	One or more of the engine protection values has been exceeded or a serious active diagnostic fault has been detected.	The engine is shutdown or shutdown is imminent.

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Sensors and Electrical Components

Sensor Locations

Illustration 23 shows the typical locations of the sensors and the ECM on the engine. Specific engines may appear different from the illustration due to differences in applications.

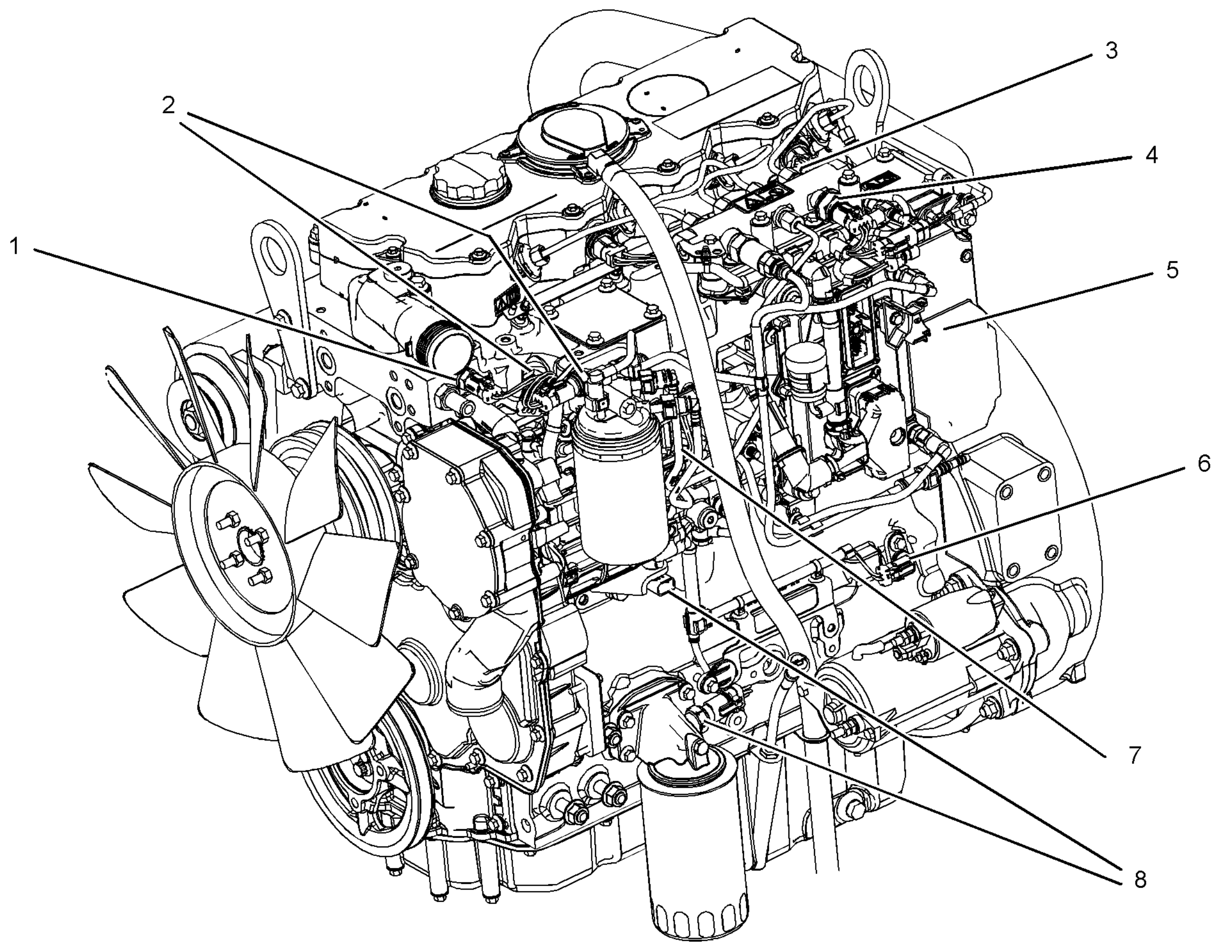

Illustration 23 g01425443

(1) Coolant temperature sensor
(2) Intake manifold pressure sensor
(3) Inlet air temperature sensor
(4) Fuel pressure sensor
(5) Electronic control module
(6) Primary position sensor
(7) Secondary position sensor
(8) Engine oil pressure sensor

Illustration 24 shows the sensors and the ECM in position on the engine.

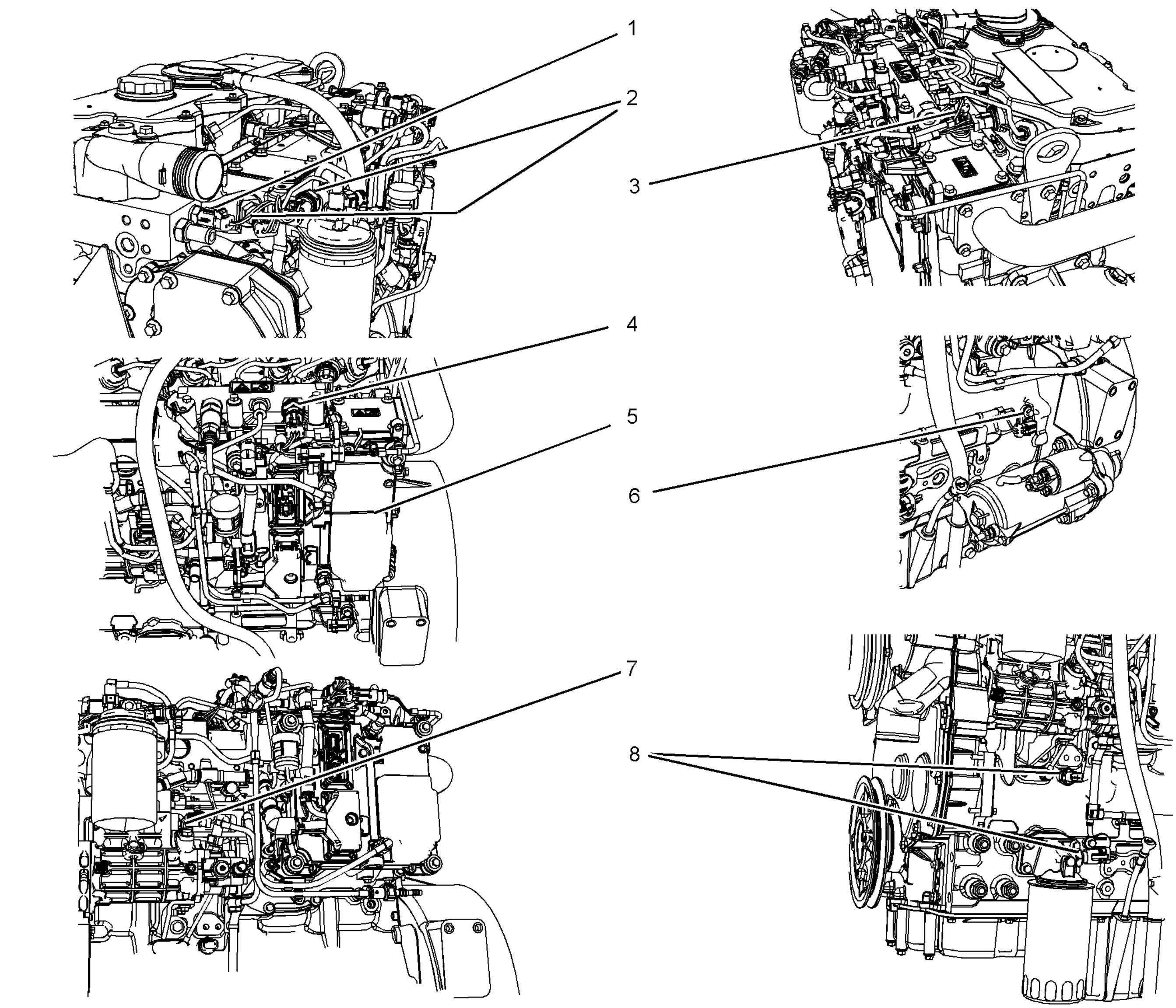

Illustration 24

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Failure of Sensors

All Sensors

A failure of any of the sensors may be caused by one of the following malfunctions:

- Sensor output is open.
- Sensor output is shorted to “- battery” or “+ battery”.
- Measured reading of the sensor is out of the specification.

Programmable Monitoring System (PMS)

The Programmable Monitoring System determines the level of action that is taken by the Electronic Control Module (ECM) in response to a condition that can damage the engine. These conditions are identified by the ECM from the signals that are produced from the following sensors.

- Coolant Temperature Sensor
- Intake manifold Air Temperature Sensor
- Intake manifold Pressure Sensor
- Fuel Pressure Sensor

- Engine Oil Pressure Sensor
- Primary Speed/Timing Sensor
- Secondary Speed/Timing Sensor

Coolant Temperature Sensor 1

The coolant temperature sensor monitors engine coolant temperature. The output of the ECM (5) can indicate a high coolant temperature through a relay or a lamp. The coolant temperature sensor is used by the ECM to determine initiation of the Cold Start Condition.

Failure of the Coolant Temperature Sensor

The ECM (5) will detect a failure of the coolant temperature sensor. The diagnostic lamp will warn the operator about the status of the coolant temperature sensor. A failure of the coolant temperature sensor will not cause a shutdown of the engine or any horsepower change. In order to check the correct operation of the sensor, refer to Troubleshooting, “Engine Temperature Sensor Circuit - Test”.

Intake Manifold Air Temperature Sensor 2

Note: This sensor can have two different locations. The location will depend on the type of engine.

The intake manifold air temperature sensor measures the intake air temperature. A signal is sent to the ECM (5). The intake manifold air temperature sensor is also used by the ECM to determine initiation of the Cold Start Strategy.

In order to check the correct operation of the sensor, refer to Troubleshooting, “EngineTemperature Sensor Circuit - Test”.

Intake Manifold Pressure Sensor 3

The intake manifold pressure sensor measures pressure in the manifold. A signal is sent to the ECM (5).

Fuel Pressure Sensor 4

The fuel pressure sensor measures the fuel pressure in the fuel manifold. A signal is sent to the ECM (5).

Electronic Control Module 5

The ECM is the control computer of the engine. The ECM provides power to the electronics. The ECM monitors data that is input from the sensors of the engine. The ECM acts as a governor in order to control the speed and the power of the engine.

The ECM adjusts injection timing and fuel pressure for the best engine performance, the best fuel economy and the best control of exhaust emissions.

Primary Speed/Timing Sensor 6

If the ECM (5) does not receive a signal from the primary speed/timing sensor , the “DIAGNOSTIC” lamp will indicate a diagnostic fault code which will be logged in the ECM memory.

If the ECM does not receive a signal from the primary speed/timing sensor (7), the ECM will read the signal from the secondary speed/timing sensor (8). The ECM continually checks in order to determine if there is a signal from both sensors.

Intermittent failure of the sensors will cause erratic engine control.

Failure of the Primary Speed/Timing Sensor

Correct operation of the primary speed/timing sensor is essential. Software in the ECM protects against reverse running of the engine. If the primary speed/timing sensor fails there is no automatic protection against reverse running. In some applications, it is possible for the transmission to run the engine in reverse. In this event, Stop the engine immediately. Turn the keyswitch to the “OFF” position.

In order to check the correct operation of the sensor, refer to Troubleshooting, “Engine speed/Timing sensor - Test”.

Secondary Speed/Timing Sensor 7

The signal from the secondary speed/timing sensor is used by the ECM (5) on engine start-up in order to check the stroke of the pistons. The secondary speed/timing sensor may be used by the ECM in order to operate the engine if the primary speed/timing sensor is faulty.

In order to check the correct operation of the sensor, refer to Troubleshooting, “Engine speed/Timing sensor-Test”.

Engine Oil Pressure Sensor 8

Note: This sensor can have two different locations. The location will depend on the type of engine.

The engine oil pressure sensor is an absolute pressure sensor that measures the engine oil pressure in the main oil gallery. The engine oil pressure sensor detects engine oil pressure for diagnostic purposes. The engine oil pressure sensor sends a signal to the ECM (5).

Low Oil Pressure Warning

The setpoint for the low pressure warning is dependent upon the engine speed. The fault will be active and logged only if the engine has been running for more than 8 seconds.

Very Low Oil Pressure Warning

The very low oil pressure setpoint is dependent upon the engine speed. If the DERATE mode of the engine monitoring system is selected, the ECM (5) will derate the engine power. The engine horsepower will be limited.

Failure of the Engine Oil Pressure Sensor

The ECM (5) will detect failure of the engine oil pressure sensor. The diagnostic lamp warns the user about the status of the engine oil pressure sensor. The engine oil pressure related strategies will be disabled in the event of a failure of the engine oil pressure sensor. A failure of the engine oil pressure sensor will not cause a shutdown of the engine or any horsepower change. In order to check the correct operation of the sensor, refer to Troubleshooting, “5 Volt Sensor Supply Circuit - Test”.

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Engine Shutoffs and Engine Alarms

Shutoffs

The shutoffs are electrically operated or mechanically operated. The electrically operated shutoffs are controlled by the ECM.

Shutoffs are set at critical levels for the following items:

- Operating temperature
- Operating pressure
- Operating level
- Operating rpm

The particular shutoff may need to be reset before the engine will start.

NOTICE

Always determine the cause of the engine shutdown. Make necessary repairs before attempting to restart the engine.

Be familiar with the following items:

- Types and locations of shutoff
- Conditions which cause each shutoff to function
- The resetting procedure that is required to restart the engine

Alarms

The alarms are electrically operated. The operation of the alarms are controlled by the ECM.

The alarm is operated by a sensor or by a switch. When the sensor or the switch is activated a signal is sent to the ECM. An event code is created by the ECM. The ECM will send a signal in order to illuminate the lamp.

Your engine may be equipped with the following sensors or switches:

Coolant level – The low coolant level switch indicates when the coolant level is low.

Coolant temperature – The coolant temperature sensor indicates high jacket water coolant temperature.

Intake manifold air temperature – The intake manifold air temperature sensor indicates high intake air temperature.

Intake manifold pressure – The intake manifold pressure sensor checks the rated pressure in the engine manifold.

Fuel rail pressure – The fuel rail pressure sensor checks for high pressure or low pressure in the fuel rail.

Engine oil pressure – The engine oil pressure sensor indicates when oil pressure drops below rated system pressure, at a set engine speed.

Engine overspeed – The primary speed/timing sensor checks the engine speed. The alarm is activated at 3000 RPM.

Air filter restriction – The switch checks the air filter when the engine is operating.

User defined switch – This switch can shut down the engine remotely.

Water in fuel switch – This switch checks for water in the primary fuel filter when the engine is operating.

Note: The sensing element of the coolant temperature switch must be submerged in coolant in order to operate.

Engines may be equipped with alarms in order to alert the operator when undesirable operating conditions occur.

NOTICE

When an alarm is activated, corrective measures must be taken before the situation becomes an emergency in order to avoid possible engine damage.

If corrective measures are not taken within a reasonable time, engine damage could result. The alarm will continue until the condition is corrected. The alarm may need to be reset.

Testing

Turning the keyswitch to the ON position will check the indicator lights on the control panel. All the indicator lights will be illuminated for two seconds after the keyswitch is operated. Replace suspect bulbs immediately.

Refer to Troubleshooting for more information.

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Overspeed

An overspeed condition is detected by the Electronic Control Module (ECM). The event code will be logged if the engine speed exceeds 3000 rpm. The “DIAGNOSTIC” lamp will indicate a diagnostic active code. The diagnostic active code will remain active until the engine speed drops to 2800 rpm.

Engine Diagnostics

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Self-Diagnostics

Perkins electronic engines have the capability to perform a self-diagnostics test. When the system detects an active problem, a diagnostic lamp is activated. Diagnostic codes will be stored in permanent memory in the Electronic Control Module (ECM). The diagnostic codes can be retrieved by using the electronic service tool. Refer to Troubleshooting , “Electronic Service Tools” for further information.

Some installations have electronic displays that provide direct readouts of the engine diagnostic codes. Refer to the manual that is provided by the OEM for more information on retrieving engine diagnostic codes. Alternatively refer to Troubleshooting , “Indicator Lamps” for further information.

Active codes represent problems that currently exist. These problems should be investigated first.

Logged codes represent the following items:

- Intermittent problems
- Recorded events
- Performance history

The problems may have been repaired since the logging of the code. These codes do not indicate that a repair is needed. The codes are guides or signals when a situation exists. Codes may be helpful to troubleshoot problems.

When the problems have been corrected, the corresponding logged fault codes should be cleared.

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Diagnostic Lamp

A diagnostic lamp is used to indicate the existence of an active fault. Refer to Troubleshooting , “Indicator Lamps” for more information. A fault diagnostic code will remain active until the problem is repaired. The diagnostic code may be retrieved by using the electronic service tool. Refer to Troubleshooting , “Electronic Service Tools” for more information.

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Diagnostic Flash Code Retrieval

“Diagnostic” Lamp

Use the “DIAGNOSTIC” Lamp or an electronic service tool to determine the diagnostic flash code.

Use the following procedure to retrieve the flash codes if the engine is equipped with a “DIAGNOSTIC” lamp:

1. Turn the keyswitch “ON/OFF” two times within 3 seconds.

A flashing“YELLOW” lamp indicates a 3 digit code for the engine. The sequence of flashes represents the system diagnostic message. Count the first sequence of flashes in order to determine the first digit of the flash code. After a two second pause, the second sequence of flashes will identify the second digit of the flash code. After the second pause, the third sequence of flashes will identify the flash code.

Any additional flash codes will follow after a pause. These codes will be displayed in the same manner. Flash Code 551 indicates that No Detected Faults have occurred since the ignition keyswitch has been turned to the ON position.

For further information, assistance for repairs, or troubleshooting, refer to the Service Manual or consult an authorized Perkins dealer.

Table 3 lists the flash codes and the table also gives a brief description of the flash codes.

Note: Table 3indicates the potential effect on engine performance with “ACTIVE” flash codes.

Some codes record events. Also, some codes may also indicate that a mechanical system needs attention. Troubleshooting is not required for code “551”. Code 001 will not display a flash code. Some codes will limit the operation or the performance of the engine.

Table 3 indicates the potential effect on the engine performance with active flash codes. Table 3 also forms a list of Electronic diagnostic codes and descriptions.

Table 3

Flash Codes for the Industrial Engine								
Diagnostic Flash Code		Effect On Engine Performance (1)				Suggested Operator Action		
		Engine Misfire	Low Power	Reduced Engine Speed	Engine Shutdown	Shut Down the Engine (2)	Service (3)	Schedule a Service. (4)
111	Cylinder 1 Fault	X	X				X	
112	Cylinder 2 Fault	X	X				X	
113	Cylinder 3 Fault	X	X				X	
114	Cylinder 4 Fault	X	X				X	
133	Intake Manifold Temperature sensor fault (5)	X					X	
141	Primary Speed/ Timing Sensor Fault			X			X	
142	Secondary Speed/Timing Sensor Fault						X	
143	Timing Calibration Fault	X						X
144	Engine Operation Mode Selector Switch Fault		X				X	
151	High Air Filter Restriction		X				X	
154	Throttle Position sensor Fault			X			X	
155	Secondary Throttle Position sensor Fault			X			X	
157	Oil Pressure Sensor Fault(5)		X	X	X	X	X	
159	Fuel Rail Pressure Sensor Fault		X				X	
162	High Pressure Fuel Pump Fault		X	X			X	
168	Coolant Temperature Sensor Fault			X	X		X	
169	Low Engine Coolant				X			X
177	Wastegate Solenoid Fault			X				
185	High Exhaust Temperature		X				X	
197	Intake Manifold Pressure Sensor Fault		X				X	
199	Glow Plug Start Relay Fault						X	

(continued)

(Table 3, contd)

Flash Codes for the Industrial Engine								
Diagnostic Flash Code		Effect On Engine Performance [1]				Suggested Operator Action		
		Engine Misfire	Low Power	Reduced Engine Speed	Engine Shutdown	Shut Down the Engine [2]	Service [3]	Schedule a Service. [4]
415	Incorrect Engine Software			X	X		X	
426	Machine Security System Module Fault [6]						X	
429	Keyswitch Fault							X
511	Intermittent Battery Power to ECM	X	X		X		X	
514	SAE J1939 Data Link Fault			X			X	
516	5 Volt Sensor DC Power Supply Fault[5]		X					X
517	8 Volt Sensor DC Power Supply Fault		X					X
527	Check Customer Parameters or System Parameters [5]		X	X				X

[1] An "X" indicates that the effect on engine performance may occur if the code is active.
[2] Shut Down the Engine: Operate the engine cautiously. Get immediate service. Severe engine damage may result.
[3] The operator should go to the nearest location that has a qualified service program.
[4] Schedule Service: The problem should be investigated when the operator has access to a qualified service program.
[5] These Flash Codes may affect the system under specific environmental conditions such as engine start-up at cold temperature and cold weather operation at high altitudes.
[6] The engine will not start.

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Fault Logging

The system provides the capability of Fault Logging. When the Electronic Control Module (ECM) generates an active diagnostic code, the code will be logged in the memory of the ECM. The codes that have been logged by the ECM can be identified by the electronic service tool. The active codes that have been logged will be cleared when the fault has been rectified or the fault is no longer active. The following logged faults can not be cleared from the memory of the ECM without using a factory password: Overspeed, low engine oil pressure, and high engine coolant temperature.

i02651197

Engine Operation with Active Diagnostic Codes

If a diagnostic lamp illuminates during normal engine operation, the system has identified a situation that is not within the specification. Use the electronic service tool to check the active diagnostic codes.

The active diagnostic code should be investigated. The cause of the problem should be corrected as soon as possible. If the cause of the active diagnostic code is repaired and there is only one active diagnostic code, the diagnostic lamp will turn off.

Operation of the engine and performance of the engine can be limited as a result of the active diagnostic code that is generated. Acceleration rates may be significantly slower and power outputs may be automatically reduced. Refer to Troubleshooting , “Troubleshooting with a Diagnostic Code” for more information on the relationship between each active diagnostic code and the possible effect on engine performance.

i01902995

Engine Operation with Intermittent Diagnostic Codes

If a diagnostic lamp illuminates during normal engine operation and the diagnostic lamp shuts off, an intermittent fault may have occurred. If a fault has occurred, the fault will be logged into the memory of the Electronic Control Module (ECM).

In most cases, it is not necessary to stop the engine because of an intermittent code. However, the operator should retrieve the logged fault codes and the operator should reference the appropriate information in order to identify the nature of the event. The operator should log any observation that could have caused the lamp to light.

- Low power
- Limits of the engine speed
- Excessive smoke, etc

This information can be useful to help troubleshoot the situation. The information can also be used for future reference. For more information on diagnostic codes, refer to the Troubleshooting Guide for this engine.

Engine Starting

i02322201

Before Starting Engine

Before the engine is started, perform the required daily maintenance and any other periodic maintenance that is due. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for more information.

- Open the fuel supply valve (if equipped).

NOTICE
All valves in the fuel return line must be open before and during engine operation to help prevent high fuel pressure. High fuel pressure may cause filter housing failure or other damage.

If the engine has not been started for several weeks, fuel may have drained from the fuel system. Air may have entered the filter housing. Also, when fuel filters have been changed, some air pockets will be trapped in the engine. In these instances, prime the fuel system. Refer to the Operation and Maintenance Manual, "Fuel System - Prime" for more information on priming the fuel system.

WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

- Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.
- Reset all of the shutoffs or alarm components (if equipped).
- Ensure that any equipment that is driven by the engine has been disengaged from the engine. Minimize electrical loads or remove any electrical loads.

i02322203

Starting the Engine

Note: Do not adjust the engine speed control during start-up. The electronic control module (ECM) will control the engine speed during start-up.

Starting the Engine

1. Disengage any equipment that is driven by the engine.
2. Turn the keyswitch to the RUN position. Leave the keyswitch in the RUN position until the warning light for the glow plugs is extinguished.
3. When the warning light for the glow plugs is extinguished turn the keyswitch to the START position in order to engage the electric starting motor and crank the engine.

Note: The operating period of the warning light for the glow plugs will change due to the temperature of the engine.

NOTICE
Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before attempting to start the engine again.

4. Allow the keyswitch to return to the RUN position after the engine starts.
5. Repeat step 2 through step 4 if the engine fails to start.

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Cold Weather Starting

WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

Startability will be improved at temperatures below −18 °C (0 °F) from the use of a jacket water heater or extra battery capacity.

When Group 2 diesel fuel is used, the following items provide a means of minimizing starting problems and fuel problems in cold weather: Engine oil pan heaters, jacket water heaters, fuel heaters, and fuel line insulation.

Use the procedure that follows for cold weather starting.

Note: Do not adjust the engine speed control during start-up. The electronic control module (ECM) will control the engine speed during start-up.

1. Disengage any driven equipment.

2. Turn the keyswitch to the RUN position. Leave the keyswitch in the RUN position until the warning light for the glow plugs is extinguished.

NOTICE

Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before attempting to start the engine again.

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3. When the warning light for the glow plugs is extinguished turn the keyswitch to the START position in order to engage the electric starting motor and crank the engine.

Note: The operating period of the warning light for the glow plugs will change due to the temperature of the engine.

4. Allow the keyswitch to return to the RUN position after the engine starts.

5. Repeat step 2 through step 4 if the engine fails to start.

Note: The engine should not be “raced” in order to speed up the warm up process.

6. Allow the engine to idle for three to five minutes, or allow the engine to idle until the water temperature indicator begins to rise. When idling after the engine has started in cold weather, increase the engine rpm from 1000 to 1200 rpm. This will warm up the engine more quickly. Maintaining an elevated low idle speed for extended periods will be easier with the installation of a hand throttle. Allow the white smoke to disperse before proceeding with normal operation.

7. Operate the engine at low load until all systems reach operating temperature. Check the gauges during the warm-up period.

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Starting with Jump Start Cables

WARNING

Improper jump start cable connections can cause an explosion resulting in personal injury.

Prevent sparks near the batteries. Sparks could cause vapors to explode. Do not allow jump start cable ends to contact each other or the engine.

Note: If it is possible, first diagnose the reason for the starting failure. Refer to Troubleshooting, “Engine Will Not Crank and Engine Cranks But Will Not Start” for further information. Make any necessary repairs. If the engine will not start only due to the condition of the battery, either charge the battery, or start the engine by using another battery with jump start cables.
The condition of the battery can be rechecked after the engine has been switched OFF.

NOTICE

Using a battery source with the same voltage as the electric starting motor. Use ONLY equal voltage for jump starting. The use of higher voltage will damage the electrical system.

Do not reverse the battery cables. The alternator can be damaged. Attach ground cable last and remove first.

Turn all electrical accessories OFF before attaching the jump start cables.

Ensure that the main power switch is in the OFF position before attaching the jump start cables to the engine being started.

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1. Turn the start switch on the stalled engine to the OFF position. Turn off all the engine's accessories.

2. Connect one positive end of the jump start cable to the positive cable terminal of the discharged battery. Connect the other positive end of the jump start cable to the positive cable terminal of the electrical source.

3. Connect one negative end of the jump start cable to the negative cable terminal of the electrical source. Connect the other negative end of the jump start cable to the engine block or to the chassis ground. This procedure helps to prevent potential sparks from igniting the combustible gases that are produced by some batteries.

4. Start the engine.

5. Immediately after the engine is started, disconnect the jump start cables in reverse order.

After jump starting, the alternator may not be able to fully recharge batteries that are severely discharged. The batteries must be replaced or charged to the proper voltage with a battery charger after the engine is stopped. Many batteries which are considered unusable are still rechargeable. Refer to Operation and Maintenance Manual, “Battery - Replace” and Testing and Adjusting Manual, “Battery - Test”.

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After Starting Engine

Note: In ambient temperatures from 0 to 60°C (32 to 140°F), the warm-up time is approximately three minutes. In temperatures below 0°C (32°F), additional warm-up time may be required.

When the engine idles during warm-up, observe the following conditions:

Do not check the high pressure fuel lines with the engine or the starting motor in operation. If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General hazard Information”.

- Check for any fluid or for any air leaks at idle rpm and at one-half full rpm (no load on the engine) before operating the engine under load. This is not possible in some applications.

- Allow the engine to idle for three to five minutes, or allow the engine to idle until the water temperature indicator begins to rise. Check all gauges during the warm-up period.

Note: Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

Engine Operation

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Engine Operation

Correct operation and maintenance are key factors in obtaining the maximum life and economy of the engine. If the directions in the Operation and Maintenance Manual are followed, costs can be minimized and engine service life can be maximized.

The engine can be operated at the rated rpm after the engine reaches operating temperature. The engine will reach normal operating temperature if the engine is operated at low idle speed and operated with a light load. This procedure is more effective than idling the engine at no load. The engine should reach operating temperature in a few minutes.

Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

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Fuel Conservation Practices

The efficiency of the engine can affect the fuel economy. Perkins design and technology in manufacturing provides maximum fuel efficiency in all applications. Follow the recommended procedures in order to attain optimum performance for the life of the engine.

- Avoid spilling fuel.

Fuel expands when the fuel is warmed up. The fuel may overflow from the fuel tank. Inspect fuel lines for leaks. Repair the fuel lines, as needed.

- Be aware of the properties of the different fuels. Use only the recommended fuels.

- Avoid unnecessary idling.

Shut off the engine rather than idle for long periods of time.

- Observe the air cleaner service indicator frequently. Keep the air cleaner elements clean.

- Maintain the electrical systems.

One damaged battery cell will overwork the alternator. This will consume excess power and excess fuel.

- Ensure that the drive belts are correctly adjusted. The drive belts should be in good condition.

- Ensure that all of the connections of the hoses are tight. The connections should not leak.

- Ensure that the driven equipment is in good working order.

- Cold engines consume excess fuel. Utilize heat from the jacket water system and the exhaust system, when possible. Keep cooling system components clean and keep cooling system components in good repair. Never operate the engine without water temperature regulators. All of these items will help maintain operating temperatures.

Engine Stopping

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Stopping the Engine

NOTICE

Stopping the engine immediately after it has been working under load, can result in overheating and accelerated wear of the engine components.

Avoid accelerating the engine prior to shutting it down.

Avoiding hot engine shutdowns will maximize turbocharger shaft and bearing life.

Note: Individual applications will have different control systems. Ensure that the shutoff procedures are understood. Use the following general guidelines in order to stop the engine.

1. Remove the load from the engine. Reduce the engine speed (rpm) to low idle. Allow the engine to idle for five minutes in order to cool the engine.

2. Stop the engine after the cool down period according to the shutoff system on the engine and turn the ignition key switch to the OFF position. If necessary, refer to the instructions that are provided by the OEM.

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Emergency Stopping

NOTICE

Emergency shutoff controls are for EMERGENCY use ONLY. DO NOT use emergency shutoff devices or controls for normal stopping procedure.

The OEM may have equipped the application with an emergency stop button. For more information about the emergency stop button, refer to the OEM information.

Ensure that any components for the external system that support the engine operation are secured after the engine is stopped.

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After Stopping Engine

Note: Before you check the engine oil, do not operate the engine for at least 10 minutes in order to allow the engine oil to return to the oil pan.

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

- After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, “Fuel Injection Lines - Install”.

- Check the crankcase oil level. Maintain the oil level between the “MIN” mark and the “MAX” mark on the engine oil level gauge.

- If the engine is equipped with a service hour meter, note the reading. Perform the maintenance that is in the Operation and Maintenance Manual, “Maintenance Interval Schedule”.

- Fill the fuel tank in order to help prevent accumulation of moisture in the fuel. Do not overfill the fuel tank.

NOTICE

Only use antifreeze/coolant mixtures recommended in the Coolant Specifications that are in the Operation and Maintenance Manual. Failure to do so can cause engine damage.

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

- Allow the engine to cool. Check the coolant level.

- Check the coolant for correct antifreeze protection and the correct corrosion protection. Add the correct coolant/water mixture, if necessary.

- Perform all required periodic maintenance on all driven equipment. This maintenance is outlined in the instructions from the OEM.

Cold Weather Operation

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Cold Weather Operation

Perkins Diesel Engines can operate effectively in cold weather. During cold weather, the starting and the operation of the diesel engine is dependent on the following items:

- The type of fuel that is used
- The viscosity of the engine oil
- The operation of the glow plugs
- Optional Cold starting aid
- Battery condition

This section will cover the following information:

- Potential problems that are caused by cold weather operation
- Suggest steps which can be taken in order to minimize starting problems and operating problems when the ambient air temperature is between 0° to−40 °C (32° to 40 °F).

The operation and maintenance of an engine in freezing temperatures is complex . This is because of the following conditions:

- Weather conditions
- Engine applications

Recommendations from your Perkins dealer or your Perkins distributor are based on past proven practices. The information that is contained in this section provides guidelines for cold weather operation.

Hints for Cold Weather Operation

- If the engine will start, operate the engine until a minimum operating temperature of 81 °C (177.8 °F) is achieved. Achieving operating temperature will help prevent the intake valves and exhaust valves from sticking.
- The cooling system and the lubrication system for the engine do not lose heat immediately upon shutdown. This means that an engine can be shut down for a period of time and the engine can still have the ability to start readily.
- Install the correct specification of engine lubricant before the beginning of cold weather.
- Check all rubber parts (hoses, fan drive belts, etc) weekly.
- Check all electrical wiring and connections for any fraying or damaged insulation.
- Keep all batteries fully charged and warm.
- Fill the fuel tank at the end of each shift.
- Check the air cleaners and the air intake daily. Check the air intake more often when you operate in snow.
- Ensure that the glow plugs are in working order. Refer to Testing and Adjusting Manual, “Glow Plug - Test”.

WARNING

Personal injury or property damage can result from alcohol or starting fluids.

Alcohol or starting fluids are highly flammable and toxic and if improperly stored could result in injury or property damage.

WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

- For jump starting with cables in cold weather, refer to the Operation and Maintenance Manual, “Starting with Jump Start Cables.” for instructions.

Viscosity of the Engine Lubrication Oil

Correct engine oil viscosity is essential. Oil viscosity affects the amount of torque that is needed to crank the engine. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for the recommended viscosity of oil.

Recommendations for the Coolant

Provide cooling system protection for the lowest expected outside temperature. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for the recommended coolant mixture.

In cold weather, check the coolant often for the correct glycol concentration in order to ensure adequate freeze protection.

Engine Block Heaters

Engine block heaters (if equipped) heat the engine jacket water that surrounds the combustion chambers. This provides the following functions:

- Startability is improved.
- Warm up time is reduced.

An electric block heater can be activated once the engine is stopped. An effective block heater is typically a 1250/1500 W unit. Consult your Perkins dealer or your Perkins distributor for more information.

Idling the Engine

When idling after the engine is started in cold weather, increase the engine rpm from 1000 to 1200 rpm. This will warm up the engine more quickly. Maintaining an elevated low idle speed for extended periods will be easier with the installation of a hand throttle. The engine should not be “raced” in order to speed up the warm up process.

While the engine is idling, the application of a light load (parasitic load) will assist in achieving the minimum operating temperature. The minimum operating temperature is 82 °C (179.6 °F).

Recommendations for Coolant Warm Up

Warm up an engine that has cooled below normal operating temperatures due to inactivity. This should be performed before the engine is returned to full operation. During operation in very cold temperature conditions, damage to engine valve mechanisms can result from engine operation for short intervals. This can happen if the engine is started and the engine is stopped many times without being operated in order to warm up completely.

When the engine is operated below normal operating temperatures, fuel and oil are not completely burned in the combustion chamber. This fuel and oil causes soft carbon deposits to form on the valve stems. Generally, the deposits do not cause problems and the deposits are burned off during operation at normal engine operating temperatures.

When the engine is started and the engine is stopped many times without being operated in order to warm up completely, the carbon deposits become thicker. This can cause the following problems:

- Free operation of the valves is prevented.
- Valves become stuck.
- Pushrods may become bent.
- Other damage to valve train components can result.

For this reason, when the engine is started, the engine must be operated until the coolant temperature is 71 °C (160 °F) minimum. Carbon deposits on the valve stems will be kept at a minimum and the free operation of the valves and the valve components will be maintained.

In addition, the engine must be thoroughly warmed in order to keep other engine parts in better condition and the service life of the engine will be generally extended. Lubrication will be improved. There will be less acid and less sludge in the oil. This will provide longer service life for the engine bearings, the piston rings, and other parts. However, limit unnecessary idle time to ten minutes in order to reduce wear and unnecessary fuel consumption.

The Water Temperature Regulator and Insulated Heater Lines

The engine is equipped with a water temperature regulator. When the engine coolant is below the correct operating temperature jacket water circulates through the engine cylinder block and into the engine cylinder head. The coolant then returns to the cylinder block via an internal passage that bypasses the valve of the coolant temperature regulator. This ensures that coolant flows around the engine under cold operating conditions. The water temperature regulator begins to open when the engine jacket water has reached the correct minimum operating temperature. As the jacket water coolant temperature rises above the minimum operating temperature the water temperature regulator opens further allowing more coolant through the radiator to dissipate excess heat.

The progressive opening of the water temperature regulator operates the progressive closing of the bypass passage between the cylinder block and head. This ensures maximum coolant flow to the radiator in order to achieve maximum heat dissipation.

Note: Perkins discourages the use of all air flow restriction devices such as radiator shutters. Restriction of the air flow can result in the following: high exhaust temperatures, power loss, excessive fan usage, and reduction in fuel economy.

A cab heater is beneficial in very cold weather. The feed from the engine and the return lines from the cab should be insulated in order to reduce heat loss to the outside air.

Insulating the Air Inlet and Engine Compartment

When temperatures below −18 °C (−0 °F) will be frequently encountered, an air cleaner inlet that is located in the engine compartment may be specified. An air cleaner that is located in the engine compartment may also minimize the entry of snow into the air cleaner. Also, heat that is rejected by the engine helps to warm the intake air.

Additional heat can be retained around the engine by insulating the engine compartment.

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Fuel and the Effect from Cold Weather

Note: Only use grades of fuel that are recommended by Perkins. Refer to this Operation and Maintenance Manual, “Fluid Recommendations”.

The following components provide a means of minimizing problems in cold weather:

- Glow plugs (if equipped)
- Engine coolant heaters, which may be an OEM option
- Fuel heaters, which may be an OEM option
- Fuel line insulation, which may be an OEM option

The cloud point is a temperature that allows wax crystals to form in the fuel. These crystals can cause the fuel filters to plug.

The pour point is the temperature when diesel fuel will thicken. The diesel fuel becomes more resistant to flow through fuel lines, fuel filters,and fuel pumps.

Be aware of these facts when diesel fuel is purchased. Consider the average ambient air temperature for the engine's application. Engines that are fueled in one climate may not operate well if the engines are moved to another climate. Problems can result due to changes in temperature.

Before troubleshooting for low power or for poor performance in the winter, check the fuel for waxing.

Low temperature fuels may be available for engine operation at temperatures below 0 °C (32 °F). These fuels limit the formation of wax in the fuel at low temperatures.

For more information on cold weather operation, refer to the Operation and Maintenance Manual, “Cold Weather Operation and Fuel Related Components in Cold Weather”.

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Fuel Related Components in Cold Weather

Fuel Tanks

Condensation can form in partially filled fuel tanks. Top off the fuel tanks after you operate the engine.

Fuel tanks should contain some provision for draining water and sediment from the bottom of the tanks.

Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe.

Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Drain the water and sediment from any fuel storage tank at the following intervals: weekly, service intervals, and refueling of the fuel tank. This will help prevent water and/or sediment from being pumped from the fuel storage tank and into the engine fuel tank.

Fuel Filters

A primary fuel filter is installed between the fuel tank and the engine fuel inlet. After you change the fuel filter, always prime the fuel system in order to remove air bubbles from the fuel system. Refer to the Operation and Maintenance Manual in the Maintenance Section for more information on priming the fuel system.

The location of a primary fuel filter is important in cold weather operation. The primary fuel filter and the fuel supply line are the most common components that are affected by cold fuel.

Fuel Heaters

Note: The OEM may equip the application with fuel heaters. If this is the case, the temperature of the fuel must not exceed 73 °C (163 °F) at the fuel transfer pump.

For more information about fuel heaters (if equipped), refer to the OEM information.

Maintenance Section

Refill Capacities

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Refill Capacities

Lubrication System

The refill capacities for the engine crankcase reflect the approximate capacity of the crankcase or sump plus standard oil filters. Auxiliary oil filter systems will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter. Refer to the Operation and Maintenance Manual, “Maintenance Section” for more information on Lubricant Specifications.

Table 4

Engine Refill Capacities		
Compartment or System	**Minimum** (1)	**Maximum** (2)
Crankcase Oil Sump	6 L (1.32 Imp gal)	14 L (3.1 Imp gal)

(1) The minimum value is the approximate capacity for the crankcase oil sump (aluminum) which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter. The design of the oil pan can change the oil capacity of the oil pan.
(2) Approximate capacity of the largest crankcase oil sump. Refer to OEM for more information.

Cooling System

Refer to the OEM specifications for the External System capacity. This capacity information will be needed in order to determine the amount of coolant/antifreeze that is required for the Total Cooling System.

Table 5

Engine Refill Capacities		
Compartment or System	**Liters**	
	Engine	Engine
Engine Only	TA[1]	TTA[2]
	9 L (1.97 Imp gal)	9.4 L (2.07 Imp gal)
External System Per OEM[3]		

(1) Single Turbocharger
(2) Series Turbochargers
(3) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.

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Fluid Recommendations

General Lubricant Information

Because of government regulations regarding the certification of exhaust emissions from the engine, the lubricant recommendations must be followed.

- EMA__________Engine Manufacturers Association
- API_______________American Petroleum Institute
- SAE_______________________________Society Of Automotive Engineers Inc.

EMA Guidelines

The “Engine Manufacturers Association Recommended Guideline on Diesel Engine Oil” is recognized by Perkins. For detailed information about this guideline, see the latest edition of EMA publication, “EMA DHD -1”.

API Licensing

The Engine Oil Licensing and Certification System by the American Petroleum Institute (API) is recognized by Perkins. For detailed information about this system, see the latest edition of the “API publication No. 1509”. Engine oils that bear the API symbol are authorized by API.

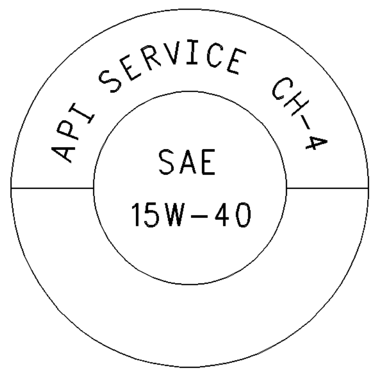

Illustration 25 g00546535

Typical API symbol

Terminology

Certain abbreviations follow the nomenclature of “SAE J754”. Some classifications follow “SAE J183” abbreviations, and some classifications follow the “EMA Recommended Guideline on Diesel Engine Oil”. In addition to Perkins definitions, there are other definitions that will be of assistance in purchasing lubricants. Recommended oil viscosities can be found in this publication, “Fluid Recommendations/Engine Oil” topic (Maintenance Section).

Engine Oil

Commercial Oils

NOTICE
For applications above 168 kW CI-4 oil must be used.

Table 6

API Classifications for the 1104D Industrial Engine	
Oil Specification	**Maintenance Interval**
CH-4/CI-4	500 Hours
CI-4	500 Hours
CG-4	250 Hours

Maintenance intervals for engines that use biodiesel – The oil change interval can be adversely affected by the use of biodiesel. Use oil analysis in order to monitor the condition of the engine oil. Use oil analysis also in order to determine the oil change interval that is optimum.

Note: These engine oils are not approved by perkins and these engine oils must not be used:CC, CD, CD-2, and CF-4.

The performance of commercial diesel engine oils is based on API classifications. These API classifications are developed in order to provide commercial lubricants for a broad range of diesel engines that operate at various conditions.

Only use commercial oils that meet the following classifications:

- API______________________________ CH-4 CI-4

In order to make the correct choice of a commercial oil, refer to the following explanations:

EMA DHD-1 – The EMA has developed lubricant recommendations as an alternative to the API oil classification system. DHD-1 is a Recommended Guideline that defines a level of oil performance for these types of diesel engines: high speed, four stroke cycle, heavy-duty, and light duty. DHD-1 oils may be used in Perkins engines when the following oils are recommended: API CH-4 and API CG-4. DHD-1 oils are intended to provide superior performance in comparison to API CG-4.

DHD-1 oils will meet the needs of high performance Perkins diesel engines that are operating in many applications. The tests and the test limits that are used to define DHD-1 are similar to the new API CH-4 classification. Therefore, these oils will also meet the requirements for diesel engines that require low emissions. DHD-1 oils are designed to control the harmful effects of soot with improved wear resistance and improved resistance to plugging of the oil filter. These oils will also provide superior piston deposit control for engines with either two-piece steel pistons or aluminum pistons.

All DHD-1 oils must complete a full test program with the base stock and with the viscosity grade of the finished commercial oil. The use of “API Base Oil Interchange Guidelines” are not appropriate for DHD-1 oils. This feature reduces the variation in performance that can occur when base stocks are changed in commercial oil formulations.

DHD-1 oils are recommended for use in extended oil change interval programs that optimize the life of the oil. These oil change interval programs are based on oil analysis. DHD-1 oils are recommended for conditions that demand a premium oil. Your Perkins distributor has the specific guidelines for optimizing oil change intervals.

API CH-4 – API CH-4 oils were developed in order to meet the requirements of the new high performance diesel engines. Also, the oil was designed to meet the requirements of the low emissions diesel engines. API CH-4 oils are also acceptable for use in older diesel engines and in diesel engines that use high sulfur diesel fuel. API CH-4 oils may be used in Perkins engines that use API CG-4 and API CF-4 oils. API CH-4 oils will generally exceed the performance of API CG-4 oils in the following criteria: deposits on pistons, control of oil consumption, wear of piston rings, valve train wear, viscosity control, and corrosion.

Three new engine tests were developed for the API CH-4 oil. The first test specifically evaluates deposits on pistons for engines with the two-piece steel piston. This test (piston deposit) also measures the control of oil consumption. A second test is conducted with moderate oil soot. The second test measures the following criteria: wear of piston rings, wear of cylinder liners, and resistance to corrosion. A third new test measures the following characteristics with high levels of soot in the oil: wear of the valve train, resistance of the oil in plugging the oil filter, and control of sludge.

In addition to the new tests, API CH-4 oils have tougher limits for viscosity control in applications that generate high soot. The oils also have improved oxidation resistance. API CH-4 oils must pass an additional test (piston deposit) for engines that use aluminum pistons (single piece). Oil performance is also established for engines that operate in areas with high sulfur diesel fuel.

All of these improvements allow the API CH-4 oil to achieve optimum oil change intervals. API CH-4 oils are recommended for use in extended oil change intervals. API CH-4 oils are recommended for conditions that demand a premium oil. Your Perkins distributor has specific guidelines for optimizing oil change intervals.

Some commercial oils that meet the API classifications may require reduced oil change intervals. To determine the oil change interval, closely monitor the condition of the oil and perform a wear metal analysis.

NOTICE

Failure to follow these oil recommendations can cause shortened engine service life due to deposits and/or excessive wear.

Total Base Number (TBN) and Fuel Sulfur Levels for Direct Injection (DI) Diesel Engines

The Total Base Number (TBN) for an oil depends on the fuel sulfur level. For direct injection engines that use distillate fuel, the minimum TBN of the new oil must be 10 times the fuel sulfur level. The TBN is defined by “ASTM D2896”. The minimum TBN of the oil is 5 regardless of fuel sulfur level. Illustration 26 demonstrates the TBN.

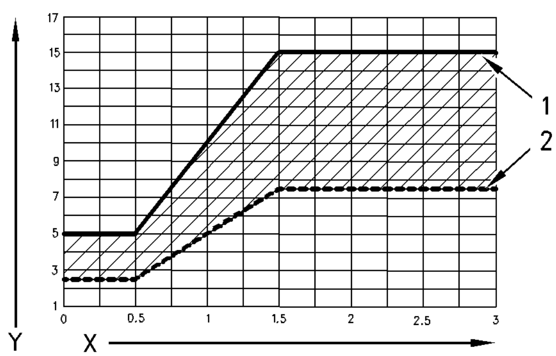

Illustration 26 g00799818

(Y) TBN by “ASTM D2896”
(X) Percentage of fuel sulfur by weight
(1) TBN of new oil
(2) Change the oil when the TBN deteriorates to 50 percent of the original TBN.

Use the following guidelines for fuel sulfur levels that exceed 1.5 percent:

- Choose an oil with the highest TBN that meets one of these classifications: EMA DHD-1 and API CH-4.

- Reduce the oil change interval. Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis.

Excessive piston deposits can be produced by an oil with a high TBN. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

NOTICE

Operating Direct Injection (DI) diesel engines with fuel sulphur levels over 0.5 percent will require shortened oil change intervals in order to help maintain adequate wear protection.

Table 7

Percentage of Sulfur in the fuel	**Oil change interval**
Lower than 0.5	Normal
0.5 to 1.0	0.75 of normal
Greater than 1.0	0.50 of normal

Lubricant Viscosity Recommendations for Direct Injection (DI) Diesel Engines

The correct SAE viscosity grade of oil is determined by the minimum ambient temperature during cold engine start-up, and the maximum ambient temperature during engine operation.

Refer to Table 8 (minimum temperature) in order to determine the required oil viscosity for starting a cold engine.

Refer to Table 8 (maximum temperature) in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Generally, use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

Table 8

Engine Oil Viscosity		
EMA LRG-1 API CH-4 Viscosity Grade	**Ambient Temperature**	
	Minimum	**Maximum**
SAE 0W20	−40 °C (−40 °F)	10 °C (50 °F)
SAE 0W30	−40 °C (−40 °F)	30 °C (86 °F)
SAE 0W40	−40 °C (−40 °F)	40 °C (104 °F)
SAE 5W30	−30 °C (−22 °F)	30 °C (86 °F)
SAE 5W40	−30 °C (−22 °F)	40 °C (104 °F)
SAE 10W30	−20 °C (−4 °F)	40 °C (104 °F)
SAE 15W40	−10 °C (14 °F)	50 °C (122 °F)

Synthetic Base Stock Oils

Synthetic base oils are acceptable for use in these engines if these oils meet the performance requirements that are specified for the engine.

Synthetic base oils generally perform better than conventional oils in the following two areas:

- Synthetic base oils have improved flow at low temperatures especially in arctic conditions.
- Synthetic base oils have improved oxidation stability especially at high operating temperatures.

Some synthetic base oils have performance characteristics that enhance the service life of the oil. Perkins does not recommend the automatic extending of the oil change intervals for any type of oil.

Re-refined Base Stock Oils

Re-refined base stock oils are acceptable for use in Perkins engines if these oils meet the performance requirements that are specified by Perkins. Re-refined base stock oils can be used exclusively in finished oil or in a combination with new base stock oils. The specification for the US military and the specifications of other heavy equipment manufacturers also allow the use of re-refined base stock oils that meet the same criteria.

The process that is used to make re-refined base stock oil should adequately remove all wear metals that are in the used oil and all the additives that are in the used oil. The process that is used to make re-refined base stock oil generally involves the process of vacuum distillation and hydrotreating the used oil. Filtering is adequate for the production of high quality, re-refined base stock oil.

Lubricants for Cold Weather

When an engine is started and an engine is operated in ambient temperatures below −20 °C (−4 °F), use multigrade oils that are capable of flowing in low temperatures.

These oils have lubricant viscosity grades of SAE 0W or SAE 5W.

When an engine is started and operated in ambient temperatures below −30 °C (−22 °F), use a synthetic base stock multigrade oil with an 0W viscosity grade or with a 5W viscosity grade. Use an oil with a pour point that is lower than −50 °C (−58 °F).

Perkins recommends the following lubricants for use in cold weather conditions:

Use a commercial oil that is API:CI-4, CI-4 PLUS, CH-4, and CG-4. The oil must have one of the following lubricant viscosity grades: SAE 0W-20, SAE 0W-30, SAE 0W-40, SAE 5W-30, and SAE 5W-40

Aftermarket Oil Additives

Perkins does not recommend the use of aftermarket additives in oil. It is not necessary to use aftermarket additives in order to achieve the engine's maximum service life or rated performance. Fully formulated, finished oils consist of base oils and of commercial additive packages. These additive packages are blended into the base oils at precise percentages in order to help provide finished oils with performance characteristics that meet industry standards.

There are no industry standard tests that evaluate the performance or the compatibility of aftermarket additives in finished oil. Aftermarket additives may not be compatible with the finished oil's additive package, which could lower the performance of the finished oil. The aftermarket additive could fail to mix with the finished oil. This could produce sludge in the crankcase. Perkins discourages the use of aftermarket additives in finished oils.

To achieve the best performance from a Perkins engine, conform to the following guidelines:

- Select the correct oil, or a commercial oil that meets the “EMA Recommended Guideline on Diesel Engine Oil” or the recommended API classification.
- See the appropriate “Lubricant Viscosities” table in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine. Use new oil and install a new oil filter.
- Perform maintenance at the intervals that are specified in the Operation and Maintenance Manual, “Maintenance Interval Schedule”.

Oil analysis

Some engines may be equipped with an oil sampling valve. If oil analysis is required the oil sampling valve is used to obtain samples of the engine oil. The oil analysis will complement the preventive maintenance program.

The oil analysis is a diagnostic tool that is used to determine oil performance and component wear rates. Contamination can be identified and measured through the use of the oil analysis. The oil analysis includes the following tests:

- The Wear Rate Analysis monitors the wear of the engine's metals. The amount of wear metal and type of wear metal that is in the oil is analyzed. The increase in the rate of engine wear metal in the oil is as important as the quantity of engine wear metal in the oil.

- Tests are conducted in order to detect contamination of the oil by water, glycol or fuel.

- The Oil Condition Analysis determines the loss of the oil's lubricating properties. An infrared analysis is used to compare the properties of new oil to the properties of the used oil sample. This analysis allows technicians to determine the amount of deterioration of the oil during use. This analysis also allows technicians to verify the performance of the oil according to the specification during the entire oil change interval.

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Fluid Recommendations (Fuel Specification)

- **Glossary**
- ISO International Standards Organization
- ASTM American Society for Testing and Materials
- HFRR High Frequency Reciprocating Rig for Lubricity testing of diesel fuels
- FAME Fatty Acid Methyl Esters
- CFR Co-ordinating Fuel Research
- LSD Low Sulfur Diesel
- ULSD Ultra Low Sulfur Diesel
- RME Rape Methyl Ester
- SME Soy Methyl Ester
- EPA Environmental Protection Agency of the United States

General Information

NOTICE
Every attempt is made to provide accurate, up to date information. By use of this document you agree that Perkins Engines Company Limited is not responsible for errors or omissions.

NOTICE
These recommendations are subject to change without notice. Contact your local Perkins distributor for the most up to date recommendations.

Diesel Fuel Requirements

Satisfactory engine performance is dependent on the use of a good quality fuel. The use of a good quality fuel will give the following results: long engine life and acceptable exhaust emissions levels. The fuel must meet the minimum requirements that are stated in table 9.

NOTICE
The footnotes are a key part of the Perkins Specification for Distillate Diesel Fuel Table. Read ALL of the footnotes.

Table 9

Perkins Specification for Distillate Diesel Fuel (1)				
Property	**UNITS**	**Requirements**	**“ASTM”Test**	**“ISO”Test**
Aromatics	%Volume	35% maximum	D1319	“ISO”3837
Ash	%Weight	0.01% maximum	D482	“ISO”6245
Carbon Residue on 10% Bottoms	%Weight	0.35% maximum	D524	“ISO”4262
Cetane Number (2)	-	40 minimum	D613/D6890	“ISO”5165
Cloud Point	°C	The cloud point must not exceed the lowest expected ambient temperature.	D2500	“ISO”3015
Copper Strip Corrosion	-	No. 3 maximum	D130	“ISO”2160
Density at 15 °C (59 °F) (3)	Kg / M^3	801 minimum and 876 maximum	No equivalent test	“ISO 3675 ”“ISO 12185”
Distillation	°C	10% at 282 °C (539.6 °F) maximum 90% at 360 °C (680 °F) maximum	D86	“ISO”3405
Flash Point	°C	legal limit	D93	“ISO”2719
Thermal Stability	-	Minimum of 80% reflectance after aging for 180 minutes at 150 °C (302 °F)	D6468	No equivalent test
Pour Point	°C	6 °C (42.8 °F) minimum below ambient temperature	D97	“ISO”3016
Sulfur (1)(4)	%mass	1% maximum	D5453/D26222	“ISO 20846 ”“ISO 20884”
Kinematic Viscosity (5)	“MM”^{2}“/S (cSt)”	The viscosity of the fuel that is delivered to the fuel injection pump. “1.4 minimum/4.5 maximum”	D445	“ISO”3405
Water and sediment	% weight	0.1% maximum	D1796	“ISO”3734
Water	% weight	0.1% maximum	D1744	No equivalent test
Sediment	% weight	0.05% maximum	D473	“ISO”3735
Gums and Resins (6)	mg/100mL	10 mg per 100 mL maximum	D381	“ISO”6246

(continued)

(Table 9, contd)

Lubricity corrected wear scar diameter at 60 °C (140 °F). (7)	mm	0.52 maximum	D6079	“ISO”12156-1

(1) This specification includes the requirements for Ultra Low Sulfur Diesel (ULSD). ULSD fuel will have ≤ 15 ppm (0.0015%) sulfur. Refer to “ASTM D5453”, “ASTM D2622”, or “ISO 20846, ISO 20884” test methods. This specification includes the requirements for Low Sulfur Diesel (LSD). LSD fuel will have ≤500 ppm (0.05%) sulfur. Refer to following:“ASTM 5453, ASTM D2622”, “ISO 20846”, and “ISO 20884 test methods”.

(2) A fuel with a higher cetane number is recommended in order to operate at a higher altitude or in cold weather.

(3) “Via standards tables, the equivalent API gravity for the minimum density of 801 kg / m^3 (kilograms per cubic meter) is 45 and for the maximum density of 876 kg / m^3 is 30”.

(4) Regional regulations, national regulations or international regulations can require a fuel with a specific sulfur limit. Consult all applicable regulations before selecting a fuel for a given engine application. Perkins fuel systems and engine components can operate on high sulfur fuels. Fuel sulfur levels affect exhaust emissions. High sulfur fuels also increase the potential for corrosion of internal components. Fuel sulfur levels above 0.5% may significantly shorten the oil change interval. For additional information, refer to this manual, “Fluid recommendations (General lubricant Information)”.

(5) The values of the fuel viscosity are the values as the fuel is delivered to the fuel injection pumps. Fuel should also meet the minimum viscosity requirement and the fuel should meet the maximum viscosity requirements at 40 °C (104 °F) of either the “ASTM D445” test method or the “ISO 3104” test method. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to 4.5 cSt at the fuel injection pump.

(6) Follow the test conditions and procedures for gasoline (motor).

(7) The lubricity of a fuel is a concern with low sulfur and ultra low sulfur fuel. To determine the lubricity of the fuel, use the “ISO 12156-1 or ASTM D6079 High Frequency Reciprocating Rig (HFRR)” test. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

NOTICE

Operating with fuels that do not meet the Perkins recommendations can cause the following effects: Starting difficulty, poor combustion, deposits in the fuel injectors, reduced service life of the fuel system, deposits in the combustion chamber, and reduced service life of the engine.

Diesel Fuel Characteristics

Perkins Recommendation

Cetane Number

Fuel that has a high cetane number will give a shorter ignition delay. This will produce a better ignition quality. Cetane numbers are derived for fuels against proportions of cetane and heptamethylnonane in the standard CFR engine. Refer to “ISO 5165” for the test method.

Cetane numbers in excess of 45 are normally expected from current diesel fuel. However, a cetane number of 40 may be experienced in some territories. The United States of America is one of the territories that can have a low cetane value. A minimum cetane value of 40 is required during average starting conditions. A higher cetane value may be required for operations at high altitudes or in cold weather operations.

Fuel with a low cetane number can be the root cause of problems during cold start.

Viscosity

Viscosity is the property of a liquid of offering resistance to shear or flow. Viscosity decreases with increasing temperature. This decrease in viscosity follows a logarithmic relationship for normal fossil fuel. The common reference is to kinematic viscosity. This is the quotient of the dynamic viscosity that is divided by the density. The determination of kinematic viscosity is normally by readings from gravity flow viscometers at standard temperatures. Refer to “ISO 3104” for the test method.

The viscosity of the fuel is significant because fuel serves as a lubricant for the fuel system components. Fuel must have sufficient viscosity in order to lubricate the fuel system in both extremely cold temperatures and extremely hot temperatures. If the kinematic viscosity of the fuel is lower than 1.4 cSt at the fuel injection pump damage to the fuel injection pump can occur. This damage can be excessive scuffing and seizure. Low viscosity may lead to difficult hot restarting, stalling and loss of performance. High viscosity may result in seizure of the pump.

Perkins recommends kinematic viscosities of 1.4 and 4.5 mm2/sec that is delivered to the fuel injection pump.

Density

Density is the mass of the fuel per unit volume at a specific temperature. This parameter has a direct influence on engine performance and a direct influence on emissions. This determines the heat output from a given injected volume of fuel. This is generally quoted in the following kg/m at 15 °C (59 °F).

Perkins recommends a value of density of 841 kg/m in order to obtain the correct power output. Lighter fuels are acceptable but these fuels will not produce the rated power.

Sulfur

The level of sulfur is governed by emissions legislations. Regional regulation, national regulations or international regulations can require a fuel with a specific sulfur limit. The sulfur content of the fuel and the fuel quality must comply with all existing local regulations for emissions.

By using the test methods “ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884”, the content of sulfur in low sulfur diesel (LSD) fuel must be below 500 PPM 0.05%. By using the test methods “ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884”, the content of sulfur in ultra low sulfur (ULSD) fuel must be below 15 PPM 0.0015%. The use of LSD fuel and the use of ULSD fuel are acceptable provided that the fuels meet the minimum requirements that are stated in table 9. The lubricity of these fuels must not exceed wear scar diameter of 0.52 mm (0.0205 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to “ISO 12156-1 ”.

In some parts of the world and for some applications, high sulfur fuels above 0.5% by mass might only be available. Fuel with very high sulfur content can cause engine wear. High sulfur fuel will have a negative impact on emissions of particulates. High sulfur fuel can be used provided that the local emissions legislation will allow the use. High sulfur fuel can be used in countries that do not regulate emissions.

When only high sulfur fuels are available, it will be necessary that high alkaline lubricating oil is used in the engine or that the lubricating oil change interval is reduced. Refer to this Operation and Maintenance Manual, “Fliud Recommendations (Genernal Lubrication Information)” for information on sulfur in fuel.

Lubricity

This is the capability of the fuel to prevent pump wear. The fluid's lubricity describes the ability of the fluid to reduce the friction between surfaces that are under load. This ability reduces the damage that is caused by friction. Fuel injection systems rely on the lubricating properties of the fuel. Until fuel sulfur limits were mandated, the fuel's lubricity was generally believed to be a function of fuel viscosity.

The lubricity has particular significance to the current low viscosity fuel, low sulfur fuel and low aromatic fossil fuel. These fuels are made in order to meet stringent exhaust emissions. A test method for measuring the lubricity of diesel fuels has been developed and the test is based on the HFRR method that is operated at 60 °C (140 °F). Refer to “ISO 12156 part 1 and CEC document F06-A-96” for the test method.

Lubricity wear scar diameter of 0.52 mm (0.0205 inch) MUST NOT be exceeded. The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to “ISO 12156-1 ”.

Fuel additives can enhance the lubricity of a fuel. Contact your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can make recommendations for additives to use and for the proper level of treatment.

Distillation

This is an indication of the mixture of different hydrocarbons in the fuel. A high ratio of light weight hydrocarbons can affect the characteristics of combustion.

Classification of the Fuels

Diesel engines have the ability to burn a wide variety of fuels. These fuels are divided into four general groups: Ref to table 10

Table 10

Fuel Groups	Classification	
Group 1	Preferred fuels	Full life of the Product
Group 2	Permissible fuels with an appropriate fuel additive	These fuels MAY cause reduced engine life and performance
Group 3	Permissible fuels with an appropriate fuel additive	These fuels WILL cause reduced engine life and performance
Group 4	Biodiesel	

Group 1 Specifications (Preferred Fuels)

This group of fuel specifications is considered acceptable:

- EN590 DERV Grade A, B, C, E, F, Class, 0, 1, 2, 3, and 4
- "BS2869 Class A2" Off-Highway Gas Oil Red Diesel
- "ASTM D975", Class 1D , and Class 2D
- "JIS K2204 Grades 1,2,3 and Special Grade 3" This grade of fuel must meet the minimum lubricity requirements that are stated in table 9.
- 5% FAME to "EN14214" can be mixed with the fuel that meets the requirements that are stated in table 9. This blend is commonly known as B5.

Note: The use of LSD fuel and the use of ULSD fuel is acceptable provided that the fuels meet the minimum requirements that are stated in table 9. The lubricity of these fuels must not exceed wear scar diameter of 0.52 mm (0.0205 inch). The lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ". By using the test methods "ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884", the content of sulfur in LSD fuel must be below 500 PPM 0.05%. By using the test methods "ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884", the content of sulfur in ULSD fuel must be below 15 PPM 0.0015%.

Group 2 Specifications (Permissible Fuels)

This group of fuel specifications is considered acceptable, but only with an appropriate fuel additive, but these fuels MAY reduce the engine life and performance.

- "JP7 (MIL-T-38219)"
- "NATO F63"
- JP8
- JP5
- "Jet A1 (ASTM D1655)"
- "Jet A (ASTM D1655)"
- "NATO F34 "

Note: These fuels are only acceptable provided that these fuels are used with an appropriate fuel additive. These fuels must meet the requirements that are stated in table 9. Fuel samples should be analyzed for the compliance. These fuels MUST NOT exceed lubricity wear scar diameter of 0.52 mm (0.0205 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ". Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

Group 3 Specifications (Permissible Fuels)

This group of fuel specification must be used only with the appropriate fuel additive. This fuel WILL reduce engine life and performance.

"JIS 2203#1 and #2 Toyu"

Note: These fuels are only acceptable provided that these fuels are used with an appropriate fuel additive. These fuels must meet the requirements that are stated in table 9. Fuel samples should be analyzed for the compliance. These fuels MUST NOT exceed lubricity wear scar diameter of 0.52 mm (0.0205 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ". Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

Group 4 Biodiesel

Biodiesel is a fuel that can be defined as mono-alkyl esters of fatty acids. Biodiesel is a fuel that can be made from a variety of feedstock. The most commonly available biodiesel in europe is Rape Methyl Ester (REM). This biodiesel is derived from rapeseed oil. Soy Methyl Ester (SME) is the most common biodiesel in the United States. This biodiesel is derived from soybean oil. Soybean oil or rapeseed oil are the primary feedstocks. These fuels are together known as Fatty Acid Methyl Esters (FAME).

Raw pressed vegetable oils are NOT acceptable for use as a fuel in any concentration in compression engines. Without esterification, these oils gel in the crankcase and the fuel tank. These fuels may not be compatible with many of the elastomers that are used in engines that are manufactured today. In original forms, these oils are not suitable for use as a fuel in compression engines. Alternate base stocks for biodiesel may include animal tallow, waste cooking oils, or a variety of other feedstocks. In order to use any of the products that are listed as fuel, the oil must be esterified.

Note: Engines that are manufactured by Perkins are certified by use of the prescribed Environmental Protection Agency (EPA) and European Certification fuels. Perkins does not certify engines on any other fuel. The user of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer and allowed by the EPA and other appropriate regulatory agencies.

Recommendation for the use of biodiesel

Use of FAME fuels is permissible. However, the following conditions apply:

- The FAME fuel must comply with “EN14214”.

- A maximum of 5% mixture of FAME can be used in mineral oil diesel fuel, provided that the fuel complies with the fuel specification that is listed in table 9. This blend is commonly known as B5. No mixture above 5% is acceptable. Concentrations above 5% will lead to reduced product service life and potential failure of the fuel injection equipment.

Note: When biodiesel, or any blend of biodiesel is used, the user has the responsibility for obtaining the proper local exemptions, regional exemptions, and/or national exemptions that are required for the use of biodiesel in any Perkins engine that is regulated by emissions standards. Biodiesel that meets EN 14214 is acceptable. The biodiesel must be blended with an acceptable distillate diesel fuel at the maximum stated percentages. However, the following operational recommendations must be followed:

- The oil change interval can be affected by the use of biodiesel. Use Services Oil Analysis in order to monitor the condition of the engine oil. Use Services Oil Analysis also in order to determine the oil change interval that is optimum.

- Confirm that biodiesel is acceptable for use with the manufacturer of the fuel filters.

- In a comparison of distillate fuels to biodiesel, biodiesel provides less energy per gallon by 5% to 7%. Do NOT change the engine rating in order to compensate for the power loss. This will help avoid engine problems when the engine is converted back to 100 percent distillate diesel fuel.

- The compatibility of the elastomers with biodiesel is being monitored. The condition of seals and hoses should be monitored regularly.

- Biodiesel may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attainment of the proper cloud point for the fuel.

- Biodiesel has poor oxidation stability, which can result in long term problems in the storage of biodiesel. The poor oxidation stability may accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because these engines operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.

- Biodiesel is a fuel that can be made from a variety of feedstock. The feedstock that is used can affect the performance of the product. Two of the characteristics of the fuel that are affected are cold flow and oxidation stability. Contact your fuel supplier for guidance.

- Biodiesel or biodiesel blends are not recommended for engines that will operate occasionally. This is due to poor oxidation stability. If the user is prepared to accept some risk, then limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles

- Biodiesel is an excellent medium for microbial contamination and growth. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. The use of conventionalanti-microbial additives and the effectiveness of conventional anti-microbial additives in biodiesel is not known. Consult your supplier of fuel and additive for assistance.

- Care must be taken in order to remove water from fuel tanks. Water accelerates microbial contamination and growth. When biodiesel is compared to distillate fuels, water is naturally more likely to exist in the biodiesel.

Fuel for Cold Weather Operation

The European standard “EN590” contains climate dependant requirements and a range of options. The options can be applied differently in each country. There are 5 classes that are given to arctic climates and severe winter climates. 0, 1, 2, 3, and 4.

Fuel that complies with “EN590 ” CLASS 4 can be used at temperatures as low as −44 °C (−47.2 °F). Refer to “EN590” for a detailed discretion of the physical properties of the fuel.

The diesel fuel “ASTM D975 1-D” that is used in the united states of america may be used in very cold temperatures that are below −18 °C (−0.4 °F).

In extreme cold ambient conditions, you may also use fuels that are listed in the table 11. These fuels are intended to be used in temperatures that can be as low as −54 °C (−65.2 °F).

Table 11

Light Distillate Fuels (1)	
Specification	Grade
“MIL-T-5624R”	JP-5
“MIL-T-83133D”	JP-8
“ASTM D1655”	Jet-A-1

(1) The use of these fuels is acceptable with an appropriate fuel additive and the fuels must meet minimum requirements that are stated in Table 9. Fuel samples should be analyzed for the compliance. Fuels MUST NOT exceed 0.52 mm lubricity wear scar diameter that is tested on a HFFR . The test must be performed at 60 °C. Refer to “ISO 12156-1”. Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

WARNING

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or the fuel tank. Alcohol or gasoline must not be used in order to dilute diesel fuel. Failure to follow this instruction may result in death or personal injury.

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in table 9. To ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are stated in the table 9.

Fuel Additive

Supplemental diesel fuel additives are not generally recommended. This is due to potential damage to the fuel system or the engine. Your fuel supplier or the fuel manufacturer will add the appropriate supplemental diesel fuel additives.

Perkins recognizes the fact that additives may be required in some special circumstances. Fuel additives need to be used with caution. Contact your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can recommend the appropriate fuel additive and the correct level of treatment.

Note: For the best results, your fuel supplier should treat the fuel when additives are required. The treated fuel must meet the requirements that are stated in table 9.

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Fluid Recommendations (Coolant Specifications)

General Coolant Information

NOTICE

Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

NOTICE

If the engine is to be stored in, or shipped to an area with below freezing temperatures, the cooling system must be either protected to the lowest outside temperature or drained completely to prevent damage.

NOTICE
Frequently check the specific gravity of the coolant for proper freeze protection or for anti-boil protection.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

Many engine failures are related to the cooling system. The following problems are related to cooling system failures: Overheating, leakage of the water pump, and plugged radiators or heat exchangers.

These failures can be avoided with correct cooling system maintenance. Cooling system maintenance is as important as maintenance of the fuel system and the lubrication system. Quality of the coolant is as important as the quality of the fuel and the lubricating oil.

Coolant is normally composed of three elements: Water, additives, and glycol.

Water

Water is used in the cooling system in order to transfer heat.

Distilled water or deionized water is recommended for use in engine cooling systems.

DO NOT use the following types of water in cooling systems: Hard water, softened water that has been conditioned with salt, and sea water.

If distilled water or deionized water is not available, use water with the properties that are listed in Table 12.

Table 12

Acceptable Water	
Property	**Maximum Limit**
Chloride (Cl)	40 mg/L
Sulfate (SO_4)	100 mg/L
Total Hardness	170 mg/L
Total Solids	340 mg/L
Acidity	pH of 5.5 to 9.0

For a water analysis, consult one of the following sources:

- Local water utility company
- Agricultural agent
- Independent laboratory

Additives

Additives help to protect the metal surfaces of the cooling system. A lack of coolant additives or insufficient amounts of additives enable the following conditions to occur:

- Corrosion
- Formation of mineral deposits
- Rust
- Scale
- Foaming of the coolant

Many additives are depleted during engine operation. These additives must be replaced periodically.

Additives must be added at the correct concentration. Overconcentration of additives can cause the inhibitors to drop out-of-solution. The deposits can enable the following problems to occur:

- Formation of gel compounds
- Reduction of heat transfer
- Leakage of the water pump seal
- Plugging of radiators, coolers, and small passages

Glycol

Glycol in the coolant helps to provide protection against the following conditions:

- Boiling

- Freezing
- Cavitation of the water pump

For optimum performance, Perkins recommends a 1:1 mixture of a water/glycol solution.

Note: Use a mixture that will provide protection against the lowest ambient temperature.

Note: 100 percent pure glycol will freeze at a temperature of −23 °C (−9 °F).

Most conventional antifreezes use ethylene glycol. Propylene glycol may also be used. In a 1:1 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling. See Tables 13 and 14.

Table 13

Ethylene Glycol	
Concentration	**Freeze Protection**
50 Percent	−36 °C (−33 °F)
60 Percent	−51 °C (−60 °F)

NOTICE

Do not use propylene glycol in concentrations that exceed 50 percent glycol because of propylene glycol's reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing.

Table 14

Propylene Glycol	
Concentration	**Freeze Protection**
50 Percent	−29 °C (−20 °F)

To check the concentration of glycol in the coolant, measure the specific gravity of the coolant.

Coolant Recommendations

- ELC____________________Extended Life Coolant
- SCA______________Supplement Coolant Additive
- ASTM______________________________American Society for Testing and Materials

The following two coolants are used in Perkins diesel engines:

Preferred – Perkins ELC

Acceptable – A commercial heavy-duty antifreeze that meets "ASTM D4985" specifications

NOTICE

Do not use a commercial coolant/antifreeze that only meets the ASTM D3306 specification. This type of coolant/antifreeze is made for light automotive applications.

Perkins recommends a 1:1 mixture of water and glycol. This mixture of water and glycol will provide optimum heavy-duty performance as a antifreeze. This ratio may be increased to 1:2 water to glycol if extra freezing protection is required.

Note: A commercial heavy-duty antifreeze that meets "ASTM D4985" specifications MAY require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

In stationary engine applications and marine engine applications that do not require anti-boil protection or freeze protection, a mixture of SCA and water is acceptable. Perkins recommends a six percent to eight percent concentration of SCA in those cooling systems. Distilled water or deionized water is preferred. Water which has the recommended properties may be used.

Table 15

Coolant Service Life	
Coolant Type	**Service Life**
Perkins ELC	6,000 Service Hours or Three Years
Commercial Heavy-Duty Antifreeze that meets "ASTM D4985"	3000 Service Hours or Two Years
Perkins POWERPART SCA	3000 Service Hours or Two Years
Commercial SCA and Water	3000 Service Hours or Two Years

ELC

Perkins provides ELC for use in the following applications:

- Heavy-duty spark ignited gas engines
- Heavy-duty diesel engines
- Automotive applications

The anti-corrosion package for ELC is different from the anti-corrosion package for other coolants. ELC is an ethylene glycol base coolant. However, ELC contains organic corrosion inhibitors and antifoam agents with low amounts of nitrite. Perkins ELC has been formulated with the correct amount of these additives in order to provide superior corrosion protection for all metals in engine cooling systems.

ELC is available in a premixed cooling solution with distilled water. ELC is a 1:1 mixture. The Premixed ELC provides freeze protection to −36 °C (−33 °F). The Premixed ELC is recommended for the initial fill of the cooling system. The Premixed ELC is also recommended for topping off the cooling system.

Containers of several sizes are available. Consult your Perkins distributor for the part numbers.

ELC Cooling System Maintenance

Correct additions to the Extended Life Coolant

NOTICE

Use only Perkins products for pre-mixed or concentrated coolants.

Mixing Extended Life Coolant with other products reduces the Extended Life Coolant service life. Failure to follow the recommendations can reduce cooling system components life unless appropriate corrective action is performed.

In order to maintain the correct balance between the antifreeze and the additives, you must maintain the recommended concentration of ELC. Lowering the proportion of antifreeze lowers the proportion of additive. This will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

NOTICE

Do not use a conventional coolant to top-off a cooling system that is filled with Extended Life Coolant (ELC).

Do not use standard supplemental coolant additive (SCA).

When using Perkins ELC, do not use standard SCA's or SCA filters.

ELC Cooling System Cleaning

Note: If the cooling system is already using ELC, cleaning agents are not required to be used at the specified coolant change interval. Cleaning agents are only required if the system has been contaminated by the addition of some other type of coolant or by cooling system damage.

Clean water is the only cleaning agent that is required when ELC is drained from the cooling system.

Before the cooling system is filled, the heater control (if equipped) must be set to the hot position. Refer to the OEM in order to set the heater control. After the cooling system is drained and the cooling system is refilled, operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture in order to fill the system to the specified level.

Changing to Perkins ELC

To change from heavy-duty antifreeze to the Perkins ELC, perform the following steps:

NOTICE

Care must be taken to ensure that all fluids are contained during performance of inspection, maintenance, testing, adjusting and the repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant into a suitable container.

2. Dispose of the coolant according to local regulations.

3. Flush the system with clean water in order to remove any debris.

4. Use Perkins cleaner to clean the system. Follow the instruction on the label.

5. Drain the cleaner into a suitable container. Flush the cooling system with clean water.

6. Fill the cooling system with clean water and operate the engine until the engine is warmed to 49° to 66°C (120° to 150°F).

NOTICE
Incorrect or incomplete flushing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all the signs of the cleaning agent are gone.

7. Drain the cooling system into a suitable container and flush the cooling system with clean water.

Note: The cooling system cleaner must be thoroughly flushed from the cooling system. Cooling system cleaner that is left in the system will contaminate the coolant. The cleaner may also corrode the cooling system.

8. Repeat Steps 6 and 7 until the system is completely clean.

9. Fill the cooling system with the Perkins Premixed ELC.

ELC Cooling System Contamination

NOTICE
Mixing ELC with other products reduces the effectiveness of the ELC and shortens the ELC service life. Use only Perkins Products for premixed or concentrate coolants. Failure to follow these recommendations can result in shortened cooling system component life.

ELC cooling systems can withstand contamination to a maximum of ten percent of conventional heavy-duty antifreeze or SCA. If the contamination exceeds ten percent of the total system capacity, perform ONE of the following procedures:

- Drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Flush the system with clean water. Fill the system with the Perkins ELC.
- Drain a portion of the cooling system into a suitable container according to local regulations. Then, fill the cooling system with premixed ELC. This should lower the contamination to less than 10 percent.
- Maintain the system as a conventional Heavy-Duty Coolant. Treat the system with an SCA. Change the coolant at the interval that is recommended for the conventional Heavy-Duty Coolant.

Commercial Heavy-Duty Antifreeze and SCA

NOTICE
Commercial Heavy-Duty Coolant which contains Amine as part of the corrision protection system must not be used.

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the correct operating temperature. Cooling system problems can develop without water temperature regulators.

Check the antifreeze (glycol concentration) in order to ensure adequate protection against boiling or freezing. Perkins recommends the use of a refractometer for checking the glycol concentration.

Perkins engine cooling systems should be tested at 500 hour intervals for the concentration of SCA.

Additions of SCA are based on the results of the test. An SCA that is liquid may be needed at 500 hour intervals.

Refer to Table 16 for part numbers and for quantities of SCA.

Table 16

Perkins Liquid SCA	
Part Number	**Quantity**
21825735	10

Adding the SCA to Heavy-Duty Coolant at the Initial Fill

Commercial heavy-duty antifreeze that meets “ASTM D4985” specifications MAY require an addition of SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

Use the equation that is in Table 17 to determine the amount of Perkins SCA that is required when the cooling system is initially filled.

Table 17

Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill
$V \times 0.045 = X$
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 18 is an example for using the equation that is in Table 17.

Table 18

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.045	0.7 L (24 oz)

Adding The SCA to The Heavy-Duty Coolant For Maintenance

Heavy-duty antifreeze of all types REQUIRE periodic additions of an SCA.

Test the antifreeze periodically for the concentration of SCA. For the interval, refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” (Maintenance Section). Test the concentration of SCA.

Additions of SCA are based on the results of the test. The size of the cooling system determines the amount of SCA that is needed.

Use the equation that is in Table 19 to determine the amount of Perkins SCA that is required, if necessary:

Table 19

Equation For Adding The SCA To The Heavy-Duty Coolant For Maintenance
V × 0.014 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 20 is an example for using the equation that is in Table 19.

Table 20

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant For Maintenance		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.014	0.2 L (7 oz)

Cleaning the System of Heavy-Duty Antifreeze

Perkins cooling system cleaners are designed to clean the cooling system of harmful scale and corrosion. Perkins cooling system cleaners dissolve mineral scale, corrosion products, light oil contamination and sludge.

- Clean the cooling system after used coolant is drained or before the cooling system is filled with new coolant.
- Clean the cooling system whenever the coolant is contaminated or whenever the coolant is foaming.

Maintenance Recommendations

i04103075

Welding on Engines with Electronic Controls

NOTICE
Because the strength of the frame may decrease, some manufacturers do not recommend welding onto a chassis frame or rail. Consult the OEM of the equipment or your Perkins dealer regarding welding on a chassis frame or rail.

Proper welding procedures are necessary in order to avoid damage to the engines ECM, sensors, and associated components. When possible, remove the component from the unit and then weld the component. If removal of the component is not possible, the following procedure must be followed when you weld on a unit equipped with an Electronic Engine. The following procedure is considered to be the safest procedure to weld on a component. This procedure should provide a minimum risk of damage to electronic components.

NOTICE
Do not ground the welder to electrical components such as the ECM or sensors. Improper grounding can cause damage to the drive train bearings, hydraulic components, electrical components, and other components.

Clamp the ground cable from the welder to the component that will be welded. Place the clamp as close as possible to the weld. This will help reduce the possibility of damage.

Note: Perform the welding in areas that are free from explosive hazards.

1. Stop the engine. Turn the switched power to the OFF position.

2. Ensure that the fuel supply to the engine is turned off.

3. Disconnect the negative battery cable from the battery. If a battery disconnect switch is provided, open the switch.

4. Disconnect all electronic components from the wiring harnesses. Include the following components:

- Electronic components for the driven equipment
- ECM
- Sensors
- Electronically controlled valves
- Relays
- Aftertreatment ID module

NOTICE
Do not use electrical components (ECM or ECM sensors) or electronic component grounding points for grounding the welder.

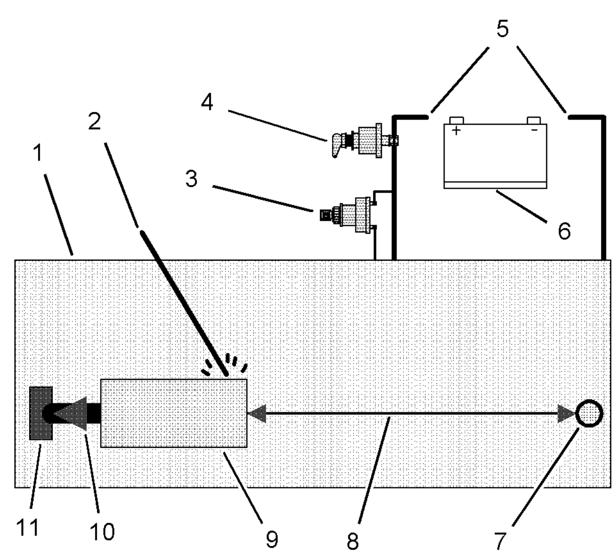

Illustration 27 g01075639

Use the example above. The current flow from the welder to the ground clamp of the welder will not damage any associated components.

(1) Engine
(2) Welding electrode
(3) Keyswitch in the OFF position
(4) Battery disconnect switch in the open position
(5) Disconnected battery cables
(6) Battery
(7) Electrical/Electronic component
(8) Minimum distance between the component that is being welded and any electrical/electronic component
(9) The component that is being welded
(10) Current path of the welder
(11) Ground clamp for the welder

5. Connect the welding ground cable directly to the part that will be welded. Place the ground cable as close as possible to the weld in order to reduce the possibility of welding current damage to the following components. Bearings, hydraulic components, electrical components, and ground straps.

Note: If electrical/electronic components are used as a ground for the welder, or electrical/electronic components are located between the welder ground and the weld, current flow from the welder could severely damage the component.

6. Protect the wiring harness from welding debris and spatter.

7. Use standard welding practices to weld the materials.

i04949917

Maintenance Interval Schedule

When Required

Daily

Every 50 Service Hours or Weekly

Every 250 Service Hours

Initial 500 Service Hours

Every 500 Service Hours

Every 500 Service Hours or 1 Year

Every 1000 Service Hours

Every 2000 Service Hours

Every 3000 Service Hours

Every 3000 Service Hours or 2 Years

Every 4000 Service Hours

Every 12 000 Service Hours or 6 Years

Commissioning

i02322260

Aftercooler Core - Clean/Test

1. Remove the core. Refer to the OEM information for the correct procedure.

2. Turn the aftercooler core upside-down in order to remove debris.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

3. Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction of the fan's air flow. Hold the nozzle approximately 6 mm (.25 inch) away from the fins. Slowly move the air nozzle in a direction that is parallel with the tubes. This will remove debris that is between the tubes.

4. Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

NOTICE

Do not use a high concentration of caustic cleaner to clean the core. A high concentration of caustic cleaner can attack the internal metals of the core and cause leakage. Only use the recommended concentration of cleaner.

5. Back flush the core with a suitable cleaner.

6. Steam clean the core in order to remove any residue. Flush the fins of the aftercooler core. Remove any other trapped debris.

7. Wash the core with hot, soapy water. Rinse the core thoroughly with clean water.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

8. Dry the core with compressed air. Direct the air in the reverse direction of the normal flow.

9. Inspect the core in order to ensure cleanliness. Pressure test the core. If necessary, repair the core.

10. Install the core. Refer to the OEM information for the correct procedure.

11. After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

i02322295

Aftercooler Core - Inspect

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the aftercooler for these items: damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the aftercooler, if necessary.

For air-to-air aftercoolers, use the same methods that are used for cleaning radiators.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a “comb”.

Note: If parts of the aftercooler system are repaired or replaced, a leak test is highly recommended.

Inspect these items for good condition: Welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

i02322311

Alternator - Inspect

Perkins recommends a scheduled inspection of the alternator. Inspect the alternator for loose connections and correct battery charging. Check the ammeter (if equipped) during engine operation in order to ensure correct battery performance and/or correct performance of the electrical system. Make repairs, as required.

Check the alternator and the battery charger for correct operation. If the batteries are correctly charged, the ammeter reading should be very near zero. All batteries should be kept charged. The batteries should be kept warm because temperature affects the cranking power. If the battery is too cold, the battery will not crank the engine. When the engine is not run for long periods of time or if the engine is run for short periods, the batteries may not fully charge. A battery with a low charge will freeze more easily than a battery with a full charge.

i02491869

Alternator Belt - Inspect/Adjust/Replace (Poly V-Belt)

Inspection

To maximize the engine performance, inspect the belt (1) for wear and for cracking. Replace the belt if the belt is worn or damaged.

- If the belt (1) has more than four cracks per 25.4000 mm (1 inch) the belt must be replaced.
- Check the belt of cracks, splits, glazing, grease, and splitting.

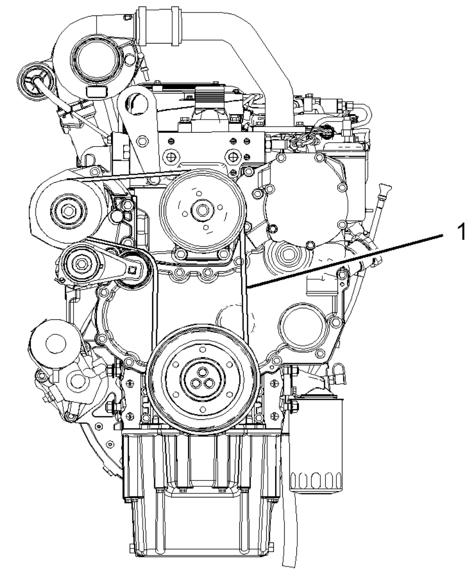

Illustration 28 g01251375

Typical example

Adjustment

This type of belt has an automatic belt tensioner.

Replace

Refer to Disassembly and Assembly manual, “Alternator Belt - Remove and Install”.

i02322315

Battery - Replace

WARNING

Batteries give off combustible gases which can explode. A spark can cause the combustible gases to ignite. This can result in severe personal injury or death.

Ensure proper ventilation for batteries that are in an enclosure. Follow the proper procedures in order to help prevent electrical arcs and/or sparks near batteries. Do not smoke when batteries are serviced.

WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Switch the engine to the OFF position. Remove all electrical loads.
2. Turn off any battery chargers. Disconnect any battery chargers.
3. The NEGATIVE “-” cable connects the NEGATIVE “-” battery terminal to the NEGATIVE “-” terminal on the starting motor. Disconnect the cable from the NEGATIVE “-” battery terminal.
4. The POSITIVE “+” cable connects the POSITIVE “+” battery terminal to the POSITIVE “+” terminal on the starting motor. Disconnect the cable from the POSITIVE “+” battery terminal.

Note: Always recycle a battery. Never discard a battery. Dispose of used batteries to an appropriate recycling facility.

5. Remove the used battery.
6. Install the new battery.

Note: Before the cables are connected, ensure that the engine start switch is OFF.

7. Connect the cable from the starting motor to the POSITIVE “+” battery terminal.
8. Connect the NEGATIVE “-” cable to the NEGATIVE “-” battery terminal.

i02747977

Battery Electrolyte Level - Check

When the engine is not run for long periods of time or when the engine is run for short periods, the batteries may not fully recharge. Ensure a full charge in order to help prevent the battery from freezing. If batteries are correctly charged, the ammeter reading should be very near zero, when the engine is in operation.

WARNING

All lead-acid batteries contain sulfuric acid which can burn the skin and clothing. Always wear a face shield and protective clothing when working on or near batteries.

1. Remove the filler caps. Maintain the electrolyte level to the “FULL” mark on the battery.

   If the addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

2. Check the condition of the electrolyte with a suitable battery tester.
3. Install the caps.
4. Keep the batteries clean.

   Clean the battery case with one of the following cleaning solutions:

   - Use a solution of 0.1 kg (0.2 lb) baking soda and 1 L (1 qt) of clean water.
   - Use a solution of ammonium hydroxide.

   Thoroughly rinse the battery case with clean water.

i02323088

Battery or Battery Cable - Disconnect

WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Turn the start switch to the OFF position. Turn the ignition switch (if equipped) to the OFF position and remove the key and all electrical loads.
2. Disconnect the negative battery terminal. Ensure that the cable cannot contact the terminal. When four 12 volt batteries are involved, two negative connection must be disconnected.

3. Remove the positive connection.

4. Clean all disconnected connection and battery terminals.

5. Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright or shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit correctly. Coat the clamps and the terminals with a suitable silicone lubricant or petroleum jelly.

6. Tape the cable connections in order to help prevent accidental starting.

7. Proceed with necessary system repairs.

8. In order to connect the battery, connect the positive connection before the negative connector.

i02870187

Belt Tensioner - Inspect

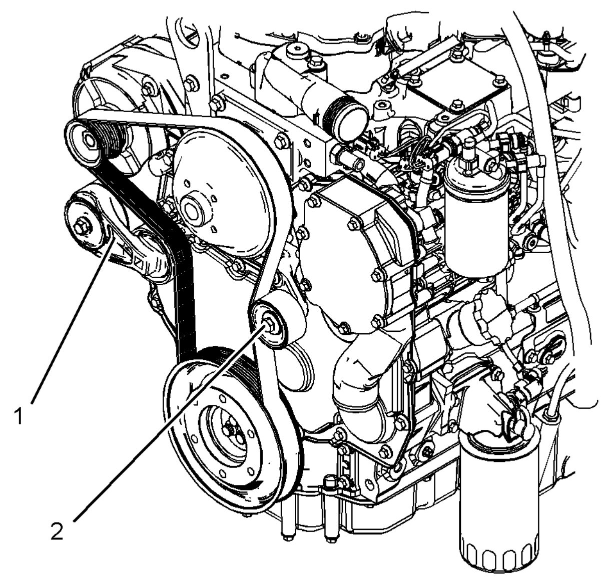

Illustration 29 g01429637

Typical example

Remove the belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

Ensure that the belt tensioner is securely installed. Visually inspect the belt tensioner (1) for damage. Check that the roller on the tensioner rotates freely. Some engines have a guide roller (2). Ensure that the guide roller is securely installed. Visually inspect the guide roller for damage. Ensure that the guide roller can rotate freely.

Install the belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

i02854855

Cooling System Coolant (Commercial Heavy-Duty) - Change

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to Local regulations and mandates.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming of the coolant is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed.

Drain

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

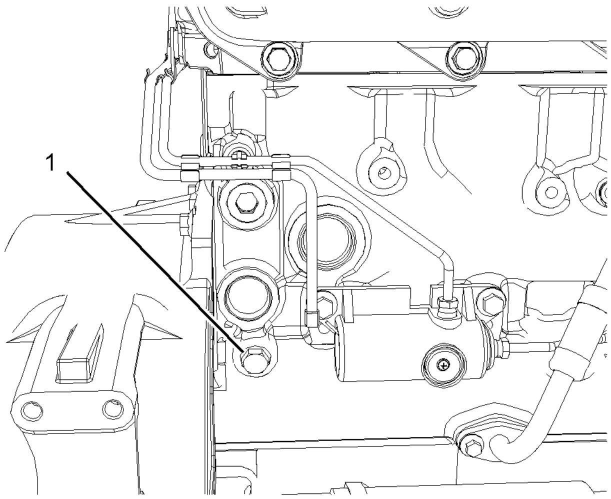

Illustration 30 g01244659

Typical example

2. Open the drain cock or remove the drain plug (1) on the engine. Open the drain cock or remove the drain plug on the radiator.

Allow the coolant to drain.

NOTICE

Dispose of used engine coolant or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Perkins to reclaim the coolant.

For information regarding the disposal and the recycling of used coolant, consult your Perkins distributor.

Flush

1. Flush the cooling system with clean water in order to remove any debris.

2. Close the drain cock or install the drain plug in the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE

Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

3. Fill the cooling system with clean water. Install the cooling system filler cap.

4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain cock or remove the drain plug on the engine. Open the drain cock or remove the drain plug on the radiator. Allow the water to drain. Flush the cooling system with clean water.

Fill

1. Close the drain cock or install the drain plug on the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE

Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

2. Fill the cooling system with Commercial Heavy-Duty Coolant. Add Supplemental Coolant Additive to the coolant. For the correct amount, refer to the Operation and Maintenance Manual, “Fluid Recommendations” topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.

3. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Decrease the engine speed to low idle. Stop the engine.

4. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level in the expansion bottle (if equipped) at the correct level.

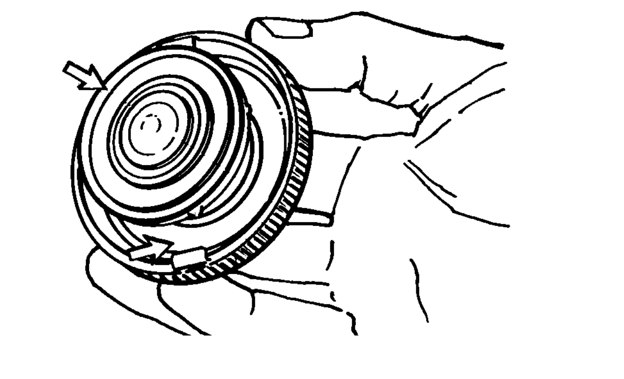

Illustration 31 g00103639

Filler cap

5. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.

6. Start the engine. Inspect the cooling system for leaks and for correct operating temperature.

i02490917

Cooling System Coolant (ELC) - Change

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to Local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming of the coolant is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed when the ELC is drained and replaced.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator and the hoses, if necessary.

Drain

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

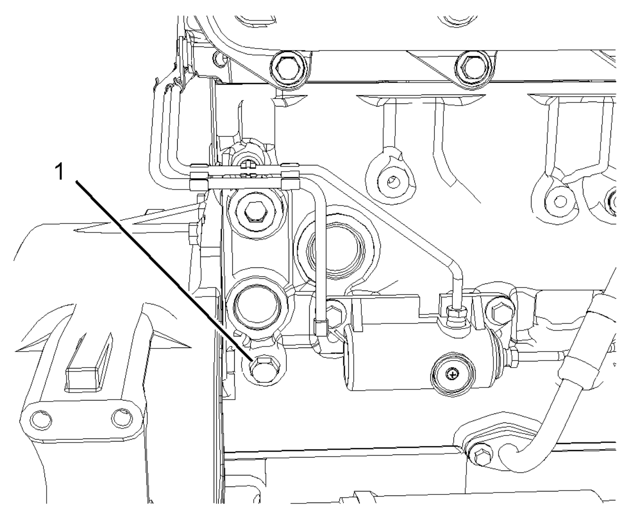

Illustration 32 g01244659

Typical example

2. Open the drain cock or remove the drain plug (1) on the engine. Open the drain cock or remove the drain plug on the radiator.

   Allow the coolant to drain.

NOTICE
Dispose of used engine coolant or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Perkins to reclaim the coolant.

For information regarding the disposal and the recycling of used coolant, consult your Perkins dealer or your Perkins distributor.

Flush

1. Flush the cooling system with clean water in order to remove any debris.

2. Close the drain cock or install the drain plug in the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

3. Fill the cooling system with clean water. Install the cooling system filler cap.

4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain cock or remove the drain plug on the engine. Open the drain cock or remove the drain plug on the radiator. Allow the water to drain. Flush the cooling system with clean water.

Fill

1. Close the drain cock or install the drain plug on the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

2. Fill the cooling system with Extended Life Coolant (ELC). Refer to the Operation and Maintenance Manual, “Fluid Recommendations” topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.

3. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Decrease the engine speed to low idle. Stop the engine.

4. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level in the expansion bottle (if equipped) at the correct level.

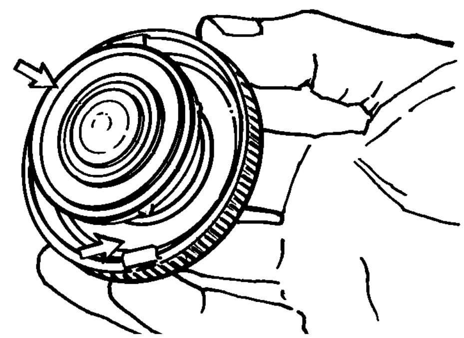

Illustration 33 g00103639

Filler cap

5. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.

6. Start the engine. Inspect the cooling system for leaks and for correct operating temperature.

i04408743

Cooling System Coolant Level - Check

Engines With a Coolant Recovery Tank

Note: The cooling system may not have been provided by Perkins. The procedure that follows is for typical cooling systems. Refer to the OEM information for the correct procedures.

Check the coolant level when the engine is stopped and cool.

NOTICE
When any servicing or repair of the engine cooling system is performed, the procedure must be performed with the engine on level ground. This will allow you to accurately check the coolant level. This will also help in avoiding the risk of introducing an air lock into the coolant system.

1. Observe the coolant level in the coolant recovery tank. Maintain the coolant level to “COLD FULL” mark on the coolant recovery tank.

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

2. Loosen filler cap slowly in order to relieve any pressure. Remove the filler cap.

3. Pour the correct coolant mixture into the tank. Refer to the Operation and Maintenance Manual, “Refill Capacities and Recommendations” for information on the correct mixture and type of coolant. Refer to the Operation and Maintenance Manual, “Refill Capacities and Recommendations” for the cooling system capacity. Do not fill the coolant recovery tank above “COLD FULL” mark.

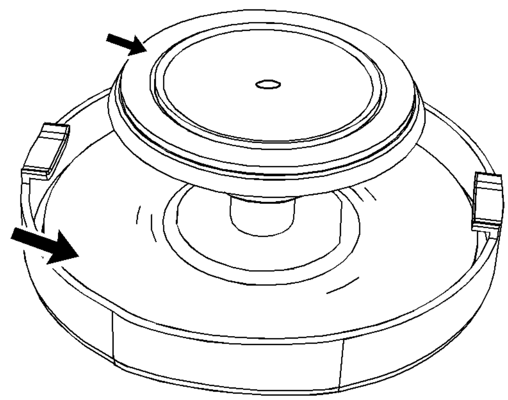

Illustration 34 g02590196

Filler cap

4. Clean filler cap and the receptacle. Reinstall the filler cap and inspect the cooling system for leaks.

Note: The coolant will expand as the coolant heats up during normal engine operation. The additional volume will be forced into the coolant recovery tank during engine operation. When the engine is stopped and cool, the coolant will return to the engine.

Engines Without a Coolant Recovery Tank

Check the coolant level when the engine is stopped and cool.

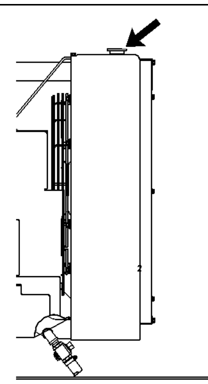

Illustration 35 g00285520

Cooling system filler cap

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly in order to relieve pressure.

2. Maintain the coolant level at the maximum mark that is correct for your application. If the engine is equipped with a sight glass, maintain the coolant level to the correct level in the sight glass.

3. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.

4. Inspect the cooling system for leaks.

i03644948

Cooling System Supplemental Coolant Additive (SCA) - Test/Add

WARNING

Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and the eyes. Do not drink cooling system coolant additive.

Test for SCA Concentration

Heavy-Duty Coolant/Antifreeze and SCA

NOTICE

Do not exceed the recommended six percent supplemental coolant additive concentration.

Use a Coolant Conditioner Test Kit in order to check the concentration of the SCA.

Add the SCA, If Necessary

NOTICE

Do not exceed the recommended amount of supplemental coolant additive concentration. Excessive supplemental coolant additive concentration can form deposits on the higher temperature surfaces of the cooling system, reducing the engine's heat transfer characteristics. Reduced heat transfer could cause cracking of the cylinder head and other high temperature components. Excessive supplemental coolant additive concentration could also result in radiator tube blockage, overheating, and/or accelerated water pump seal wear. Never use both liquid supplemental coolant additive and the spin-on element (if equipped) at the same time. The use of those additives together could result in supplemental coolant additive concentration exceeding the recommended maximum.

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

NOTICE

When any servicing or repair of the engine cooling system is performed the procedure must be performed with the engine on level ground. This will allow you to accurately check the coolant level. This will also help in avoiding the risk of introducing an air lock into the coolant system.

1. Slowly loosen the cooling system filler cap in order to relieve the pressure. Remove the cooling system filler cap.

Note: Always discard drained fluids according to local regulations.

2. If necessary, drain some coolant from the cooling system into a suitable container in order to allow space for the extra SCA.

3. Add the correct amount of SCA. Refer to the Operation and Maintenance Manual, “Refill Capacities and Recommendations” for more information on SCA requirements.

4. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.

i02866782

Crankcase Breather (Canister) - Replace

NOTICE
Ensure that the engine is stopped before any servicing or repair is performed.

Note: The breather assembly is not installed on all engines.

1. Place a container under the canister (1).

2. Clean the outside of the canister. Use a suitable tool in order to remove the canister.

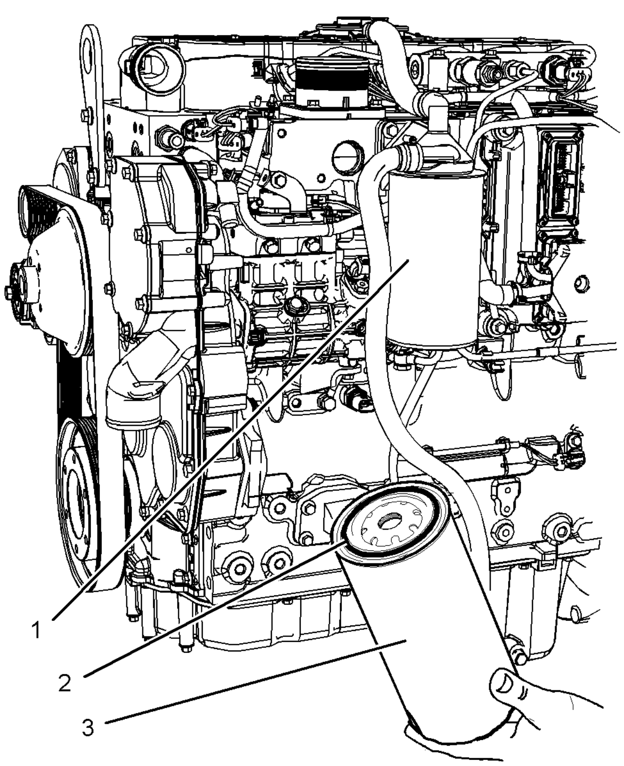

Illustration 36 g01428096

Typical example

3. Lubricate the O ring seal (2) on the new canister (3) with clean engine lubricating oil. Install the new canister. Tighten the canister to 12 N·m (8 lb ft). Do not overtighten the canister.

4. Remove the container. Dispose of the old canister and any split oil in a safe place.

i02151646

Driven Equipment - Check

Refer to the OEM specifications for more information on the following maintenance recommendations for the driven equipment:

- Inspection
- Adjustment
- Lubrication
- Other maintenance recommendations

Perform any maintenance for the driven equipment which is recommended by the OEM.

i01909392

Engine - Clean

WARNING

Personal injury or death can result from high voltage.

Moisture can create paths of electrical conductivity.

Make sure that the electrical system is OFF. Lock out the starting controls and tag the controls “DO NOT OPERATE”.

NOTICE
Accumulated grease and oil on an engine is a fire hazard. Keep the engine clean. Remove debris and fluid spills whenever a significant quantity accumulates on the engine.

NOTICE
Failure to protect some engine components from washing may make your engine warranty invalid. Allow the engine to cool for one hour before washing the engine.

Periodic cleaning of the engine is recommended. Steam cleaning the engine will remove accumulated oil and grease. A clean engine provides the following benefits:

- Easy detection of fluid leaks
- Maximum heat transfer characteristics
- Ease of maintenance

Note: Caution must be used in order to prevent electrical components from being damaged by excessive water when the engine is cleaned. Pressure washers and steam cleaners should not be directed at any electrical connectors or the junction of cables into the rear of the connectors. Avoid electrical components such as the alternator, the starter, and the ECM. Protect the fuel injection pump from fluids in order to wash the engine.

i02334355

Engine Air Cleaner Element (Dual Element) - Clean/Replace

NOTICE
Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent air-borne debris from entering the air inlet.

NOTICE
Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

Servicing the Air Cleaner Elements

Note: The air filter system may not have been provided by Perkins. The procedure that follows is for a typical air filter system. Refer to the OEM information for the correct procedure.

If the air cleaner element becomes plugged, the air can split the material of the air cleaner element. Unfiltered air will drastically accelerate internal engine wear. Refer to the OEM information for the correct air cleaner elements for your application.

- Check the precleaner (if equipped) and the dust bowl daily for accumulation of dirt and debris. Remove any dirt and debris, as needed.
- Operating in dirty conditions may require more frequent service of the air cleaner element.
- The air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Replace the dirty air cleaner elements with clean air cleaner elements. Before installation, the air cleaner elements should be thoroughly checked for tears and/or holes in the filter material. Inspect the gasket or the seal of the air cleaner element for damage. Maintain a supply of suitable air cleaner elements for replacement purposes.

Dual Element Air Cleaners

The dual element air cleaner contains a primary air cleaner element and a secondary air cleaner element.

The primary air cleaner element can be used up to six times if the element is properly cleaned and properly inspected. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

The secondary air cleaner element is not serviceable. Refer to the OEM information for instructions in order to replace the secondary air cleaner element.

When the engine is operating in environments that are dusty or dirty, air cleaner elements may require more frequent replacement.

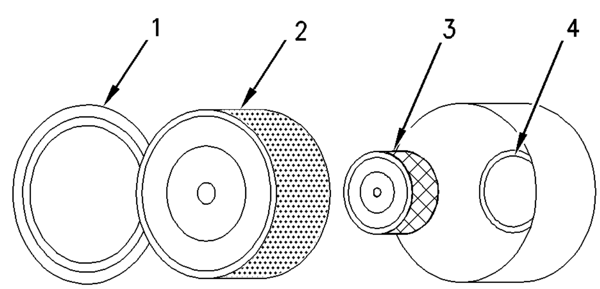

Illustration 37 g00736431

(1) Cover
(2) Primary air cleaner element
(3) Secondary air cleaner element
(4) Air inlet

1. Remove the cover. Remove the primary air cleaner element.
2. The secondary air cleaner element should be removed and discarded for every three cleanings of the primary air cleaner element.

Note: Refer to “Cleaning the Primary Air Cleaner Elements”.

3. Cover the air inlet with tape in order to keep dirt out.

4. Clean the inside of the air cleaner cover and body with a clean, dry cloth.

5. Remove the tapefrom the air inlet. Install the secondary air cleaner element. Install a primary air cleaner element that is new or cleaned.

6. Install the air cleaner cover.

7. Reset the air cleaner service indicator.

Cleaning the Primary Air Cleaner Elements

Refer to the OEM information in order to determine the number of times that the primary filter element can be cleaned. When the primary air cleaner element is cleaned, check for rips or tears in the filter material. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

NOTICE

Do not tap or strike the air cleaner element.

Do not wash the primary air cleaner element.

Use low pressure (207 kPa; 30 psi maximum) pressurised air or vacuum cleaning to clean the primary air cleaner element.

Take extreme care in order to avoid damage to the air cleaner elements.

Do not use air cleaner elements that have damaged pleats, gaskets or seals.

Refer to the OEM information in order to determine the number of times that the primary air cleaner element can be cleaned. Do not clean the primary air filter element more than three times. The primary air cleaner element must be replaced at least one time per year.

Cleaning the air filter element will not extend the life of the air filter element.

Visually inspect the primary air cleaner element before cleaning. Inspect air cleaner elements for damage to the pleats, the seals, the gaskets and the outer cover. Discard any damaged air cleaner element.

Two methods may be used in order to clean the primary air cleaner element:

- pressurized air
- Vacuum cleaning

Pressurized Air

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

Pressurized air can be used to clean primary air cleaner elements that have not been cleaned more than three times. Use filtered, dry air with a maximum pressure of 207 kPa (30 psi). Pressurized air will not remove deposits of carbon and oil.

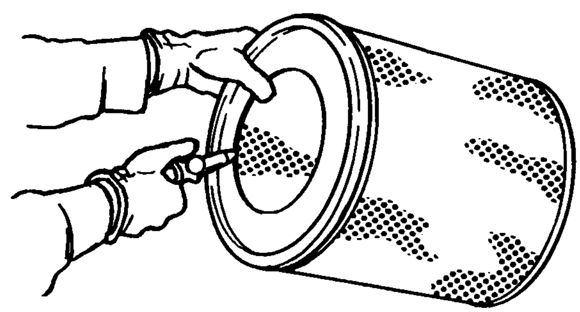

Illustration 38 g00281692

Note: When the primary air cleaner elements are cleaned, always begin with the clean side (inside) in order to force dirt particles toward the dirty side (outside).

Aim the air hose so that air flows along the length of the filter. Follow the direction of the paper pleats in order to prevent damage to the pleats. Do not aim the air directly at the face of the paper pleats.

Note: Refer to “Inspecting the Primary Air Cleaner Elements”.

Vacuum Cleaning

Vacuum cleaning is a good method for removing accumulated dirt from the dirty side (outside) of a primary air cleaner element. Vacuum cleaning is especially useful for cleaning primary air cleaner elements which require daily cleaning because of a dry, dusty environment.

Cleaning from the clean side (inside) with pressurized air is recommended prior to vacuum cleaning the dirty side (outside) of a primary air cleaner element.

Note: Refer to “Inspecting the Primary Air Cleaner Elements”.

Inspecting the Primary Air Cleaner Elements

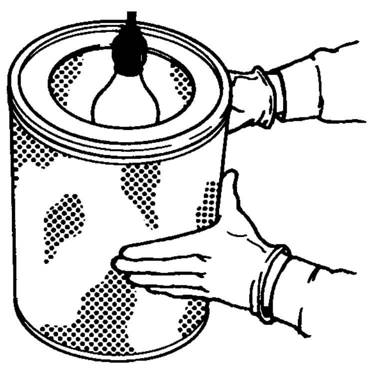

Illustration 39 g00281693

Inspect the clean, dry primary air cleaner element. Use a 60 watt blue light in a dark room or in a similar facility. Place the blue light in the primary air cleaner element. Rotate the primary air cleaner element. Inspect the primary air cleaner element for tears and/or holes. Inspect the primary air cleaner element for light that may show through the filter material. If it is necessary in order to confirm the result, compare the primary air cleaner element to a new primary air cleaner element that has the same part number.

Do not use a primary air cleaner element that has any tears and/or holes in the filter material. Do not use a primary air cleaner element with damaged pleats, gaskets or seals. Discard damaged primary air cleaner elements.

i02335405

Engine Air Cleaner Service Indicator - Inspect

Some engines may be equipped with a different service indicator.

Some engines are equipped with a differential gauge for inlet air pressure. The differential gauge for inlet air pressure displays the difference in the pressure that is measured before the air cleaner element and the pressure that is measured after the air cleaner element. As the air cleaner element becomes dirty, the pressure differential rises. If your engine is equipped with a different type of service indicator, follow the OEM recommendations in order to service the air cleaner service indicator.

The service indicator may be mounted on the air cleaner element or in a remote location.

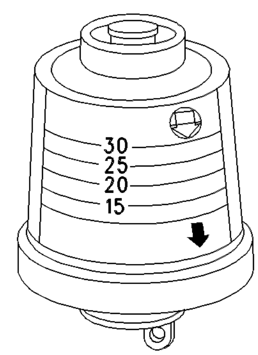

Illustration 40 g00103777

Typical service indicator

Observe the service indicator. The air cleaner element should be cleaned or the air cleaner element should be replaced when one of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.

Test the Service Indicator

Service indicators are important instruments.

- Check for ease of resetting. The service indicator should reset in less than three pushes.
- Check the movement of the yellow core when the engine is accelerated to the engine rated speed. The yellow core should latch at the greatest vacuum that is attained.

If the service indicator does not reset easily, or if the yellow core does not latch at the greatest vacuum, the service indicator should be replaced. If the new service indicator will not reset, the hole for the service indicator may be restricted.

The service indicator may need to be replaced frequently in environments that are severely dusty.

i02343354

Engine Air Precleaner - Check/Clean

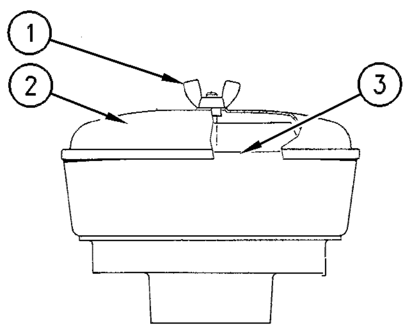

Illustration 41 g00287039

Typical example

(1) Wing nut
(2) Cover
(3) Body

Remove wing nut (1) and cover (2). Check for an accumulation of dirt and debris in body (3). Clean the body, if necessary.

After cleaning the precleaner, install cover (2) and wing nut (1).

Note: When the engine is operated in dusty applications, more frequent cleaning is required.

i02323089

Engine Mounts - Inspect

Note: The engine mounts may not have been supplied by Perkins. Refer to the OEM information for further information on the engine mounts and the correct bolt torque.

Inspect the engine mounts for deterioration and for correct bolt torque. Engine vibration can be caused by the following conditions:

- Incorrect mounting of the engine
- Deterioration of the engine mounts
- Loose engine mounts

Any engine mount that shows deterioration should be replaced. Refer to the OEM information for the recommended torques.

i02335785

Engine Oil Level - Check

WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

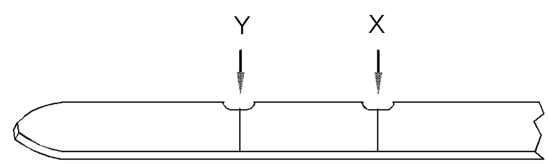

Illustration 42 g01165836

(Y) “Min” mark. (X) “Max” mark.

NOTICE
Perform this maintenance with the engine stopped.

Note: Ensure that the engine is either level or that the engine is in the normal operating position in order to obtain a true level indication.

Note: After the engine has been switched OFF, wait for ten minutes in order to allow the engine oil to drain to the oil pan before checking the oil level.

1. Maintain the oil level between the “ADD” mark (Y) and the “FULL” mark (X) on the engine oil dipstick. Do not fill the crankcase above the “FULL” mark (X).

NOTICE

Operating your engine when the oil level is above the "FULL" mark could cause your crankshaft to dip into the oil. The air bubbles created from the crankshaft dipping into the oil reduces the oil's lubricating characteristics and could result in the loss of power.

2. Remove the oil filler cap and add oil, if necessary. Clean the oil filler cap. Install the oil filler cap.

i01907674

Engine Oil Sample - Obtain

The condition of the engine lubricating oil may be checked at regular intervals as part of a preventive maintenance program. Perkins include an oil sampling valve as an option. The oil sampling valve (if equipped) is included in order to regularly sample the engine lubricating oil. The oil sampling valve is positioned on the oil filter head or the oil sampling valve is positioned on the cylinder block.

Perkins recommends using a sampling valve in order to obtain oil samples. The quality and the consistency of the samples are better when a sampling valve is used. The location of the sampling valve allows oil that is flowing under pressure to be obtained during normal engine operation.

Obtain the Sample and the Analysis

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

In order to help obtain the most accurate analysis, record the following information before an oil sample is taken:

- The date of the sample
- Engine model
- Engine number
- Service hours on the engine
- The number of hours that have accumulated since the last oil change
- The amount of oil that has been added since the last oil change

Ensure that the container for the sample is clean and dry. Also ensure that the container for the sample is clearly labelled.

To ensure that the sample is representative of the oil in the crankcase, obtain a warm, well mixed oil sample.

To avoid contamination of the oil samples, the tools and the supplies that are used for obtaining oil samples must be clean.

The sample can be checked for the following: the quality of the oil, the existence of any coolant in the oil, the existence of any ferrous metal particles in the oil, and the existence of any nonferrous metal particles in the oil.

i02867741

Engine Oil and Filter - Change

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Do not drain the engine lubricating oil when the engine is cold. As the engine lubricating oil cools, suspended waste particles settle on the bottom of the oil pan. The waste particles are not removed with draining cold oil. Drain the oil pan with the engine stopped. Drain the oil pan with the oil warm. This draining method allows the waste particles that are suspended in the oil to be drained properly.

Failure to follow this recommended procedure will cause the waste particles to be recirculated through the engine lubrication system with the new oil.

Drain the Engine Lubricating Oil

Note: Ensure that the vessel that will be used is large enough to collect the waste oil.

After the engine has been run at the normal operating temperature, stop the engine. Use one of the following methods to drain the engine oil pan:

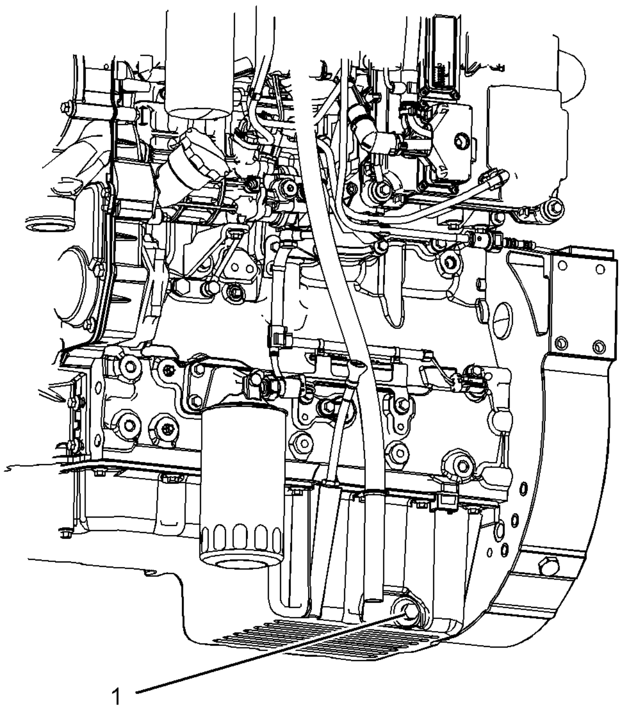

Illustration 43 g01428532

Typical example

- If the engine is equipped with a drain valve, turn the drain valve knob counterclockwise in order to drain the oil. After the oil has drained, turn the drain valve knob clockwise in order to close the drain valve.

- If the engine is not equipped with a drain valve, remove the oil drain plug (1) in order to allow the oil to drain. If the engine is equipped with a shallow oil pan, remove the bottom oil drain plugs from both ends of the oil pan.

After the oil has drained, the oil drain plugs should be cleaned and installed. If necessary, replace the O ring seal. Tighten the drain plug to 34 N·m (25 lb ft).

Replace the Oil Filter

NOTICE

Perkins oil filters are manufactured to Perkins specifications. Use of an oil filter that is not recommended by Perkins could result in severe damage to the engine bearings, crankshaft, etc., as a result of the larger waste particles from unfiltered oil entering the engine lubricating system. Only use oil filters recommended by Perkins.

1. Remove the oil filter with a suitable tool. A horizontally installed oil filter can be drained before removal.

Note: The following actions can be carried out as part of the preventive maintenance program.

2. Cut the oil filter open with a suitable tool. Break apart the pleats and inspect the oil filter for metal debris. An excessive amount of metal debris in the oil filter may indicate early wear or a pending failure.

   Use a magnet to differentiate between the ferrous metals and the nonferrous metals that are found in the oil filter element. Ferrous metals may indicate wear on the steel and cast iron parts of the engine.

   Nonferrous metals may indicate wear on the aluminum parts, brass parts or bronze parts of the engine. Parts that may be affected include the following items: main bearings, rod bearings, and turbocharger bearings.

   Due to normal wear and friction, it is not uncommon to find small amounts of debris in the oil filter.

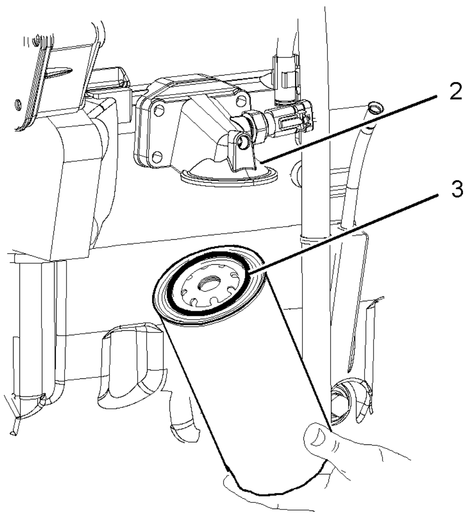

Illustration 44 g01187802

Typical example

3. Clean the sealing surface of the oil filter head (2). Ensure that the union is secure in the filter head.

4. Apply clean engine oil to the O ring seal (3) for the new oil filter.

NOTICE
Do not fill the oil filters with oil before installing them. This oil would not be filtered and could be contaminated. Contaminated oil can cause accelerated wear to engine components.

5. Install the oil filter. Tighten the oil filter to 12 N·m (8.8 lb ft). Do not overtighten the oil filter.

Horizontal Oil Filter

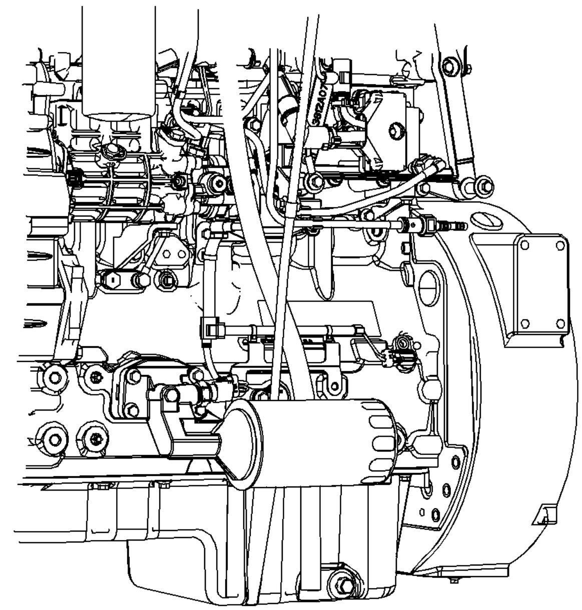

Illustration 45 g01428535

Typical example

Note: Some oil filters may be installed horizontally. Refer to illustration 45. This type of oil filter assembly can be drained before the filter is removed. Start at step 1 in order to remove the oil filter and install the oil filter.

Fill the Oil Pan

1. Remove the oil filler cap. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for more information on suitable oils. Fill the oil pan with the correct amount of new engine lubricating oil. Refer to this Operation and Maintenance Manual, “Refill Capacities” for more information on refill capacities.

NOTICE
If equipped with an auxilliary oil filter system or a remote filter system, follow the OEM or the filter manufacture's remonmendations. Under filling or over filling the crankcase with oil can cause engine damage.

2. Start the engine and run the engine at “LOW IDLE” for two minutes. Perform this procedure in order to ensure that the lubrication system has oil and that the oil filters are filled. Inspect the oil filter for oil leaks.

3. Stop the engine and allow the oil to drain back to the oil pan for a minimum of ten minutes.

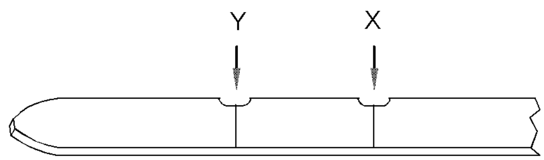

Illustration 46 g01165836

(Y) “Min” mark. (X) “Max” mark.

4. Remove the engine oil level gauge in order to check the oil level. Maintain the oil level between the “MIN” and “MAX” marks on the engine oil level gauge.

i02869394

Engine Oil and Filter - Change (CG-4 Oil)

CG-4 engine oil may be used. If this grade of engine oil is used a 250 hour service interval is required for the engine oil and the engine oil filter.

i02503009

Engine Valve Lash - Inspect/Adjust

This maintenance is recommended by Perkins as part of a lubrication and preventive maintenance schedule in order to help provide maximum engine life.

NOTICE

Only qualified service personel should perform this maintenance. Refer to the Service Manual or your authorized Perkins dealer or your Perkins distributor for the complete valve lash adjustment procedure.

Operation of Perkins engines with incorrect valve lash can reduce engine efficiency, and also reduce engine component life.

WARNING

Ensure that the engine can not be started while this maintenance is being performed. To help prevent possible injury, do not use the starting motor to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring/adjusting valve lash clearance.

Ensure that the engine is stopped before measuring the valve lash. The engine valve lash can be inspected and adjusted when the temperature of the engine is hot or cold.

Refer to Systems Operation/Testing and Adjusting, “Engine Valve Lash - Inspect/Adjust” for more information.

i02862580

Exhaust Manifold - Inspect

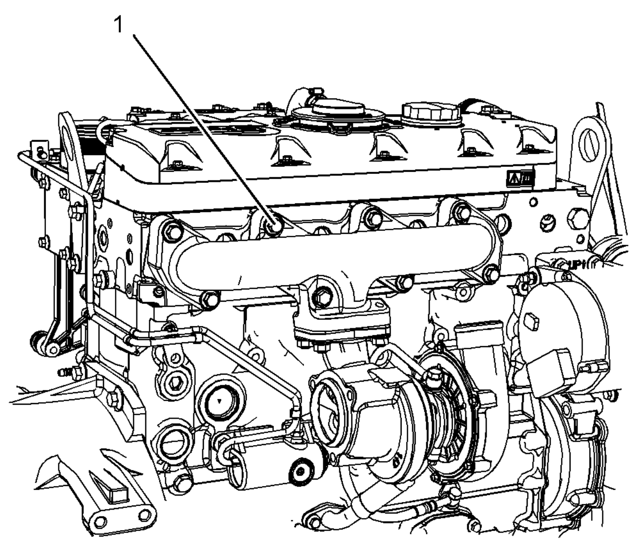

Illustration 47 g01425829

1. Inspect the exhaust manifold for damage. If necessary, replace the exhaust manifold. Refer to Disassembly and Assembly, “Exhaust Manifold - Remove and Install”.

2. Check the torque on all the bolts (1). The bolts must be tightened in the sequence that is shown in illustration 48.

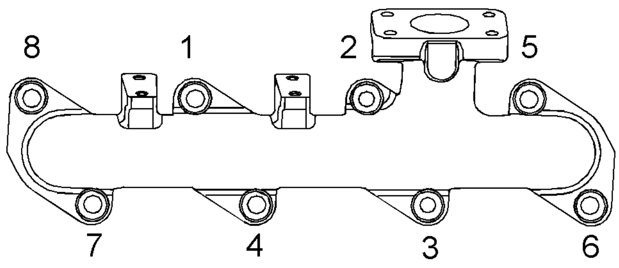

Illustration 48 g01363916

3. Tighten the bolts to the following torque 40 N·m (29.5 lb ft).

i02683336

Fan Clearance - Check

There are different types of cooling systems. Refer to the OEM for information on clearance for the fan.

Ensure that the engine is stopped. Ensure that the cooling system is full. The clearance between the cover (1) and the fan (2) will require checking. The gap (A) between the edge of the cover and the tip of the fan blade must be checked in four equally spaced positions.

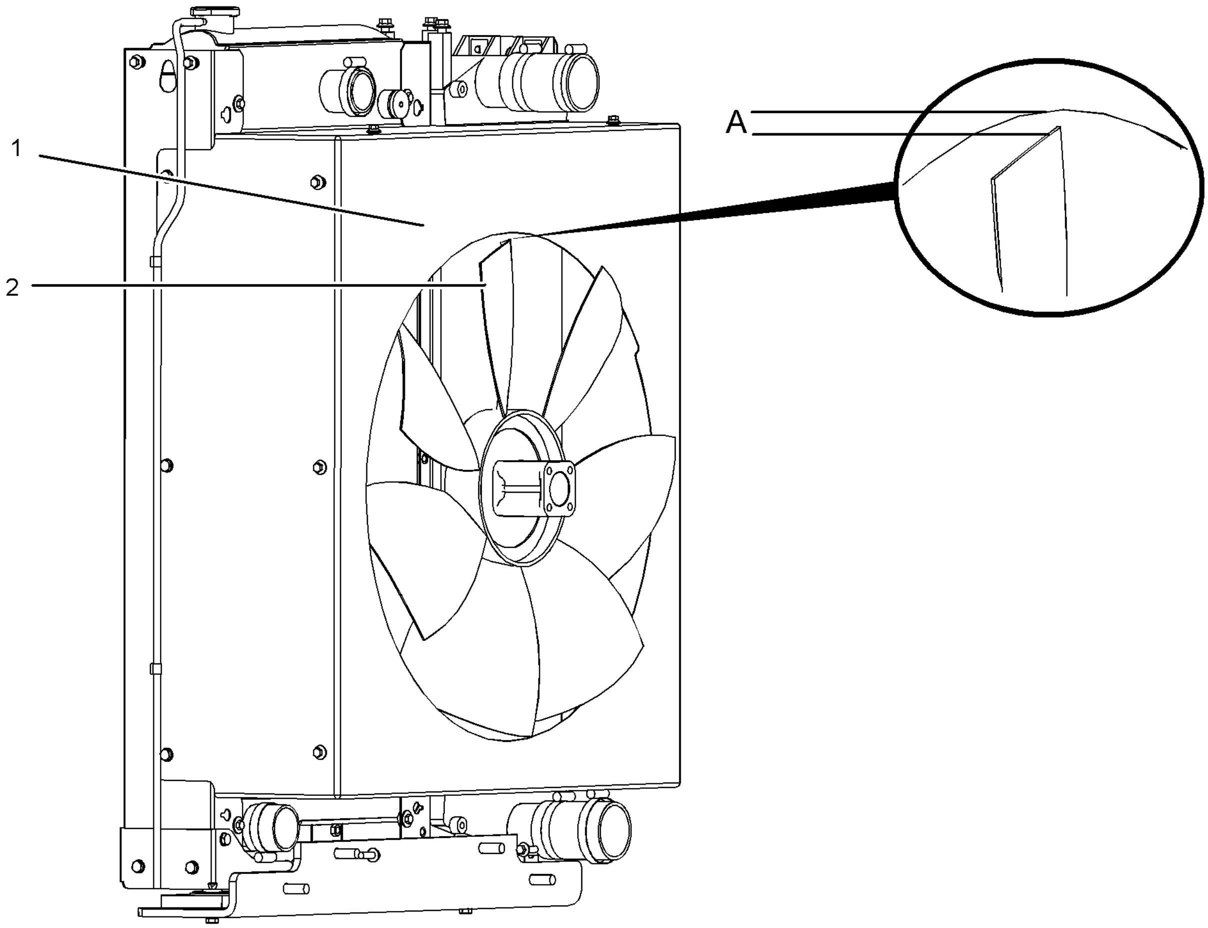

Illustration 49 g01348394

Adjustment of the cover will change the clearance (gap) between the edge of the cover and the tip of the fan blade. Ensure that the cover is centralized to the fan.

The maximum clearance is 12.5 mm (0.4921 inch). The minimum clearance is 6 mm (0.2362 inch).

i02871014

Fuel System - Prime

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

Refer to the Operation and Maintenance Manual , “General Hazard Information and High Pressure Fuel Lines” before adjustments and repairs are performed.

Note: Refer to Systems Operation, Testing and Adjusting, “Cleanliness of Fuel System Components” for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

NOTICE

Do not crank the engine continuously for more than 30 seconds. Allow the starting motor to cool for two minutes before cranking the engine again.

If air enters the fuel system, the air must be purged from the fuel system before the engine can be started. Air can enter the fuel system when the following events occur:

- The fuel tank is empty or the fuel tank has been partially drained.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system.
- The fuel filter has been replaced.

Hand Fuel Priming Pump

Use the following procedures in order to remove air from the fuel system:

1. Ensure that the fuel system is in working order. Check that the fuel supply valve (if equipped) is in the “ON” position.

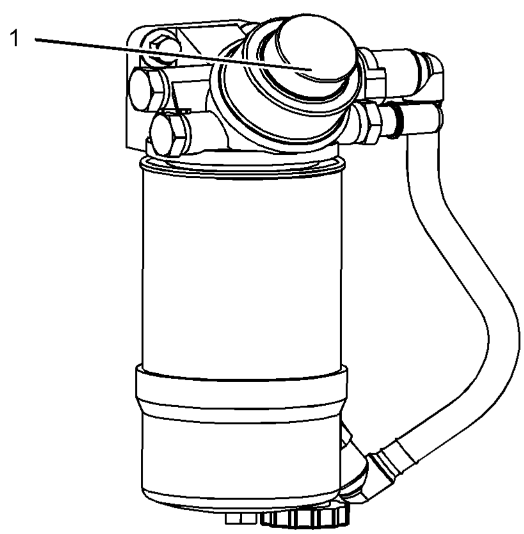

Illustration 50 g01476592

Typical example

2. Operate the fuel priming pump (1). Count the number of operations of the fuel priming pump. After 100 depressions of the fuel priming pump stop.

3. The engine fuel system should now be primed and the engine should now be able to start.

4. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of five minutes, immediately after air has been removed from the fuel system.

Note: Operating the engine for this period of time will help ensure that the fuel system is free of air.

Note: Do not loosen the high pressure fuel line in order to purge air from the fuel system. This procedure is not required.

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General hazard Information”.

i02869425

Fuel System Primary Filter (Water Separator) Element - Replace

Type One Filter

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

Note: Refer to Testing and Adjusting Manual , “Cleanliness of Fuel System Components” for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Ensure that the engine is stopped before any servicing or repair is performed.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

1. Turn the fuel supply valve (if equipped) to the OFF position before performing this maintenance.

2. Place a suitable container under the water separator in order to catch any fuel that might spill. Clean up any spilled fuel. Clean the outside of the water separator.

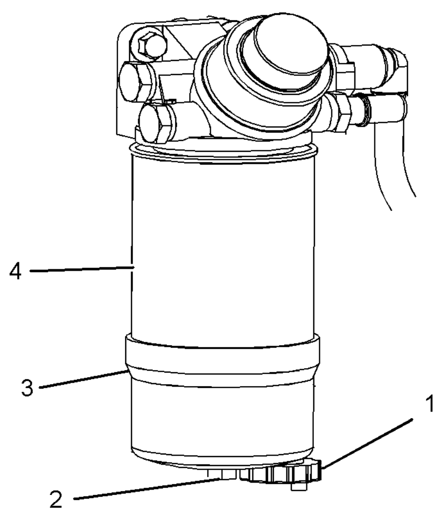

Illustration 51 g01259363

Typical example

3. Install a suitable tube onto drain (1). Open the drain (1). Allow the fluid to drain into the container. Remove the tube.

4. Tighten drain (1) by hand pressure only.

5. If equipped, remove the wiring harness from the sensor on the bottom of the glass bowl.

6. Hold glass bowl (3) and remove screw (2). Remove glass bowl (3) from canister (4).

7. Use a suitable tool in order to remove canister (4). Discard the old seals (5 and 6) and the canister in a safe place.

8. Clean glass bowl (3).

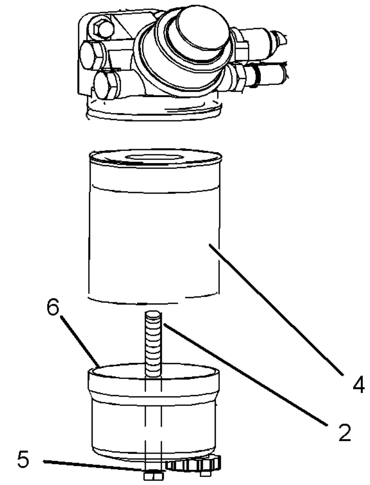

Illustration 52 g01259366

Typical example

9. Install the new canister. Do not use a tool in order to install the canister. Tighten the canister by hand.

10. Install new O ring seal (5) onto setscrew (2). Install new O ring seal (6) into the glass bowl.

11. Align the glass bowl to the canister. Ensure that the sensor (if equipped) is in the correct position. Install setscrew (2). Tighten the setscrew to a torque of 5 N·m (44 lb in).

12. If equipped, install the wiring harness to the sensor.

13. Remove the container and dispose of the fuel in a safe place.

14. The secondary filter must be replaced at the same time as the primary filter. Refer to the Operation and Maintenance Manual , "Fuel System Filter - Replace".

Type Two Filter

Note: Refer to Testing and Adjusting Manual , "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

NOTICE
Ensure that the engine is stopped before any servicing or repair is performed.

1. Turn the fuel supply valve (if equipped) to the OFF position before performing this maintenance.

2. Place a suitable container under the water separator in order to catch any fuel that might spill. Clean up any spilled fuel. Clean the outside of the water separator.

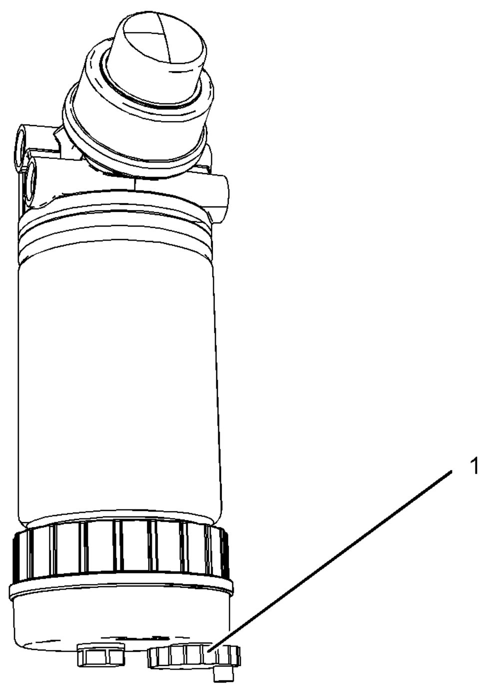

Illustration 53 g01429124

3. Install a suitable tube onto drain (1). Open drain (1). Allow the fluid to drain into the container. Remove the tube.

4. Tighten drain (1) by hand pressure only.

5. If equipped, remove the wiring harness from the sensor on the bottom of the bowl .

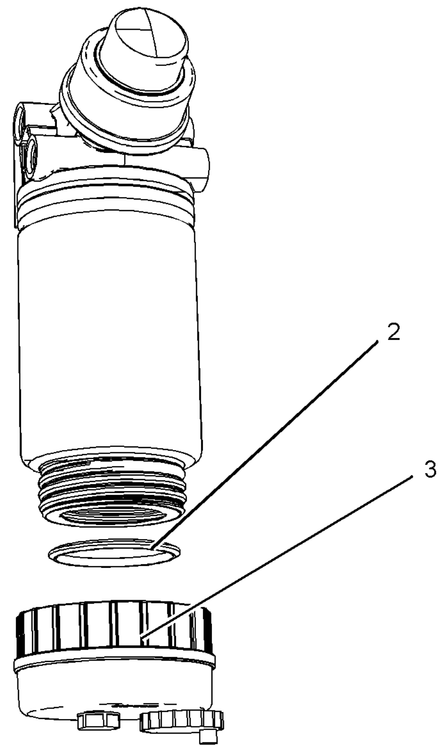

Illustration 54 g01429125

6. Rotate bowl (3) counterclockwise in order to remove the bowl. Remove O ring seal (2). Clean the bowl.

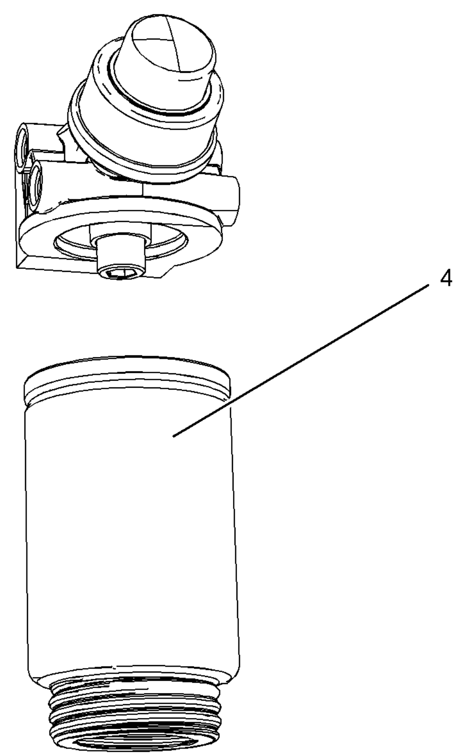

Illustration 55 g01429126

7. Use a suitable tool in order to remove old canister (4).

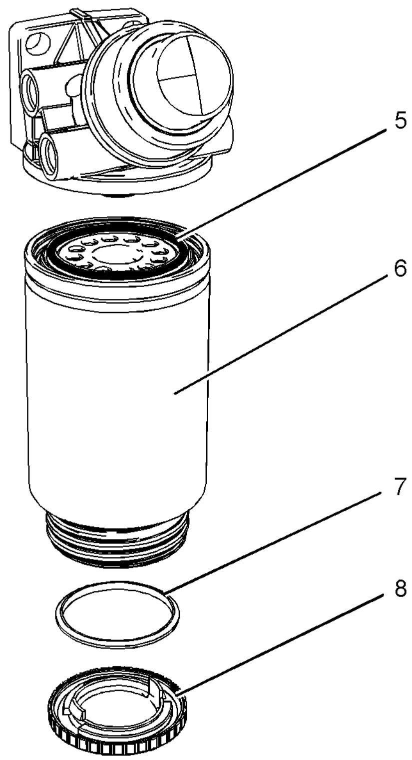

Illustration 56 g01429127

8. Lubricate O ring seal (5) with clean engine oil on the new canister. Install new canister (6). Spin on the canister until the O ring seal contacts the sealing surface. Then rotate the canister 360 degree in order to tighten the canister correctly.

9. Remove cap (8) from the threaded end of the new canister and remove new O ring seal (7). Install the new O ring seal into bowl (3).

10. Lubricate O ring seal (7) with clean engine oil. Install the bowl onto the new canister. Tighten the bowl to 15 N·m (11 lb ft).

11. If equipped, install the wiring harness to the sensor. Open the fuel supply valve.

12. Remove the container and dispose of the fluid in a safe place.

13. The secondary filter must be replaced at the same time as the primary filter. Refer to the Operation and Maintenance Manual , "Fuel System Filter - Replace".

i02869410

Fuel System Primary Filter/Water Separator - Drain

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE

Ensure that the engine is stopped before any servicing or repair is performed.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

NOTICE

The water separator can be under suction during normal engine operation. Ensure that the drain valve is tightened securely to help prevent air from entering the fuel system.

1. Place a suitable container under the water separator in order to catch any fuel that might spill. Clean up any spilled fuel.

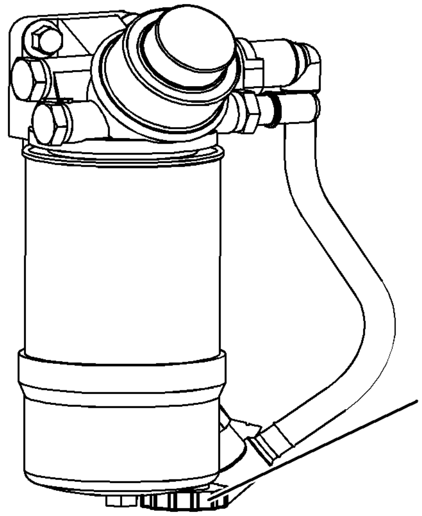

Illustration 57 g01476633

Typical example

2. Install a suitable tube onto the drain (1). Open the drain (1). Allow the fluid to drain into the container.

3. Tighten the drain (1) by hand pressure only. Remove the tube and dispose of the drained fluid in a safe place.

Primary Filter with a Vent Screw

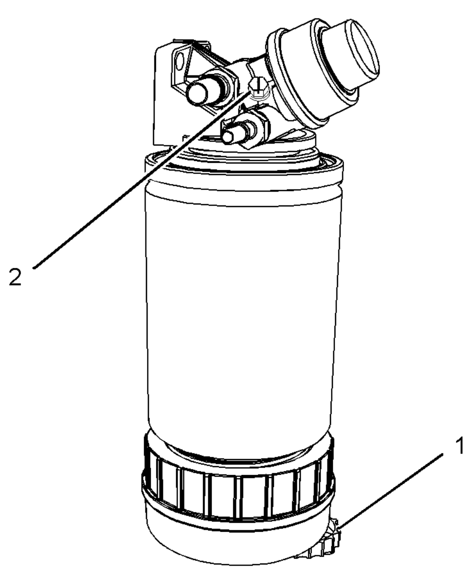

Illustration 58 g01371846

Typical example

Note: Not all primary filters require vent screw (2). This primary fuel filter that has a vent screw may be installed on a fuel system that has a low fuel tank.

1. Install a suitable tube onto drain (1). Loosen vent screw (2).

2. Open drain (1). Allow the fluid to drain into the container.

3. Tighten drain (1) by hand pressure only. Remove the tube and dispose of the drained fluid in a safe place.

4. Tighten vent screw to 6 N·m (53 lb in).

i02869989

Fuel System Secondary Filter - Replace

Type One

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

Note: Refer to Testing and Adjusting Manual , "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Ensure that the engine is stopped before any servicing or repair is performed.

This fuel filter can be identified by the six drain holes in the filter. Refer to illustration 59.

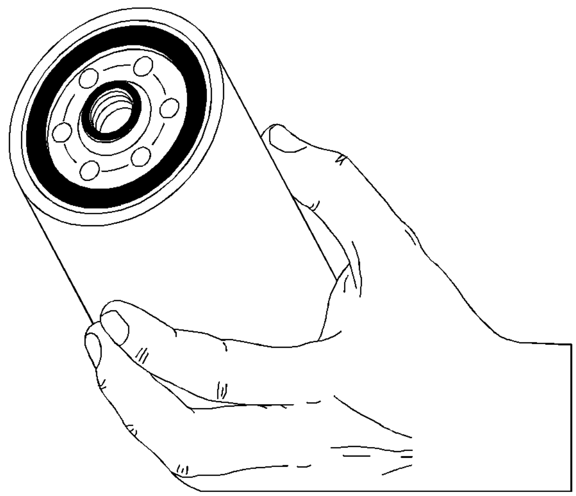

Illustration 59 g01429525

Typical example

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

1. Ensure that the fuel supply valve (if equipped) is in the OFF position. Place a suitable container under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel.

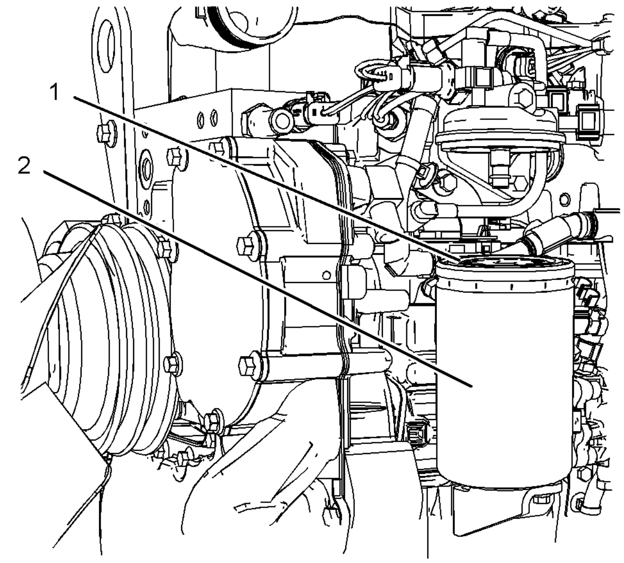

Illustration 60 g01429517

Typical example

2. Clean the outside of the fuel filter. Use a suitable tool in order to remove the canister (2) from the engine and dispose of the canister in a safe place.

3. Ensure that dirt can not enter the new canister. Do not fill the canister with fuel before the canister is installed. Lubricate the O ring seal (1) with clean engine oil on the new canister.

4. Install the new canister. Do not use a tool in order to install the canister. Tighten the canister by hand.

5. Spin on the canister until the O ring seal contacts the sealing surface. The canister will require a ¾ of a full turn in order to tighten the canister correctly.

6. Prime the fuel system. Refer to the Operation and Maintenance Manual, “Fuel System - Prime” for more information.

Type Two

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

Note: Refer to Testing and Adjusting Manual , “Cleanliness of Fuel System Components” for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

NOTICE

Ensure that the engine is stopped before any servicing or repair is performed.

Illustration 61 g01429532

This fuel filter can be identified by the 12 drain holes in the filter. Refer to illustration 61.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

1. Ensure that the fuel supply valve (if equipped) is in the OFF position. Place a suitable container under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel.

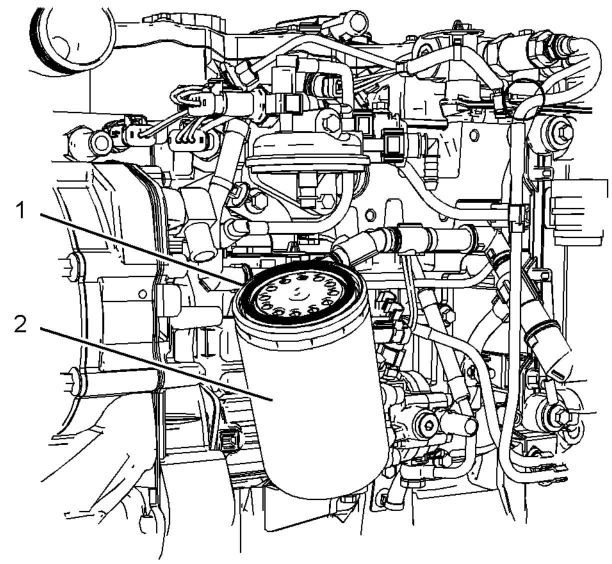

Illustration 62 g01429516

Typical example

2. Clean the outside of the fuel filter. Use a suitable tool in order to remove the canister (2) from the engine and dispose of the canister in a safe place.

3. Ensure that dirt can not enter the new canister. Do not fill the canister with fuel before the canister is installed. Lubricate the O ring seal (1) with clean engine oil on the new canister.

4. Install the new canister. Do not use a tool in order to install the canister. Tighten the canister by hand.

5. Spin on the canister until the O ring seal contacts the sealing surface. Then rotate the canister 360 degree in order to tighten the canister correctly.

6. Remove the container and dispose of the fuel in a safe place. If equipped, open the fuel supply valve.

7. Prime the fuel system. Refer to the Operation and Maintenance Manual, “Fuel System - Prime” for more information.

i02335436

Fuel Tank Water and Sediment - Drain

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Fuel Tank

Fuel quality is critical to the performance and to the service life of the engine. Water in the fuel can cause excessive wear to the fuel system.

Water can be introduced into the fuel tank when the fuel tank is being filled.

Condensation occurs during the heating and cooling of fuel. The condensation occurs as the fuel passes through the fuel system and the fuel returns to the fuel tank. This causes water to accumulate in fuel tanks. Draining the fuel tank regularly and obtaining fuel from reliable sources can help to eliminate water in the fuel.

Drain the Water and the Sediment

Fuel tanks should contain some provision for draining water and draining sediment from the bottom of the fuel tanks.

Open the drain valve on the bottom of the fuel tank in order to drain the water and the sediment. Close the drain valve.

Check the fuel daily. Allow five minutes after the fuel tank has been filled before draining water and sediment from the fuel tank.

Fill the fuel tank after operating the engine in order to drive out moist air. This will help prevent condensation. Do not fill the tank to the top. The fuel expands as the fuel gets warm. The tank may overflow.

Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe. Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Fuel Storage Tanks

Drain the water and the sediment from the fuel storage tank at the following intervals:

- Weekly
- Service intervals
- Refill of the tank

This will help prevent water or sediment from being pumped from the storage tank into the engine fuel tank.

If a bulk storage tank has been refilled or moved recently, allow adequate time for the sediment to settle before filling the engine fuel tank. Internal baffles in the bulk storage tank will also help trap sediment. Filtering fuel that is pumped from the storage tank helps to ensure the quality of the fuel. When possible, water separators should be used.

i02349879

Hoses and Clamps - Inspect/Replace

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General hazard Information”.

Inspect all hoses for leaks that are caused by the following conditions:

- Cracking
- Softness
- Loose clamps

Replace hoses that are cracked or soft. Tighten any loose clamps.

Check for the following conditions:

- End fittings that are damaged or leaking
- Outer covering that is chafed or cut
- Exposed wire that is used for reinforcement
- Outer covering that is ballooning locally
- Flexible part of the hose that is kinked or crushed
- Armoring that is embedded in the outer covering

A constant torque hose clamp can be used in place of any standard hose clamp. Ensure that the constant torque hose clamp is the same size as the standard clamp.

Due to extreme temperature changes, the hose will harden. Hardening of the hoses will cause hose clamps to loosen. This can result in leaks. A constant torque hose clamp will help to prevent loose hose clamps.

Each installation application can be different. The differences depend on the following factors:

- Type of hose
- Type of fitting material
- Anticipated expansion and contraction of the hose
- Anticipated expansion and contraction of the fittings

Replace the Hoses and the Clamps

Refer to the OEM information for further information on removing and replacing fuel hoses (if equipped).

The coolant system and the hoses for the coolant system are not usually supplied by Perkins. The following text describes a typical method of replacing coolant hoses. Refer to the OEM information for further information on the coolant system and the hoses for the coolant system.

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine. Allow the engine to cool.
2. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

Note: Drain the coolant into a suitable, clean container. The coolant can be reused.

3. Drain the coolant from the cooling system to a level that is below the hose that is being replaced.
4. Remove the hose clamps.
5. Disconnect the old hose.
6. Replace the old hose with a new hose.
7. Install the hose clamps with a torque wrench.

Note: For the correct coolant, see this Operation and Maintenance Manual, “Fluid Recommendations”.

8. Refill the cooling system. Refer to the OEM information for further information on refilling the cooling system.
9. Clean the cooling system filler cap. Inspect the cooling system filler cap's seals. Replace the cooling system filler cap if the seals are damaged. Install the cooling system filler cap.
10. Start the engine. Inspect the cooling system for leaks.

i02335774

Radiator - Clean

The radiator is not usually supplied by Perkins. The following text describes a typical cleaning procedure for the radiator. Refer to the OEM information for further information on cleaning the radiator.

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the radiator for these items: Damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the radiator, if necessary.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction to the fan's air flow. Hold the nozzle approximately 6 mm (0.25 inch) away from the radiator fins. Slowly move the air nozzle in a direction that is parallel with the radiator tube assembly. This will remove debris that is between the tubes.

Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

Use a degreaser and steam for removal of oil and grease. Clean both sides of the core. Wash the core with detergent and hot water. Thoroughly rinse the core with clean water.

If the radiator is blocked internally, refer to the OEM Manual for information regarding flushing the cooling system.

After cleaning the radiator, start the engine. Allow the engine to operate at low idle speed for three to five minutes. Accelerate the engine to high idle. This will help in the removal of debris and the drying of the core. Slowly reduce the engine speed to low idle and then stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a “comb”. Inspect these items for good condition: Welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

i02335775

Severe Service Application - Check

Severe service is the application of an engine that exceeds the current published standards for that engine. Perkins maintains standards for the following engine parameters:

- Performance such as power range, speed range, and fuel consumption
- Fuel quality
- Operational Altitude
- Maintenance intervals
- Oil selection and maintenance
- Coolant type and maintenance
- Environmental qualities
- Installation
- The temperature of the fluid in the engine

Refer to the standards for the engine or consult your Perkins dealer or your Perkins distributor in order to determine if the engine is operating within the defined parameters.

Severe service operation can accelerate component wear. Engines that operate under severe conditions may need more frequent maintenance intervals in order to ensure maximum reliability and retention of full service life.

Due to individual applications, it is not possible to identify all of the factors which can contribute to severe service operation. Consult your Perkins dealer or your Perkins distributor for the unique maintenance that is necessary for the engine.

The operating environment, incorrect operating procedures and incorrect maintenance procedures can be factors which contribute to a severe service application.

Environmental Factors

Ambient temperatures – The engine may be exposed to extended operation in extremely cold environments or hot environments. Valve components can be damaged by carbon buildup if the engine is frequently started and stopped in very cold temperatures. Extremely hot intake air reduces engine performance.

Quality of the air – The engine may be exposed to extended operation in an environment that is dirty or dusty, unless the equipment is cleaned regularly. Mud, dirt and dust can encase components. Maintenance can be very difficult. The buildup can contain corrosive chemicals.

Buildup – Compounds, elements, corrosive chemicals and salt can damage some components.

Altitude – Problems can arise when the engine is operated at altitudes that are higher than the intended settings for that application. Necessary adjustments should be made.

Incorrect Operating Procedures

- Extended operation at low idle
- Frequent hot shutdowns
- Operating at excessive loads
- Operating at excessive speeds
- Operating outside the intended application

Incorrect Maintenance Procedures

- Extending the maintenance intervals
- Failure to use recommended fuel, lubricants and coolant/antifreeze

i02177969

Starting Motor - Inspect

Perkins recommends a scheduled inspection of the starting motor. If the starting motor fails, the engine may not start in an emergency situation.

Check the starting motor for correct operation. Check the electrical connections and clean the electrical connections. Refer to the Systems Operation, Testing and Adjusting Manual, "Electric Starting System - Test" for more information on the checking procedure and for specifications or consult your Perkins dealer or your Perkins distributor for assistance.

i04149590

Turbocharger - Inspect

A regular visual inspection of the turbocharger is recommended. If the turbocharger fails during engine operation, damage to the turbocharger compressor wheel and/or to the engine may occur. Damage to the turbocharger compressor wheel can cause additional damage to the pistons, the valves, and the cylinder head.

NOTICE

Turbocharger bearing failures can cause large quantities of oil to enter the air intake and exhaust systems. Loss of engine lubricant can result in serious engine damage.

Minor leakage of oil into a turbocharger under extended low idle operation should not cause problems as long as a turbocharger bearing failure has not occured.

When a turbocharger bearing failure is accompanied by a significant engine performance loss (exhaust smoke or engine rpm up at no load), do not continue engine operation until the turbocharger is renewed.

A visual inspection of the turbocharger can minimize unscheduled downtime. A visual inspection of the turbocharger can also reduce the chance for potential damage to other engine parts.

Removal and Installation

For options regarding the removal, installation, and replacement, consult your Perkins dealer or your Perkins distributor. Refer to the Disassembly and Assembly, "Turbocharger - Remove and Turbocharger - Install" and Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for further information.

Inspecting

NOTICE

The compressor housing for the turbocharger must not be removed from the turbocharger for inspection or removed for the cleaning of the compressor.

1. Remove the pipe from the turbocharger exhaust outlet and remove the air intake pipe to the turbocharger. Visually inspect the piping for the presence of oil. Clean the interior of the pipes in order to prevent dirt from entering during reassembly.

2. Check for obvious heat discoloration of the turbocharger. Check for any loose bolts or any missing bolts. Check for damage to the oil supply line and the oil drain line. Check for cracks in the housing of the turbocharger. Ensure that the compressor wheel can rotate freely.

3. Check for the presence of oil. If oil is leaking from the back side of the compressor wheel, there is a possibility of a failed turbocharger oil seal.

The presence of oil may be the result of extended engine operation at low idle. The presence of oil may also be the result of a restriction of the line for the intake air (clogged air filters), which causes the turbocharger to slobber.

4. Inspect the bore of the housing of the turbine outlet for corrosion.

5. Fasten the air intake pipe and the exhaust outlet pipe to the turbocharger housing. Ensure that all clamps are installed correctly and that all clamps are tightened securely.

i02866087

V-Belts - Inspect/Adjust/ Replace

Inspection

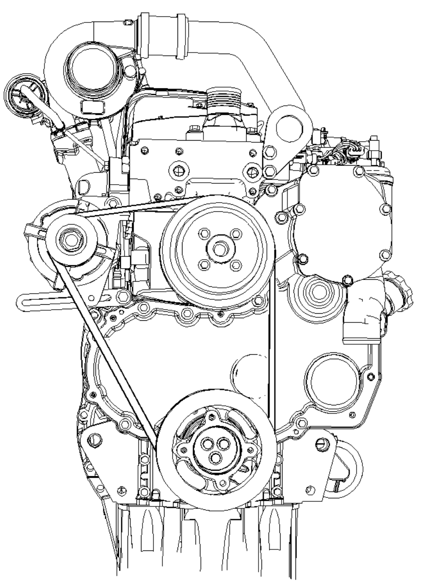

Illustration 63 g01249073

Arrangement for the V-belts

To maximize the engine performance, inspect the belts for wear and for cracking. Replace belts that are worn or damaged.

For applications that require multiple drive belts, replace the belts in matched sets. Replacing only one belt of a matched set will cause the new belt to carry more load because the older belt is stretched. The additional load on the new belt could cause the new belt to break.

If the belts are too loose, vibration causes unnecessary wear on the belts and pulleys. Loose belts may slip enough to cause overheating.

To accurately check the belt tension, a suitable gauge should be used.

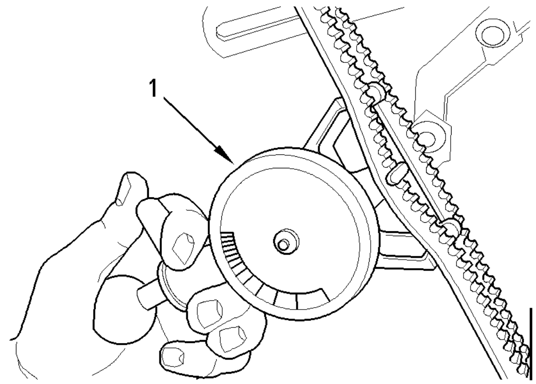

Illustration 64 g01003936

Typical example

(1) Belt tension gauge

Fit the gauge (1) at the center of the longest free length and check the tension. The correct tension for a used belt is 355 N (79.8 lb). If the tension of the belt is below 250 N (56 lb) adjust the belt to 355 N (79.8 lb).

Note: The correct tension for a new belt or new belts is 535 N (120 lb). A higher tension is required in order to compensate for the stretch that is in a new belt. Only use the higher tension on a belt that has not been used. A used belt is a belt that has been in operation for 30 minutes or a longer period of time.

If twin belts are installed, check and adjust the tension on both belts.

Adjustment

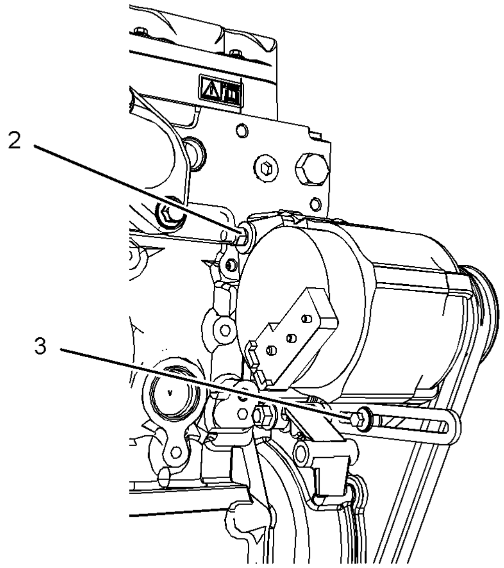

Illustration 65 g01427780

Typical example

1. Loosen nut (2) and the bolt (3).

2. Move the alternator in order to increase or decrease the belt tension. Tighten the nut (2) and the bolt (3) to 22 N·m (16 lb ft).(1).

Replace

Refer to Disassembly and Assembly manual, “V-Belts - Remove and Install” for more information.

i03577563

Walk-Around Inspection

Inspect the Tube of the Crankcase Breather

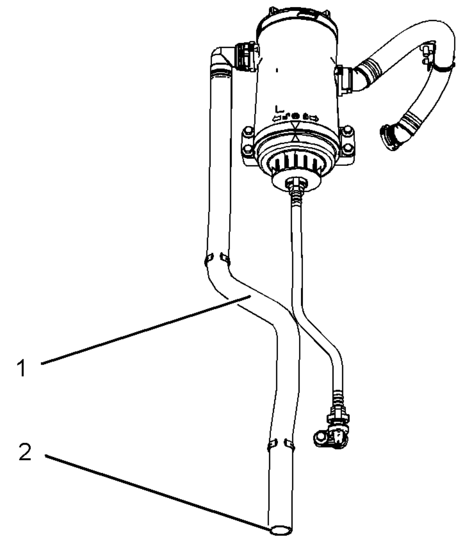

Illustration 66 g01905095

Inspect the breather tube (1) for damage. Ensure that the outlet (2) is clean and free from any obstructions. Ice can cause obstructions in adverse weather conditions.

Inspect the Engine for Leaks and for Loose Connections

A walk-around inspection should only take a few minutes. When the time is taken to perform these checks, costly repairs and accidents can be avoided.

For maximum engine service life, make a thorough inspection of the engine compartment before starting the engine. Look for items such as oil leaks or coolant leaks, loose bolts, worn belts, loose connections and trash buildup. Make repairs, as needed:

- The guards must be in the correct place. Repair damaged guards or replace missing guards.

- Wipe all caps and plugs before the engine is serviced in order to reduce the chance of system contamination.

NOTICE
For any type of leak (coolant, lube, or fuel) clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

NOTICE
Accumulated grease and/or oil on an engine is a fire hazard. Remove the accumulated grease and oil. Refer to this Operation and Maintenance Manual, "Engine - Clean" for more information.

- Ensure that the cooling system hoses are correctly clamped and that the cooling system hoses are tight. Check for leaks. Check the condition of all pipes.

- Inspect the water pump for coolant leaks.

Note: The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and the parts contract.

Excessive coolant leakage may indicate the need to replace the water pump. Remove the water pump. Refer to Disassembly and Assembly , "Water Pump - Remove and Install". For more information, consult your Perkins dealer or your Perkins distributor.

- Inspect the lubrication system for leaks at the front crankshaft seal, the rear crankshaft seal, the oil pan, the oil filters and the rocker cover.

- Inspect the piping for the air intake system and the elbows for cracks and for loose clamps. Ensure that hoses and tubes are not contacting other hoses, tubes, wiring harnesses, etc.

- Ensure that the areas around the rotating parts are clear.

- Inspect the alternator belts and any accessory drive belts for cracks, breaks or other damage.

- Inspect the wiring harness for damage.

Belts for multiple groove pulleys must be replaced as matched sets. If only one belt is replaced, the belt will carry more load than the belts that are not replaced. The older belts are stretched. The additional load on the new belt could cause the belt to break.

High Pressure Fuel Lines

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

After the engine has stopped, you must wait for 10 minutes in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General hazard Information".

Visually inspect the high pressure fuel lines for damage or signs of fuel leakage. Replace any damaged high pressure fuel lines or high pressure fuel lines that have leaked.

Ensure that all clips on the high pressure fuel lines are in place and that the clips are not loose.

- Inspect the rest of the fuel system for leaks. Look for loose fuel line clamps.

- Drain the water and the sediment from the fuel tank on a daily basis in order to ensure that only clean fuel enters the fuel system.

- Inspect the wiring and the wiring harnesses for loose connections and for worn wires or frayed wires. Check for any loose tie-wraps or missing tie-wraps.

- Inspect the ground strap for a good connection and for good condition.

- Disconnect any battery chargers that are not protected against the current drain of the starting motor. Check the condition and the electrolyte level of the batteries, unless the engine is equipped with a maintenance free battery.

- Check the condition of the gauges. Replace any gauges that are cracked. Replace any gauge that can not be calibrated.

i02499304

Water Pump - Inspect

A failed water pump may cause severe engine overheating problems that could result in the following conditions:

- Cracks in the cylinder head
- A piston seizure
- Other potential damage to the engine

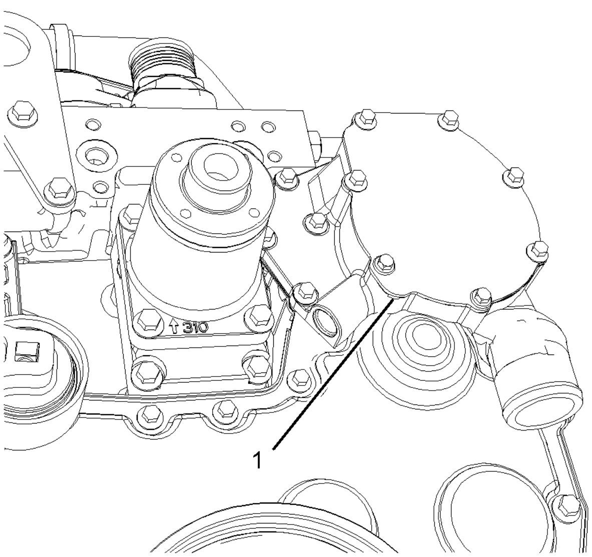

Illustration 67 g01249453

(1) Weep hole

Note: The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and parts contract.

Visually inspect the water pump for leaks. The water pump is not a serviceable item. In order to install a new water pump, refer to the Disassembly and Assembly Manual, “Water Pump - Remove and Install”.

Warranty Section

Warranty Information

i01903596

Emissions Warranty Information

This engine may be certified to comply with exhaust emission standards and gaseous emission standards that are prescribed by the law at the time of manufacture, and this engine may be covered by an Emissions Warranty. Consult your authorized Perkins dealer or your authorized Perkins distributor in order to determine if your engine is emissions certified and if your engine is subject to an Emissions Warranty.

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Product and Dealer Information

Note: For product identification plate locations, see the section "Product Identification Information" in the Operation and Maintenance Manual.

Delivery Date: ______________________

Product Information

Model: ______________________

Product Identification Number: ______________________

Engine Serial Number: ______________________

Transmission Serial Number: ______________________

Generator Serial Number: ______________________

Attachment Serial Numbers: ______________________

Attachment Information: ______________________

Customer Equipment Number: ______________________

Dealer Equipment Number: ______________________

Dealer Information

Name: ______________________ Branch: ______________________

Address: ______________________

____

____

	Dealer Contact	Phone Number	Hours
Sales:			
Parts:			
Service:			

TRANSMITTAL OF SHOP DRAWINGS, EQUIPMENT DATA, MATERIAL SAMPLES, OR MANUFACTURER'S CERTIFICATES OF COMPLIANCE
(Read instructions on the reverse side prior to initiating this form)

DATE: 02/02/2015

TRANSMITTAL NO.: 41 65 10-6

SECTION I - REQUEST FOR APPROVAL OF THE FOLLOWING ITEMS (This section will be initiated by the contractor)

TO: Eastern Area Office
926 SW Adams Street, Suite 110
Peoria, IL 61602

FROM: Kolb Grading, LLC
5731 Westwood Dr.
Saint Charles, MO 63304

CONTRACT NO.: W912EK-10-C-0122 NA

CHECK ONE:
[X] THIS IS A NEW TRANSMITTAL
[ ] THIS IS A RESUBMITTAL OF TRANSMITTAL ____

SPECIFICATION SEC. NO. (Cover only one section with each transmittal) 41 65 10

PROJECT TITLE AND LOCATION 01-Main Register
Fox Island Division Habitat Rehab and En Fox Island Missouri

CHECK ONE: THIS TRANSMITTAL IS FOR [ ] FIO [X] GA [ ] DA [ ] CR

ITEM NO. a.	DESCRIPTION OF ITEM SUBMITTED (Type size, model number/etc.) b.	MFG OR CONTR. CAT., CURVE DRAWING OR BROCHURE NO. (See instruction no. 8) c.	NO. OF COPIES d.	CONTRACT REFERENCE DOCUMENT SPEC. PARA. NO. e.	CONTRACT REFERENCE DOCUMENT DRAWING SHEET NO. f.	FOR CONTRACTOR USE CODE g.	VARIATION (See Instruction No. 6) h.	FOR CE USE CODE i.
10	Manufacturer's Published Instructions	PRODUCT DATA	4			A	N	B

REMARKS
Operating Procedures PTO Power Unit and Wiring and Control Diagrams.

I certify that the above submitted items have been reviewed in detail and are correct and in the strict conformance with the contract drawings and specifications except as otherwise stated.

D. Mark Potts

NAME AND SIGNATURE OF CONTRACTOR

SECTION II - APPROVAL ACTION

ENCLOSURES RETURNED (List by item No.)

NAME, TITLE AND SIGNATURE OF APPROVING AUTHORITY

DATE 3/15/2015

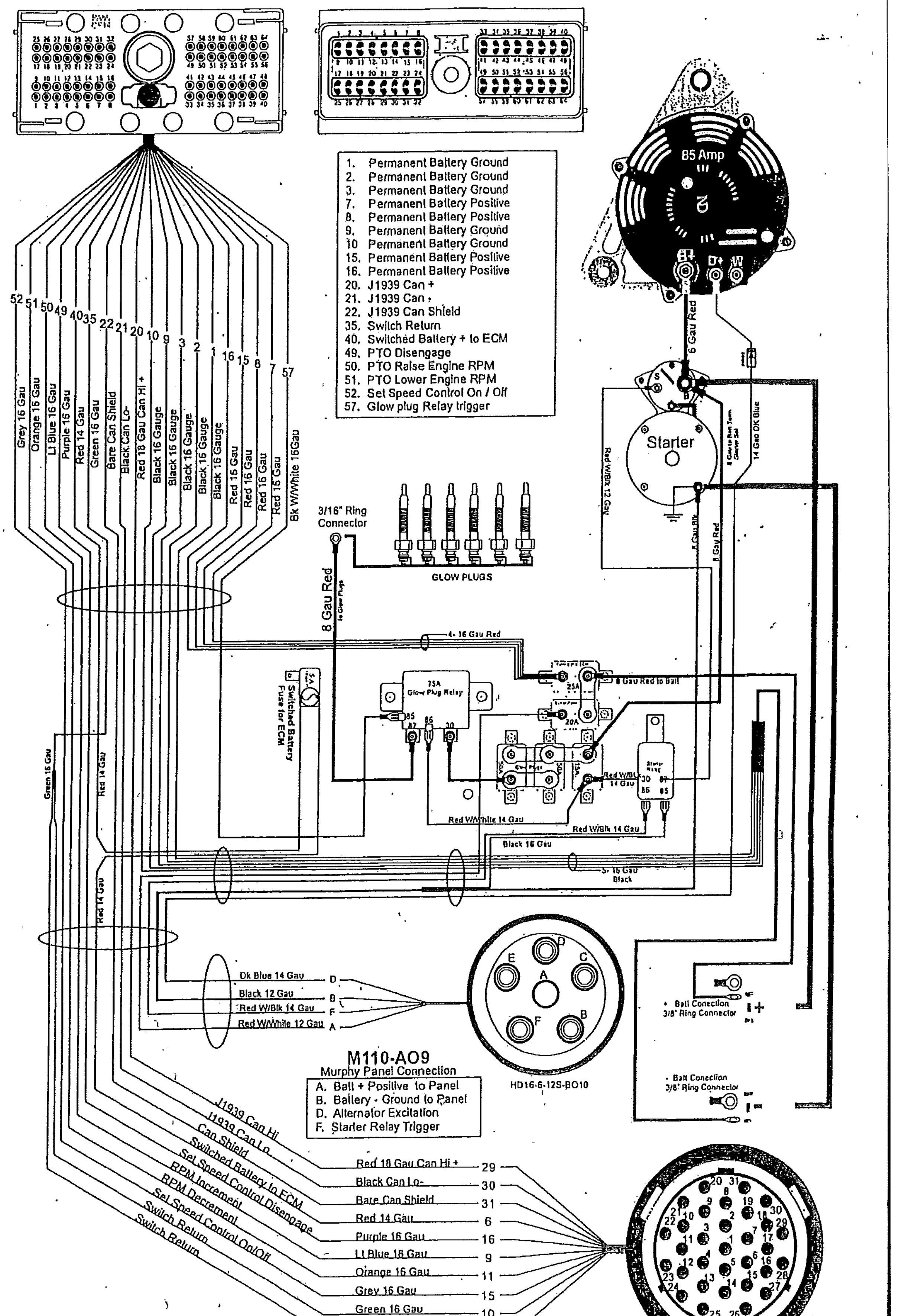
ENG FORM 4025, MAR 95 *(ER 415-1-10)* EDITION OF SEP 93 IS OBSOLETE. SHEET 1 OF 1 (Proponent: CEMP-CE)

TRANSMITTAL OF SHOP DRAWINGS, EQUIPMENT DATA, MATERIAL SAMPLES, OR MANUFACTURER'S CERTIFICATES OF COMPLIANCE	DATE 03/12/2015	TRANSMITTAL NO. 41 65 10-6
PROJECT TITLE Fox Island Division Habitat Rehab and En LOCATION Fox Island Missouri	CONTRACT NO. W912EK-10-C-0122 NA	PAGE 1 of 1

Item	Description	Variation	QA Code
10	Manufacturer's Published Instructions	No	B

SECTION III - GOVERNMENT REVIEW REMARKS

41 65 10 Para 1.3 Given the equipment is mobile, the laminated instructions and wiring diagram will be mount on the equipment by the owner.



Perkins Pacific Inc

800-882-3660
360-906-8298
7401 NE 47th Ave
Vancouver Wa 98661
FAX 360-906-8297

Dwg # 11056	1100 W/ Murphy 110 Panel
Date 10/07/08	M110 Harness

OPERATING PROCEDURES PTO POWER UNIT

SAFETY

1. Ensure all recommended maintenance has been performed.
2. Visually inspect trailer, engine and PTO Drive shaft for any damage that may have occurred in transit.
3. Block all tires and ensure stabilizing jacks are in place and trailer is level.
4. Check that **Manual PTO Clutch is DISENGAGED** prior to starting engine.
5. All persons must stand at least 3 ft from rotating PTO drive shaft while in operation.
6. Do not disengage trailer from towing vehicle while power unit is in operation.
7. No smoking within 20 ft of Power Unit Trailer

INSTALLATION AND STARTUP

1. Block all tires and level trailer using stabilizing jacks.
2. Connect PTO drive shaft to the manual clutch and to the pump. Tighten all set screws.
3. Check that **Manual PTO Clutch is DISENGAGED** before starting engine.
4. Set engine to **IDLE** and press the **START** button. Allow engine to run for 3-5 minutes.
5. Prime pump using 65 gallon water priming tank.
6. Engage manual PTO clutch.
7. Set engine to **RUN**.

SHUTDOWN AND DISCONNECT

1. Set engine to **IDLE.**
2. Disengage manual PTO clutch.
3. Allow engine to idle for 3-5 minutes.
4. Turn engine **OFF.**
5. Disconnect PTO Drive shaft from pump. And store in saddle.

MAINTENANCE AND LUBRICATION SCHEDULE

Engine maintenance: daily or every 8 hours

- Check the amount of coolant in the header tank
- Check the engine for leakage of oil and coolant
- Check the tension and condition of the drive belts
- Check for water in the pre filter bowl
- Check the amount of lubricating oil in the sump
- Check the lubricating oil pressure at the guage

Clutch and PTO maintenance

- Squeeze grease into the bearing assembly every 75 hours

TROUBLESHOOTING

For engine troubleshooting please refer to the Perkins 1100 series Operations and Maintenance Manual

Problem:

Pump is not producing desired flow.

- Ensure pump is properly primed.
- Check engine speed ensure engine is set to **RUN**
- Engage Manual PTO clutch

Excess Vibration or Mechanical Noise

- Ensure trailer is properly leveled and stabilizing jacks are properly seated
- Ensure PTO drive shaft is properly attached and set screw are tightened
- Check for proper PTO Clutch engagement

OPERATION AND MAINTENANCE INSTRUCTIONS

RANDOLPH RIGHT ANGLE GEAR DRIVES

INSTALLATION

Gear drives for domestic shipment are shipped with lubricant installed. Air freight shipments are shipped with the initial fill of oil in a separate container.

Inspect and clean top of discharge base and bottom of gear drive to assure removal of burrs or foreign material that might cause misalignment.

Install gear drive on discharge base and install non-reverse clutch over head shaft. The non-reverse clutch should fit on the head shaft and engage the drive block **without springing** the head shaft. Lubricate head shaft threads and bottom of adjusting nut before raising the pump impellers.

Remove protective material from the input shaft extension and clean the shaft. Install coupling half or flange. Hammering the flange or coupling into place may damage bearings and change gear adjustment. This is not permissible. Interference fits are permissible if coupling can be heated for installation and fitted without hammering to install on the input shaft. Check the run out of the aligning surfaces on both coupling halves before installing the connecting members.

Align driver with gear drive to obtain parallel and angular alignment within coupling or drive shaft manufacturers specification. Misalignment should be as close to zero as possible for maximum life and smoothest operation. Use only the correct specified tools and procedures when aligning the gear drive and driver. Improper alignment will void the warranty on the RANDOLPH right angle gear drive.

Excessive noise and vibration in a new gear drive is almost always an indication of misalignment or poor installation. All drives are test run at the factory and checked for noise and vibration. Failure to correct the installation can result in damage to the pump and gear drive. Our warranty will not apply unless drive is properly installed. Proper installation includes alignment of the power unit, right angle drive, and pump. Adequate foundation must be provided for engine and pump to prevent shifting or settling of either member. Positive alignment must be maintained. Recheck alignment at regular intervals after starting the operation of the system and correct if settling or drifting has occurred.

With engine drive systems, it is not uncommon for one or more resonate speeds to exist between zero RPM and the operating speed of the system. Continued operation at a resonate speed will result in torsional vibrations which can be damaging to all components in the system. Unusual rumbling or clattering noise from the gear drive at a sharply defined speed is the most common indication of torsional vibrations. As the speed is increased or decreased, the noise will disappear. This noise is not indicative of a defect but results when the vibratory torque exceeds the drive torque causing the gear teeth in the gear drive to separate and clash together very rapidly. Transition through a resonate speed range to operating speed is not normally damaging, but operation of the system close to a resonate speed should be avoided. To avoid operation at a resonate speed it may be necessary to change the elastic characteristics of the rotating components in the system, or change the speed of the engine with respect to the pump. This can be accomplished by changing the gear ratio of the gear drive.

LUBRICATION

Use only rust and oxidation inhibited (R&O) gear oils in accordance with American Gear Manufacturers Association (AGMA) standard 250.04 dated Sept. 1981.

For general operating conditions, AGMA lubricant number and corresponding viscosity range are shown on the permanent identification plate attached to the main case of the gear drive. Contact the factory for lubricant recommendations for operation under extremely hot or cold ambient conditions. Gear drives operating in extremely cold weather must be provided with an oil which will flow through the oil lines at start up. Oil flow must be immediate otherwise the bearings and gears will not be properly lubricated. A lube oil heater may be required for consistent cold weather starting.

For ambient conditions between 50 and 125 degrees Fahrenheit use the following:

LUBRICANTS

ISO Viscosity Grade	**220**
SAE Grade	50
AGMA Lubricant #	**5**
Viscosity range	
SSU @ 100 F.	**918-1122**
CST @ 40 C.	198-242
Celsius	10 to 52
Ambient Temp. F.	**50-125**

AMOCO	PERMAGEAR/AMOGEAR EP220
CASTROL	**ALPHA EP 220**
CHEVRON	NL GEAR COMPOUND 220
AMOCO	IND OIL 220
CHEVRON-USA	AW MACH. 220
CITGO	PACEMAKER 220
CONOCO	GEAR OIL 220
DIAMOND SHAMROCK	**INDIGO 220**
EXXON-USA	TERRESSTIC 220
FINA	PONTONIC N 220
MOBILE OIL	MOBILE GEAR 630
PENNZOIL	PENNZGEAR 220
PHILLIPS	MAGNUS 220
SHELL-USA	OMALA 220
SUN OIL	SUNVIS 999
TEXACO	MEROPA 220

List of brand names is for purpose of identifying types and is not to be construed as exclusive.

OIL CHANGE INTERVAL

Change oil at least every 1000 to 1500 hours of operation. If gear drive is operated intermittently less than 1000 hours per year in a season of two or three months, change oil at the end of that period of operation to eliminate water formed in the gear case due to condensation. More frequent oil changes are necessary for units operating at temperatures above 190 F. or 82 C. Oil temperatures of 200 F. or 93 C. are not dangerous, but will require changes of oil every 500 to 750 hours. To drain oil, remove plug in base flange below the inspection plate. To refill, replace drain plug and tighten securely. Fill through plug located in the inspection plate. If drive is equipped with sight gage, fill to level indicated. If drive is not equipped with sight gage, fill to oil level hole and replace plug.

COOLING

Our fan cooled drives are designed to eliminate the need of cooling water in most cases. Drive sizes M40 through M80 and G40 through G200 are not equipped with cooling coils except on special order. The operating temperature of these models should not exceed 190 F. Propeller Pump Gear Drives Model M80P thru M30A require no water cooling.

Drives sizes M100 thru M200 and G250 through F1000 are equipped with auxiliary cooling coils. **The water cooling coils must be hooked up** to reduce excessive heat generation. **Failure to properly use the water cooling system will void the warranty.** The amount of fresh water required at 70 F. will be 3 gal. per minute for G250 to 7 gal. per minute for F1000. Water pressure through the cooling coils should be limited to 90 psi or less. Oil temperature will rise with increase of speed above 1760 RPM or in rooms with limited air circulation causing high room temperatures.

NON-REVERSE CLUTCH - PIN TYPE

The four pins enclosed are for the non-reverse clutch. They are to be installed in the drilled holes of the clutch if non-reverse protection is desired. They may be omitted if non-reverse protection is not needed. Pins must be clean and free from oil so they will fall freely.

The non-reverse protection is not guaranteed. Settings of over 400 ft. (122 meters) deep will require special procedures, and in some cases the pin and ratchet type non-reverse will not work. Consult supplier for proper procedure for shutting down the well. The gear drive can be damaged by shock engagement caused by the pump starting to back spin before the pins engage. Check the gear drive carefully after shock engagement of the non-reverse for any damage to the gear drive.

NON-REVERSE CLUTCH - SPRAG TYPE

The sprag non-reverse is a positive type available on most models. The sprag clutch allows no more than 1 degree backspin of the pump. When the sprag non-reverse is in service, the engine should be idled back, and the Power Take Off clutch should be disengaged at a slow speed allowing the non-reverse to stop the pump.

CAUTION: Failure to install a P.T.O. (clutch) between the engine and gear drive, and failure to disengage same on pump shut down can cause damage to the Sprag Non-Reverse as well as the pin type non-reverse. Repeated engine roll back into the gear drive will cause damage to the non-reverse pins, the ratchet plate, and shear the clutch drive bolts. NON-REVERSE PROTECTION IS NOT GUARANTEED.

WARNING

All rotating shafts and couplings must be adequately guarded before operating the gear drive. The top cover supplied with the gear drive must be installed over the non reverse coupling and the top of the head shaft before operating the gear drive.

An adequate guard (supplied by others) must be installed around the drive line or coupling between the gear drive and the engine before operating the gear drive.

All gear drives are furnished with lifting devices which are adequate for safely lifting the gear drive.

1. **Disconnect the drive line or coupling from the horizontal shaft of the gear drive.**
2. **Remove the pump head shaft nut.**
3. **Remove the non reverse clutch from the head shaft.**
4. **Disconnect the gear drive from the pump discharge base.**
5. **Lift the gear drive using the lifting device provided with the gear drive.**

Caution: Lifting devices provided are not designed to lift the gear drive and pump together.

LONG TERM STORAGE - PRIOR TO INSTALLATION

If possible the drives should be stored inside out of the weather. All exposed machined surfaces, such as the input shaft, clutch coupling and bottom of drives should be coated with a rust-preventative, such as Tectyl No. 502-C.
In order to protect the internal parts such as gears, shafting and bearings the unit must be run at 300 to 500 RPM for approximately 10 minutes every 30 days. If the unit is exposed to the weather for an extended time it must be covered to exclude dirt, dust, moisture, and foreign materials. At a minimum, a heavy water proof bag should be slipped over the unit.

If the gear unit cannot be rotated under power, rotation of the input shaft by hand is suggested. Rotate the input shaft eight to twelve complete revolutions by hand every 30 days, and cover the unit with a vapor barrier.

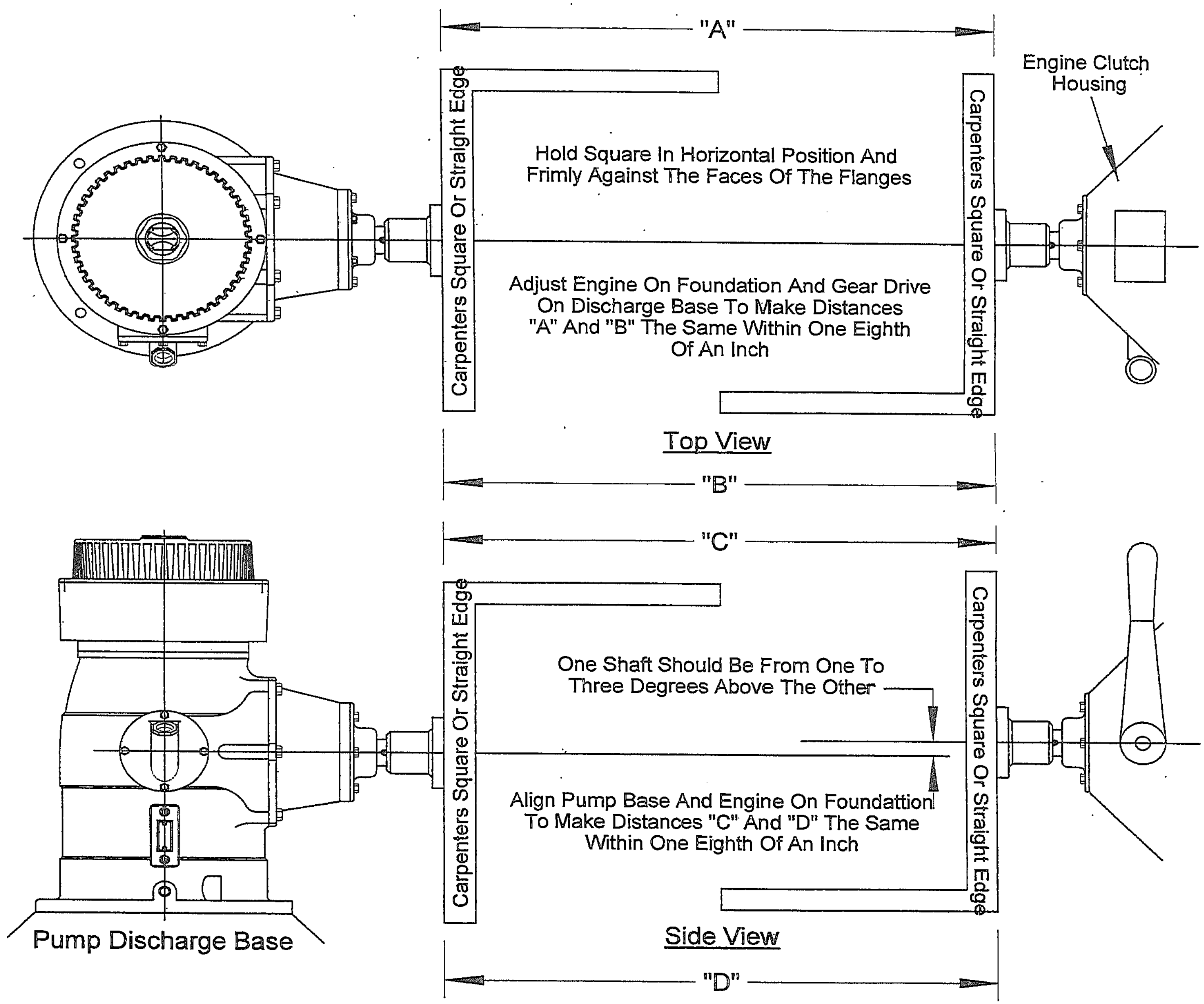
The above are recommendations and do not imply any responsibility on the part of RANDOLPH MFG. CO.

WARRANTY

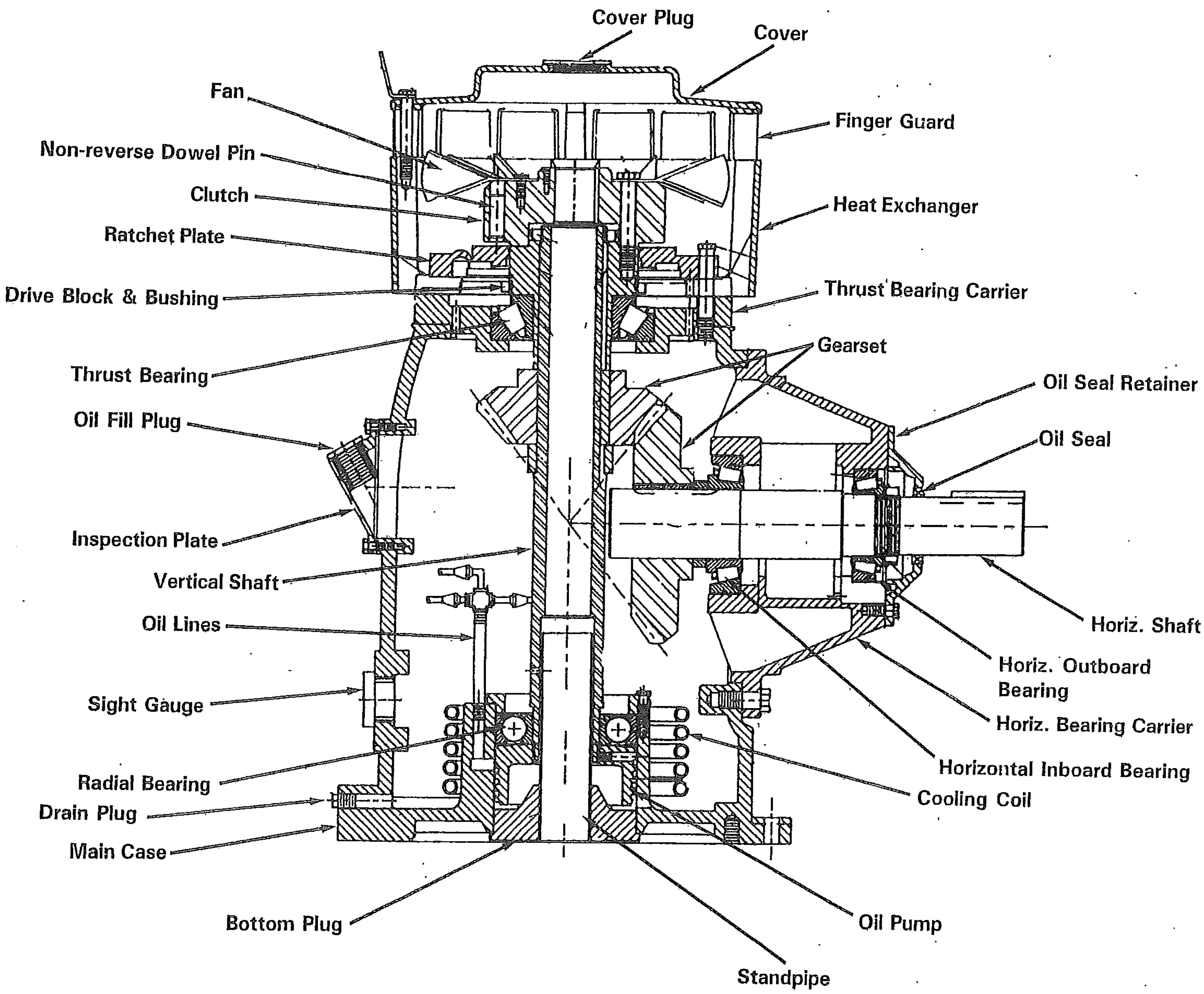
THE RANDOLPH RIGHT ANGLE GEAR DRIVE IS GUARANTEED AGAINST DEFECTS IN WORKMANSHIP AND MATERIAL FOR A PERIOD OF 24 MONTHS AFTER INSTALLATION WHEN OPERATED UNDER NORMAL SERVICE AT RATED CAPACITY. WITHIN THE ABOVE STATED PERIOD THE MANUFACTURER WILL REPLACE DEFECTIVE PARTS , RETURNED TRANSPORTATION PREPAID. THE GUARANTEE WILL NOT APPLY TO REPAIRS MADE OUTSIDE THE FACTORY WITHOUT THE CONSENT OF THE MANUFACTURER, OR TO DRIVES WHICH HAVE BEEN SUBJECT TO ABUSE, ACCIDENT, NEGLECT, IMPROPER INSTALLATION, OR TORSIONAL DAMAGE. WE MAKE NO WARRANTY OF ANY KIND WHATEVER, EXPRESSED OR IMPLIED, IN REGARD TO BEARINGS, TRADE ACCESSORIES, MACHINERY, OR OTHER ARTICLES OF MERCHANDISE NOT MANUFACTURED BY US. NO RESPONSIBILITY WILL BE ASSUMED FOR OVERLOADING THE RATED CAPACITY OF THE THRUST BEARING. (THE THRUST CAPACITY OF THE DRIVES SHOULD BE VERIFIED BY THE PUMP MANUFACTURER WITH WHOSE EQUIPMENT THE DRIVE IS USED.) THIS WARRANTY IS EXPRESSLY MADE IN LIEU OF ANY WARRANTIES OTHERWISE IMPLIED BY LAW.

RANDOLPH MFG. CO.
1110 NORTH AVE. T.
LUBBOCK, TEXAS 79415
PHONE 806-765-5583 -- FAX 806-765-7735

Always consult Drive Shaft Manufacturers literature for alignment instructions specific to your drive shaft.



Drive Shaft Alignment


Cover Plug
Cover
Fan
Finger Guard
Non-reverse Dowel Pin
Clutch
Heat Exchanger
Ratchet Plate
Drive Block & Bushing
Thrust Bearing Carrier
Gearset
Thrust Bearing
Oil Seal Retainer
Oil Fill Plug
Oil Seal
Inspection Plate
Vertical Shaft
Horiz. Shaft
Oil Lines
Horiz. Outboard Bearing
Sight Gauge
Horiz. Bearing Carrier
Horizontal Inboard Bearing
Radial Bearing
Cooling Coil
Drain Plug
Main Case
Bottom Plug
Oil Pump
Standpipe

Engineering Bulletin - Torsional Damage

Over the past 10 years, the use of diesel engines to drive right angle drives, and pumping systems has increased. Competition among engine manufacturers has led to a drastic reduction in engine weight, increased compression ratios, and turbo charging. The end result is that the transfer of power from the engine to the driven equipment is not as fluid as it was. Along with the new engine innovations has come the premature failure of the components in the pump system caused by operating at or near a torsional resonant speed (+/- 10%). Typical modes of failure are broken crank shafts, drive line shafts twisting in two, broken input shafts, and broken gear teeth. Vibratory torque much higher than the rated torque of driven components is not uncommon.

We must emphasize Paragraph 7 of our OPERATION AND MAINTENANCE INSTRUCTIONS, which reads as follows:

"With engine drive systems, it is not uncommon for one or more resonant speeds to exist between zero rpm and the operating speed of the system. Continued operation at a resonant speed will result in torsional vibrations which can be damaging to all components in the system. Unusual rumbling or clattering noise from the gear drive at a sharply defined speed is the most common indication of torsional vibrations. As the speed is increased or decreased, the noise will disappear. This noise is not indicative of a defect but results when the vibratory torque exceeds the drive torque causing the gear teeth in the gear drive to separate and clash together very rapidly. Transition through a resonant speed range to operating speed is not normally damaging, but operation of the system close to a resonant speed should be avoided. To avoid operation at a resonant speed it may be necessary to change the elastic characteristics of the rotating components in the system, or change the speed of the engine with respect to the pump. This can be accomplished by changing the gear ratio of the gear drive."

Torsional analysis by computer simulation is the most reliable alternative to actual testing. Analysis by computer simulation during system design and application is preferable. Three sources of analysis are coupling manufacturers, engine manufacturers, and independent service firms like Midland Services, Inc. When specified in advance of purchase, the engine manufacturer will perform the torsional analysis as a service to sell the engine. We recommend that a torsional analysis be done on the system before it is installed; this is a common practice in industry, government and municipal applications. *The following are furnished by Midland Services:*

1. *Lloyds Register required accurate calculation of vibratory stresses in all propulsion and auxiliary shafting, with strict limits imposed.*
2. *U.S. Navy Mil Std-167 also imposes strict limits of calculated vibratory stress in all shafting.*
3. *U.S. Corps of Engineers requires Diesel Pump Sets to be analyzed for harmful frequencies within the Pump operating speed range. Criticals within +/- 25% of such speeds are unacceptable.*
4. *For gear drives, Lloyds will not accept vibratory torques across gears exceeding 33% of full load torque, while Mil Std-167 will not accept vibratory torques across gears exceeding 25% of full load torque.*

The torsional problems are generated by the engine. Even after the torsional analysis is performed, the gear drive manufacturer and the pump manufacturer do not change or modify their products in any way to address the torsional vibrations generated by the engine.

There is serious danger of damage to the pump system, the pump system operators, and the engine if the torsional vibrations are not addressed. Steps must be taken to avoid risks and damage to the system.

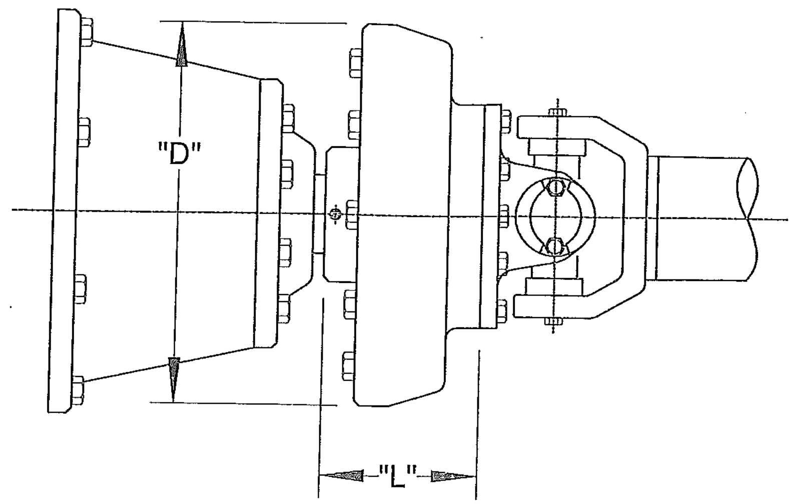
RANDOLPH GEAR, INC., is a supplier of only one component in the pumping system. We have no control over system design, or engine selection. It is the responsibility of those who select the equipment for the pumping project to assure that damage to any component does not occur due to Torsional Vibration.

RANDOLPH GEAR does not warranty products which have been subjected to torsional damage.

RANDOLPH GEAR, INC. – LUBBOCK, TEXAS
PHONE 806-765-5583, FAX 806-765-7735

(MIDLAND SERVICES, INC. – Phone 812-526-2032, Fax 812-526-8243)

TORSIONAL RUBBER COUPLING



					APPLICATION	
MODEL #	BORE	"D" DIA.	"L" LENGTH	WEIGHT	GEAR DRIVE	ONLY DRIVE SHAFT
4391.4071	1.875"	8.86"	3.47"	22 lbs	G40, G60, G80 M40, M60, M80, M100	1350, 1410
4391.4109	2.250"	10.63"	4.49"	44 lbs	G100, G125 M16AH	1480, 1550, 1610, 1710
4391.4069	2.438"	10.63"	4.49"	44 lbs	G150, G200	1480, 1550, 1610, 1710
4391.4070	2.938"	12.60"	5.31"	66 lbs	G250, G300 G350, G400	1610, 1710, 1810

This torsional coupling is designed to be installed with systems using U-joint type drive lines and standard gear drives. The bonded-rubber element is manufactured by Ringfeder and is self supporting. The coupling has been selected with the best compromise of torsional characteristics for engines operating between 1200 and 2400 rpm. In most cases the standard element will work. If all operating parameters are known, a torsional vibration analysis can be performed at an extra cost. If needed, rubber elements with different torsional characteristics can be supplied. Different selections may be determined by operation or analysis. (Reich Corp. - 201-684-9400)

In most cases, the coupling can be installed with minimal modifications to the drive line shaft length and guarding system.

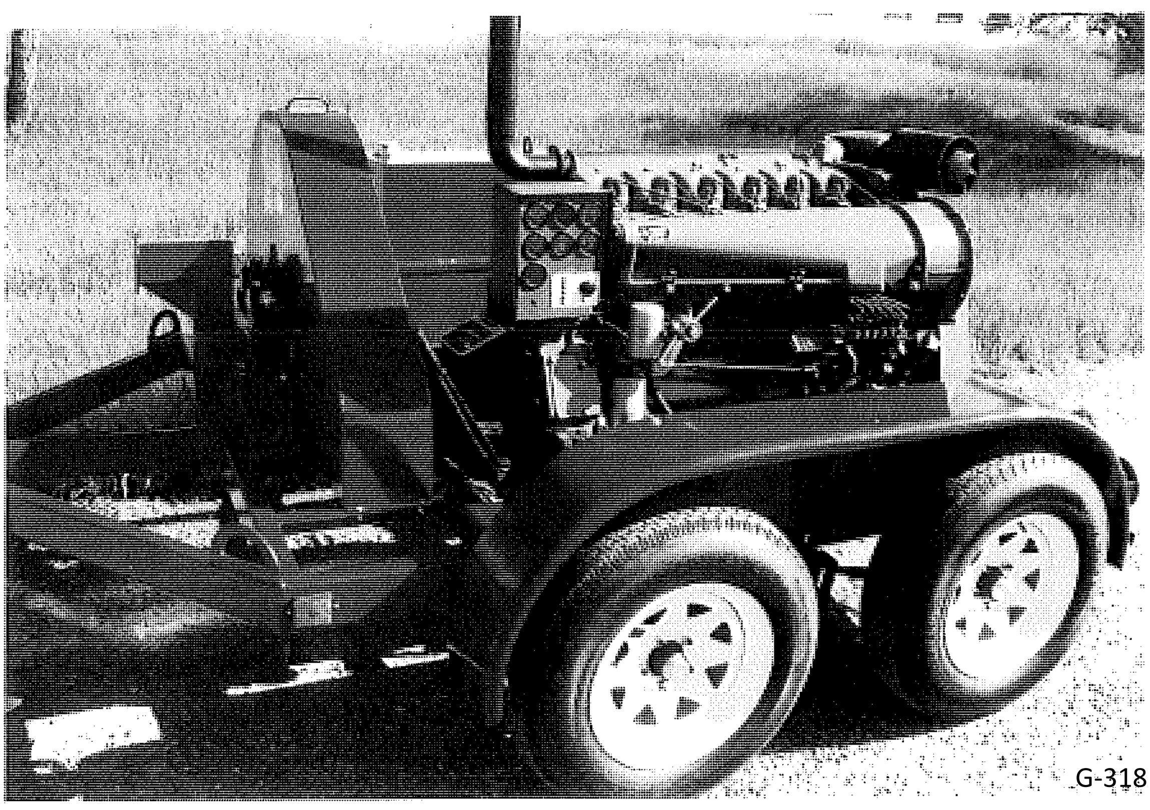
WARNING: ROTATING SHAFTS AND COUPLINGS ARE DANGEROUS AND CAN CAUSE SERIOUS INJURY. AN ADEQUATE GUARD MUST BE INSTALLED AROUND THE COUPLING AND DRIVE SHAFT BEFORE OPERATION OF THE GEAR DRIVE. THE GUARD IS NOT SUPPLIED BY RANDOLPH GEAR, INC.

RANDOLPH GEAR, INC.-LUBBOCK, TEXAS 1-888-726-4327, 806-765-5583, FAX 806-765-7735

(Contact Factory for Pricing) June, 2011

OPERATION & MAINTENANCE MANUAL

DIESEL PTO POWER UNIT



G-318

SRS CRISAFULLI
P.O. Box 1051
Glendive, MT 59330
1-800-442-7867

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SRS CRISAFULLI
P.O. Box 1051
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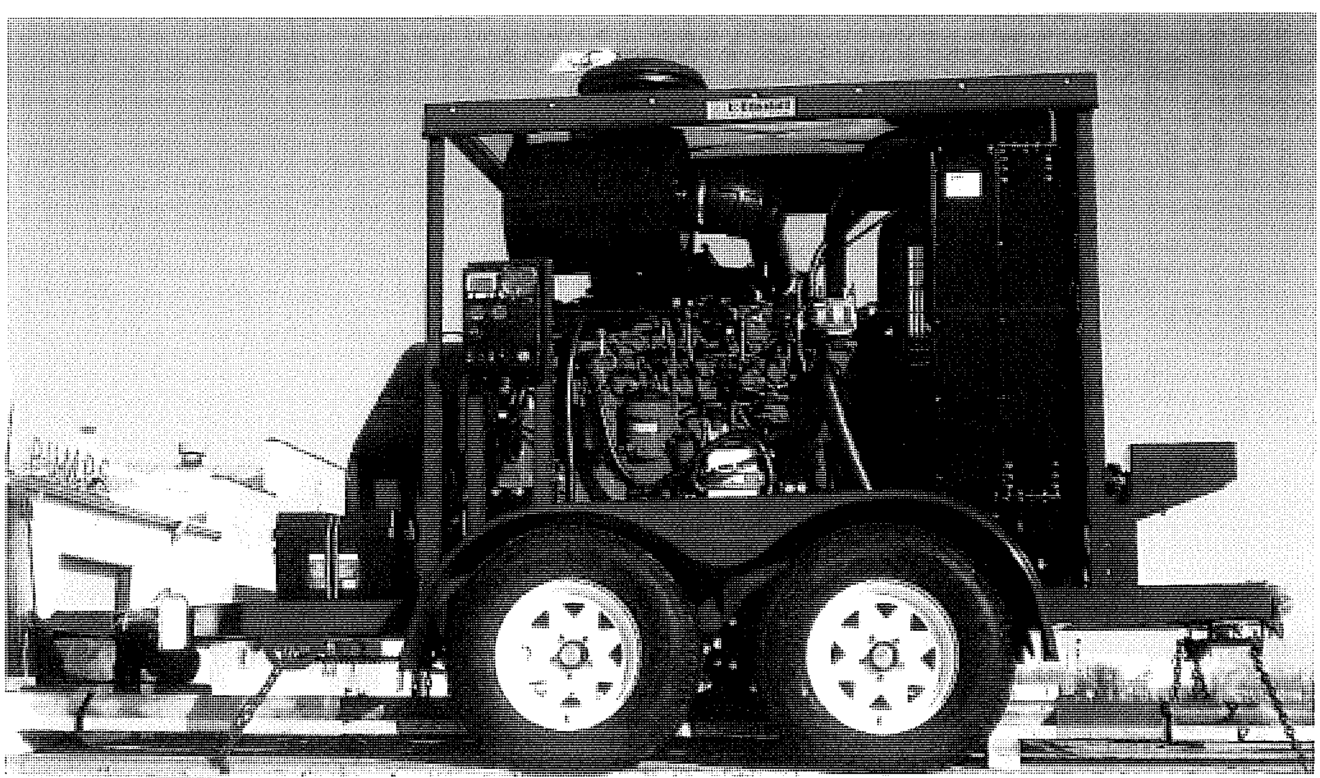
1-800-442-7867

SECTION 1 - INTRODUCTION & WARRANTY



SRS CRISAFULLI INC.
P.O. Box 1051
Glendive, Montana 59330
1-800-442-7867

INTRODUCTION

SLUDGE REMOVAL SYSTEM

In our continuing effort to provide excellence in low maintenance, easy to operate Sludge Removal Systems, we have assembled this Operations and Maintenance Manual. Contained in this manual is the information necessary to properly install, operate and maintain the Crisafulli Sludge Removal System.

SRS Crisafulli Inc., Sludge Removal Systems are effectively handling sludge for a variety of operations, which vary in size and handling requirements. Because of different requirements, the operator of each system must develop additional operational and safety guidelines, which will cover the specific site hazards of the individual operations.

We are dedicated to providing excellence in Sludge Removal Systems and after sale service. If you should have any questions or comments concerning your Sludge Removal System, please call us at 1-800-442-7867. We would appreciate hearing from you.

Sincerely,

The Employees of
SRS CRISAFULLI, INC.

SRS Crisafulli
Pumps - Dredges - Power Units – Custom or Standard

Manufacturers of reliable Crisafulli products
supported by superior service

SRS Crisafulli, Inc.
WARRANTY

The Company warrants all parts and assemblies to be free from defects in material and workmanship for a period of one (1) year after the date of acceptance unless otherwise stated on a SRS Crisafulli, Inc. ("SRSC" or the "Company") sales order document. This warranty does not cover normal wear, failure caused by corrosive applications, failure caused by abrasive materials, physical abuse or use for other than designed purposes. All parts and assemblies reported in writing to SRSC as defective in these respects, shall be repaired or replaced (FOB shipping point) without charge for routine shipping (priority shipping will be made optionally available at the customer's expense), providing that inspection by SRSC shows such defects exist. In all cases involving warranty returns, the transportation charges must be prepaid. In no event shall SRSC assume any liability for consequential cost or damage of any kind arising in connection with the use, inability to use, misuse or misapplication of SRSC products. BUYER IS SOLELY RESPONSIBLE FOR DETERMINING THE SUITABILITY OF GOODS SOLD HEREUNDER FOR USE BY BUYER.

T o validate this warranty for SRSC equipment including SRSC dredging systems the customer must employ the Company to supervise the installation and to train the customer's staff in the operation of the Company's equipment. Further, SRSC's obligations pursuant to this warranty shall exist only when the customer has paid in full any moneys due SRSC, as set forth in the initial Sales Order and any modifications thereto, for the equipment subject to the warranty.

The following equipment is covered by the original manufacturer's warranty and is thus not covered by the Company's warranty: Electronic components, electric motors, bearings, and other vendor parts. SRSC is not responsible for expenses incurred due to failure of vendor parts including, but not limited to: freight, labor, travel expenses, and service fees, etc.

SRS Crisafulli, Inc. reserves the right to make all final decisions concerning part and assembly replacement, repair and all directly related costs. If a customer fails to comply with the stipulated conditions of operation, maintenance, and/or application of products purchased from the Company, or fails to permit SRSC to inspect defects before repairing, or alters the product in any way, the Company's warranty is void and the responsibility of SRSC shall terminate.

SRS Crisafulli, Inc. shall not be held responsible for our products after delivery to a transportation company, however, if there are shortages of equipment or damage, we will, when requested, cooperate fully in obtaining an adjustment.

No person, agent, or representative is authorized to give any warranty or make any representation contrary to the foregoing warranty by SRSC.

Due to the widely varying conditions under which SRSC products are used, the Company offers no warranty, expressed or implied, as to length of service life of equipment or parts.

Warranty Manager/Director of Mfg.
SRS Crisafulli, Inc.

October 5, 2012

Headquarters & Operations: PO Box 1051 • 1610 Crisafulli Drive • Glendive MT 59330-1051 • USA
Phone: 406-365-3393 • Toll-free 800-442-7867 • Fax: 406-365-8088
Web Sites: www.crisafulli.com www.dredge.net e-mail: srsc@crisafulli.com
Corporate office: PO Box 617 • Old Greenwich CT 06870 • USA • Phone: 203-637-5494

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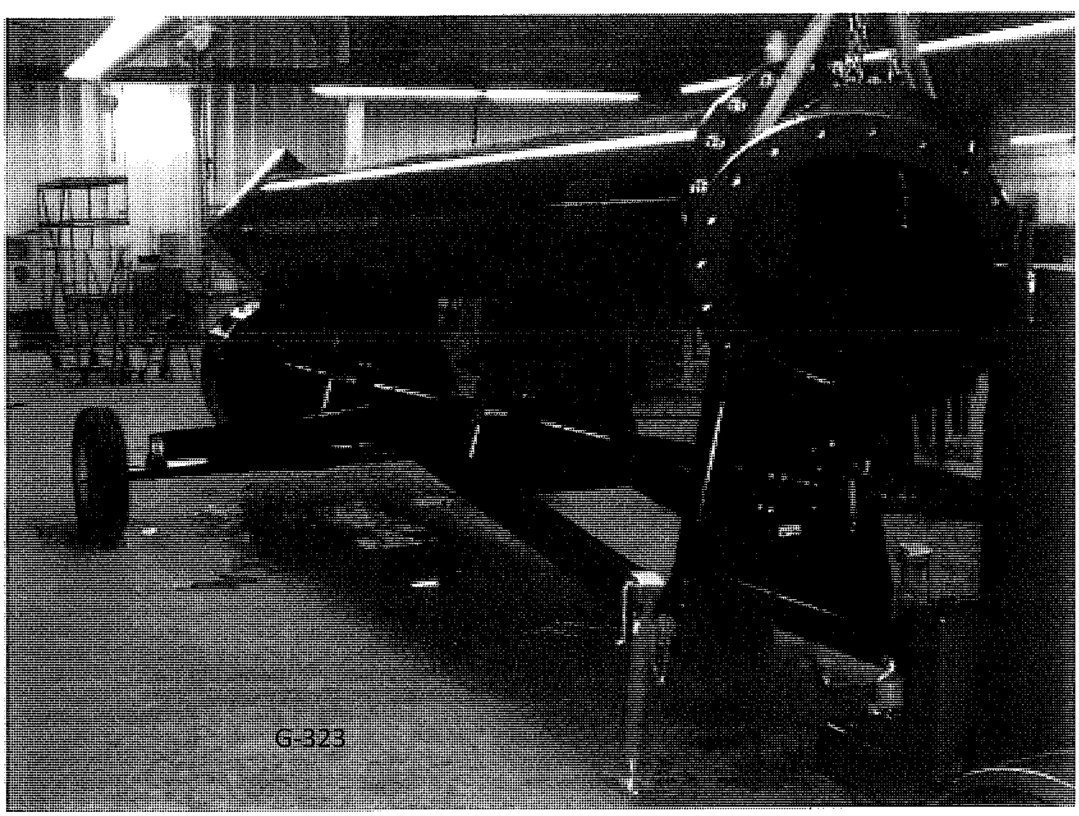
SECTION 2 –GENERAL SAFETY GUIDELINES



SRS CRISAFULLI, INC.
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GENERAL SAFETY GUIDELINES

ENGINE POWER UNIT SYSTEM

The following safety guidelines are for the safe operation of the Crisafulli diesel PTO power unit. Remember, no number of safety guidelines nor any amount of safety equipment can make operation of any piece of equipment totally safe unless the operator follows the guidelines and uses the equipment prudently. An alert, safety-conscious operator is the key to the safe operation of any piece of equipment.

SAFETY ALERT NOTICES

The following safety alert signal words are used throughout this manual to call attention to and identify different levels of hazards and special instruction.

These safety alert signal words, **Warning and Caution,** call attention to the safety statements.

Warning - Statements identify procedures or practices which must be followed to avoid serious personal injury or loss of life.

Caution - Statements identify procedures or practices which must be followed to avoid minor personal injury or damage to equipment.

Important - Statements identify special instructions necessary for the most efficient operation of this equipment.

OPERATIONS

Important: **Insure that all safety and operation signs are transcribed into the language of the operator.**

1. Review all operator's manual before operating the power unit.

2. Only responsible persons, authorized to do so, should operate the power unit.

3. Be sure all safety shields and guards are in place and in good condition before start up.

4. Check to see that all personnel and equipment are clear of the power unit before start up.

5. Clean or replace all safety decals if they can't be read.

6. Understand the power unit's limitations. Keep it under control at all times.

7. Wear the proper safety equipment. Avoid loose clothing. Obtain additional safety information and equipment when your safety may be in doubt. Such equipment may include a hard-hat, safety shoes, ear protectors, reflective clothing, safety goggles, fresh air supply equipment, self-contained breathing apparatus, sanitary overalls and/or rubber gloves as required.

8. Have a first-aid kit handy. Use proper antiseptics immediately on cuts and scratches to avoid infection.

9. Have a ABC coded fire extinguisher located nearby.

CLEANLINESS AND SERVICE

1. Keep the power unit clean. The process of cleaning will reveal loose bolts, hydraulic lines and fittings, and other trouble spots.

2. Always keep the power unit free from grease, oil, loose rags and loose tools.

3. Shut the power unit down and place all control levers and switches in neutral or off position before cleaning or servicing the power unit, unless the work to be done requires otherwise.

4. Before starting or continuing operation, correct or report any mechanical deficiency that may cause further damage.

5. Block or crib the power unit and other machine components that are suspended or held aloft by slings, hoists, jacks and hydraulic cylinders before working under or between them.

6. Wash your hands regularly and before all meals following any operation.

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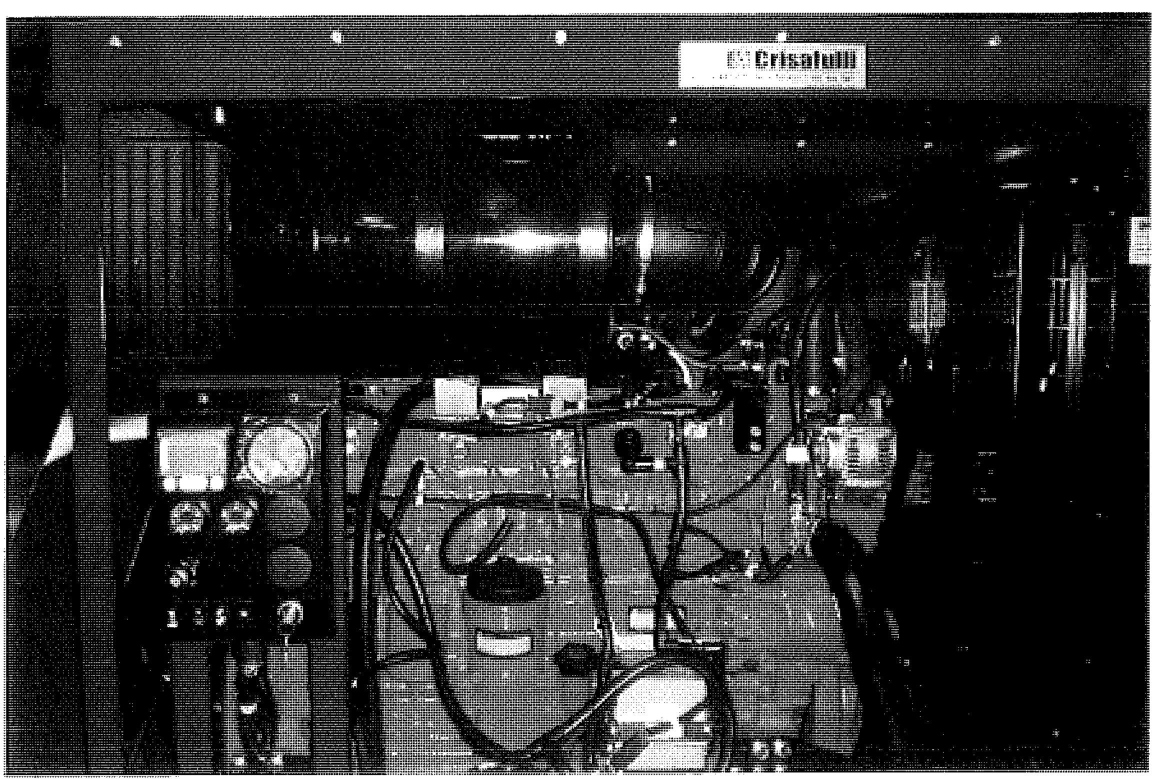
SECTION 3 –START UP AND TROUBLESHOOTING



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Glendive, MT 59330
1-800-442-7867

START UP AND OPERATING INSTRUCTIONS

DIESEL / PTO POWER UNITS

POWER UNIT SET UP

The following steps are to be followed for initial hook-up to power unit:

Warning - Trailer must be chocked on level surface to prevent accidental rolling.

1. Back towing vehicle directly in front of power unit so that the hitch fits onto the lunette eye.

2. Move to pumping location.

3. PTO power unit should be pulled forward until aligned with the pump drive shaft. Trailer must be between 12 and 30 inches from the bollards in order to properly connect PTO shaft. Optimal positioning is approximately 20 inches.

4. If towing vehicle will be remaining with the power unit. Turn vehicle engine OFF and set emergency brake. Block Trailer tires front and back.

5. If towing vehicle will be removed from site. Set trailer tongue jack disconnect pintle hitch block trailer tires front and back. Pull towing vehicle forward.

6. Using installed stabilizing jacks ensure that trailer is level.
   Warning- lifting the trailer wheels off the ground during leveling may Cause the trailer unit to become unstable. Do not lift trailer wheels off the ground during leveling .

7. Ensure PTO clutch is disengaged and install PTO Drive shaft. Tighten all set screws.

8. Check that engine is set to IDLE. Start engine and allow to warm up for 3-5 minutes.

9. Engage PTO clutch by pulling firmly on the handle.

10. Turn Engine from IDLE to RUN.

SHUT DOWN

1. Slow engine RPM to idle.

2. Disengage clutch.

   Note: If engine has been operating at full RPM for a continued period of time, allow engine to idle for 3 - 5 minutes before shut down.

3. Turn off ignition.

4. Disconnect PTO drive shaft and store. Close and lock the engine control panel

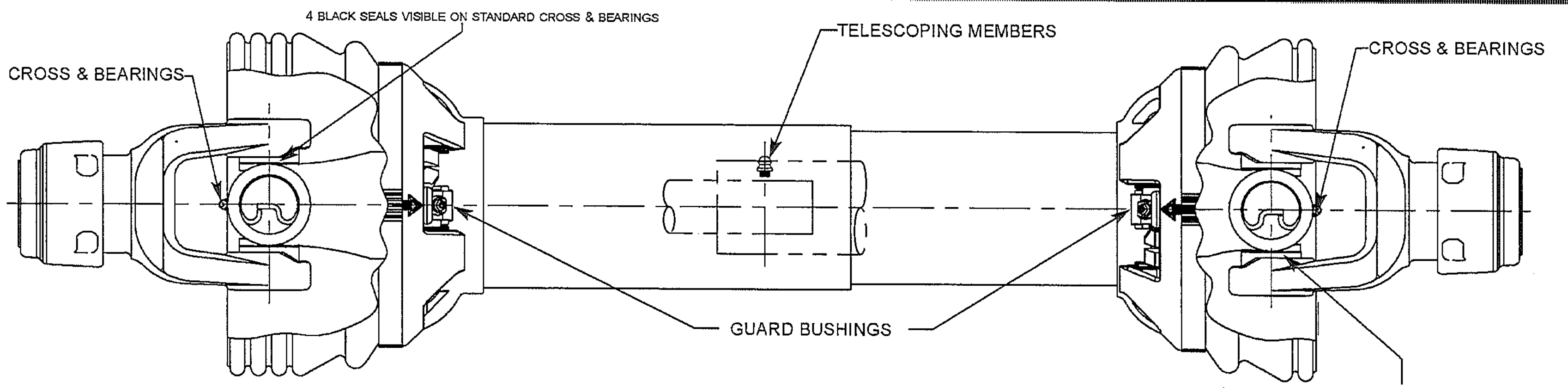
5. When connecting trailer to vehicle ensure stabilizing jacks are raised tongue jack may be used to assist in positioning trailer for towing.

SRS CRISAFULLI, INC.
OPERATION SAFETY GUIDELINES
DIESEL-PTO POWER UNIT
Page --

STORAGE

SRS Crisafulli Power Units are designed to withstand a variety of environmental conditions. However, to increase the life of regular maintenance items (e.g. filters, tires, hoses) it is encouraged to store the power unit in a protected enclosure. The power unit may be stored with fuel in the tank. If the power unit is stored in a structure with fuel in the tank the structure must comply with NFPA 30. It is encouraged to drain the water priming tank prior to storage.

Weasler® RECOMMENDED CUSTOMER LUBRICATION PROCEDURE FOR TELESCOPING DRIVELINES



LUBRICATE ALL FITTINGS WITH A GOOD QUALITY LITHIUM SOAP COMPATIBLE E.P. GREASE MEETING THE N.L.G.I. #2 SPECIFICATIONS AND CONTAINING NO MORE THAN 1% MOLYBDENUM DISULFIDE.

AN E.P. GREASE MEETING THE N.L.G.I. #2 SPECIFICATIONS AND CONTAINING 3% MOLYBDENUM DISULFIDE MAY BE SUBSTITUTED IN THE TELESCOPING MEMBERS ONLY.

LOCATION	STANDARD INTERVAL	EXTENDED LUBE INTERVAL	LEVER ACTION PUMPS
CROSS & BEARINGS	*8 HRS.	50 HRS	2-3
TELESCOPING MEMBERS	8 HRS.	50 HRS.	8-10
CE & NON-ROTATING GUARD BUSHINGS (1000 RPM MAX.)	8 HRS.	50 HRS.	2

ROTATING GUARD BUSHINGS SHOULD BE LUBRICATED UPON REPLACEMENT

*CONSTANT ANGLE APPLICATIONS MAY REQUIRE A LUBE INTERVAL OF 4 HOURS

CAUTION!! REPLACEMENT PARTS ARE NOT LUBRICATED

REPLACEMENT PARTS MUST BE LUBRICATED AT TIME OF ASSEMBLY AND DURING USE PER THE LUBE RECOMMENDATIONS

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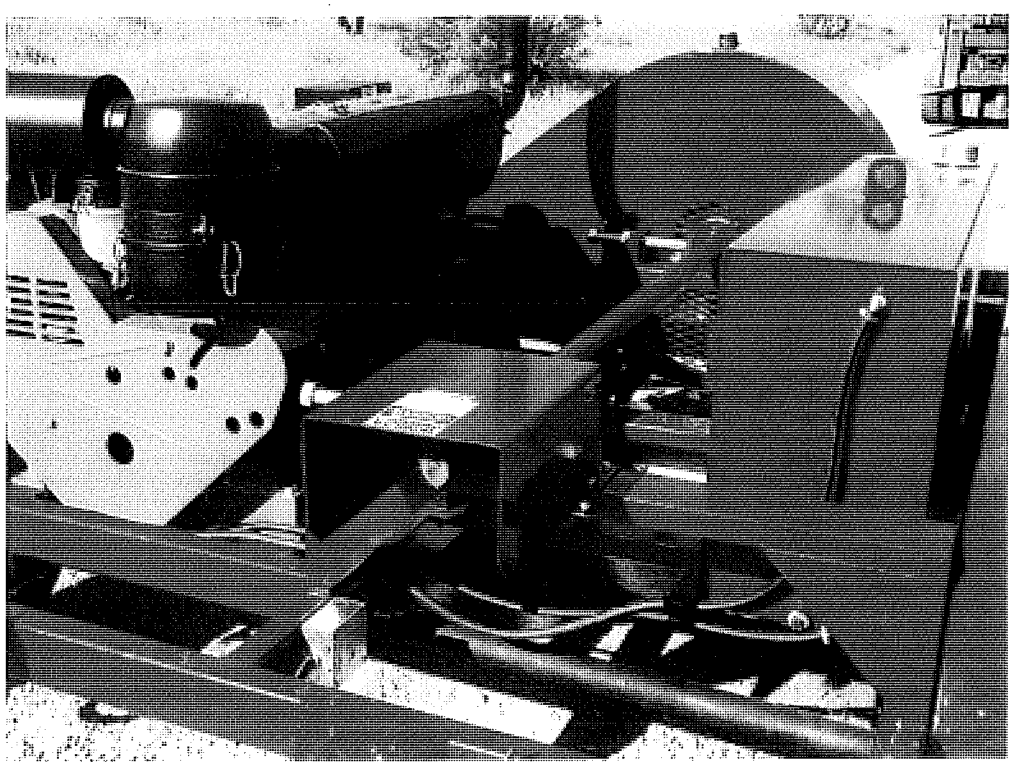
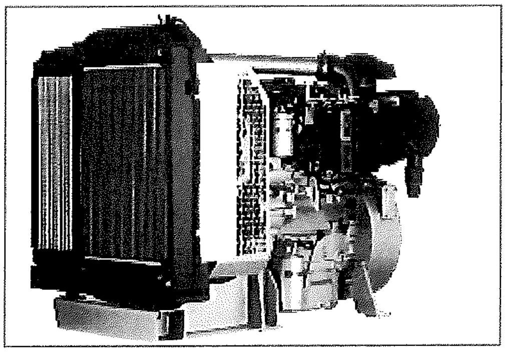
SECTION 5 –DIESEL ENGINE





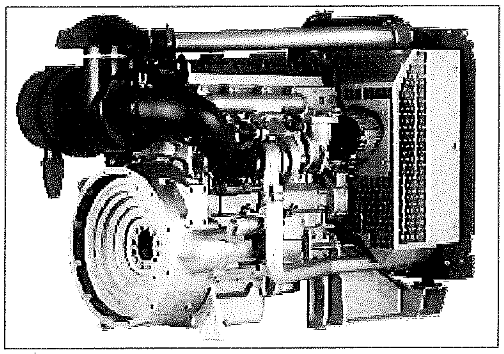
Perkins®

1100 Series

1104D-E44TA

Diesel Engine - Industrial Open Power Unit

100.2 kW/134.4 bhp



The 1104D-E44TA IOPU is a new addition to the 1100 Series range of IOPU engines. The 1100 Series electronic diesel engines are assembled on a new high technology production line, which makes frequent computerised checks during the production process ensuring high build quality/excellence is maintained.

The 1104D IOPU range of engines have a complete fuel system, air cleaner and radiator fitted as standard along with a choice of mechanical or electronic control system making these the ultimate power solution.

The 1100D range with their wide choice of build options, plus all the features and benefits, present a secure future for all our customers at Tier 3/Stage IIIA emissions legislation, and is the platform on which the long-term solution to Tier 4/Stage IIIB legislation will be built.

Powered by your Needs

- The 1104D-E44TA IOPU offers a choice of build configurations to match the power needs of customers for a diverse range of applications.

State of the Art Design

- The 1104D-E44TA IOPU incorporates the latest common-rail fuel system technologies with a closely optimised air-management system which is overseen by the latest generation of electronic engine control. This allows the 1104D range to deliver high power density and excellent fuel economy with low exhaust emissions and the minimum of heat rejection.

Reduced Noise

- Noise minimised at source - engine sound levels have been reduced by 2 dBA.
- Reduction in noise suppression costs.

Component Commonality

- Shared front and rear ends and 'repeated' components - pistons, con rods and valve gear.
- Rationalised inventory, streamlined training and consistent serviceability.

Lower Installation Costs

- Virtually identical hook-up points and envelope size as the 1104C-44TA.
- Customer enjoys a seamless transition during the emissions changeover process.

Lower Operating Costs

- The 1104D maintains Tier 2/Stage II fuel economy, allowing customers to keep existing fuel tanks.
- Service intervals are 500 hours standard.
- Perkins comprehensive warranty cover for two years with three years on major engine components.
- Low usage warranty package is also available.

Product Support

- Perkins actively pursues product support excellence by ensuring our distribution network invest in their territory - strengthening relationships and providing more value to you, our customer
- Through an experienced global network of distributors and dealers, fully trained engine experts deliver total service support around the clock, 365 days a year. They have a comprehensive suite of web based tools at their fingertips covering technical information, parts identification and ordering systems, all dedicated to maximising the productivity of your engine
- Throughout the entire life of a Perkins engine, we provide access to genuine OE specification parts and service. We give 100% reassurance that you receive the very best in terms of quality for lowest possible cost .. wherever your Perkins powered machine is operating in the world

Engines certified to Tier 3/Stage IIIA emissions legislation.

Engine Performance	Net Intermittent	Engine Speed	Pump Sets	Engine Speed
Max power (kW)	100.2	2200	85.1	2000
Max power (bhp)	134.4	2200	114.2	2000
Max torque (Nm)	556.0	1400	472.6	1400
Max torque (lbf ft)	410.1	1400	348.6	1400

Power for a run-in engine after 50 hours.
Net Intermittent = Intermittent service where maximum power and/or ave. cycle time at full load not to exceed 50%).
Rating standard ISO/TR 14396.

All information in this document is substantially correct at time of printing and may be altered subsequently

General Data

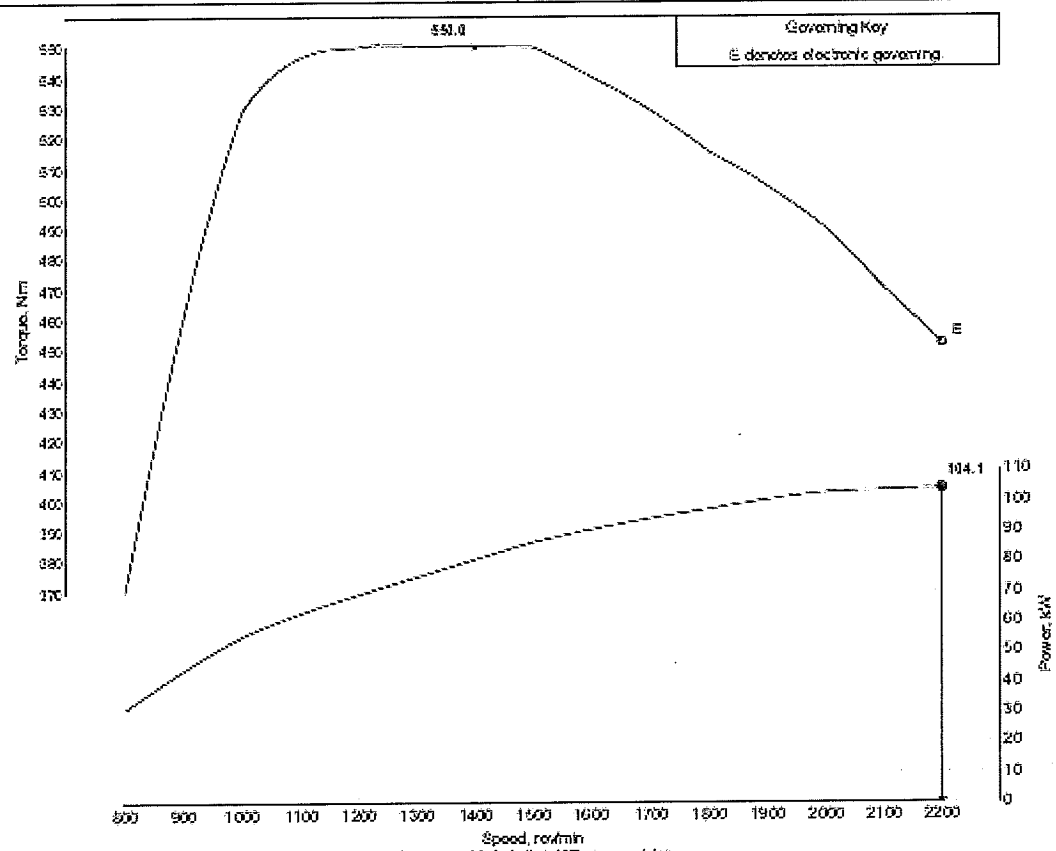
Number of cylinders	4 in-line
Bore and stroke	105 mm x 127 mm
Displacement	4.4 litres
Aspiration	Turbocharged air to air aftercooled
Cycle	4 stroke
Combustion system	Direct injection
Compression ratio	16:2
Direction of rotation	Anti-clockwise, viewed on flywheel
Cooling system	Liquid
Total lubrication system capacity	8.4 litres
Total coolant capacity	17 litres
Dimensions	Length 1358 mm Width 749 mm Height 963 mm
Dry weight (ElectropaK)	520 kg

Final weight and dimensions will depend on completed specification

1104D-E44TA - T2894, with balancer

Perkins	Engine Model: 1104D-E44TA	Curve: T 2894 Sheet 1
Perkins Engines Company Limited ©2006 Commercial In Confidence proprietary information of Perkins Engines Company Ltd.		Issue: 2 Date: 13-Feb-2006
		Development Target - May be Subject to Change

Rating Standards:	ISO 14396: 2002	Fuel Types:	Europe Off Highway	USA FED Off Highway
Production Tolerance On Power Output:	+3%, -3%	Fuel Specification:	CEC RF-06-99	EPA 2D 89.330 1999
Total Barometric Pressure (kPa):	100	Density (kg/l @ 15°C):	0.833 - 0.837	0.845 - 0.85
Vapour Pressure (kPa):	1	Viscosity (mm²/s @ 40°C):	2.5 - 3.5	2.0 - 3.2
Air Inlet Temperature (°C):	25	Sulphur Content (% mass):	0.03 max	0.03 - 0.4
		Cetane No:	52 - 54	40 - 48



Performance with fuel oil at 40C at pump inlet

Notes:
1. For duty cycle refer to Perkins Engines (Peterborough) Limited statement on Product Duty Usage Limitations.

Exhaust Quality Standard | **Certification Refs (Rated Speeds)**

Smoke:
77/537/EEC- Includes FAS.

Emissions:
US EPA 40 CFR Part 89 Tier 3.
EU NRMM 97/68/EC Stage 3A.

Power Standard | **Certification Refs (Rated Speeds)**

Auxiliaries fitted to engine:
Balancer - fitted.
Alternator - off load.
Fan - not fitted.

Rating Curves Data Sheet

Curve T 2894 Sheet 2

Note 1: Unless otherwise specified, all stated data is for maximum rated speed and 100% load.

General Data

Engine Model:	1104D-E44TA
Number Of Cylinders:	4
Bore (mm):	105.0
Stroke (mm):	127.0
Configuration:	Vertical In Line
Displacement (litres):	4.4
Aspiration:	Turbocharged
Compression Ratio:	16.2 : 1
Combustion Bowl:	

Fuel System

Fuel Pump Model:	CAT FUEL SYSTEMS HEUI SF
Injection Timing (°BTDC) - Static:	T.D.C. No.1
- Dynamic:	
HP Rail Pressure (MPa):	
Fuel Pump Pressure (In) (kPa):	
Fuel Filter Max Particle Size (micron):	2
Fuel Return System Type:	Return to Tank

Lubrication System

Lubricating Oil Specification:	See Engine Specification Manual

Exhaust System

Exhaust Flow (kg/min):	10.06 (21.6 m³/min)
Exhaust Temperature (°C):	583 (ATC)

Cold Start Capability

Unaided Start Limit (°C):	-10
Aided Start Limit (°C):	-40
Start Aid (Optional):	Glowplugs fitted as standard
Minimum Cranking Speed (rev/min) - unaided:	Not applicable
- aided:	

Cooling System

Heat Rejected @ Rated Speed (kW):	61.0
Heat Rejected @ Peak Torque (kW):	
Coolant Flow (litres/min):	
Thermostat - Start To Open (°C):	
Thermostat - Fully Open (°C):	
Recommended Cap Pressure (kPa):	
Max Top Tank Pressure (kPa):	

Air System

Engine Air Flow (kg/min):	9.65 (8.29 m³/min)
Induction Manifold Pressure (kPa):	135.4

Charge Air Cooler System

Charge Air Cooling System:	Air-to-Air
Max Total Pressure Drop inc Pipes (kPa):	10.0
Charge Air Cooler Heat Rejection (kW):	14.2
Manifold Charge Air Temperature (°C):	55.0

Turbocharger

Turbocharger Type:	Borg Warner B1 with wastegate
Maximum Altitude (m):	3000

Performance Data

Friction Power @ Rated Speed (kW):	
Friction Power @ Peak Torque (kW):	
Torque @ 800 rev/min (Nm):	370

For further performance data see table below.

Performance Data — Rating Standard: ISO 14396:2002

Speed (rev/min)	Torque (Nm)	Power (kW)	Max Exhaust Back Pressure (kPa)	Max Inlet Restriction (kPa)	Governing Categories (key on sht 1)
2200	452	104.1	15.0	5.0	E
2100	470	103.4			
2000	490	102.6			
1800	515	97.1			
1600	540	90.5			
1500	550	86.4			
1400	550	80.6			
1300	550	74.9			
1200	550	69.1			
1000	529	55.4			
800	370	31.0			

Further Notes:

Perkins

Diesel Engine

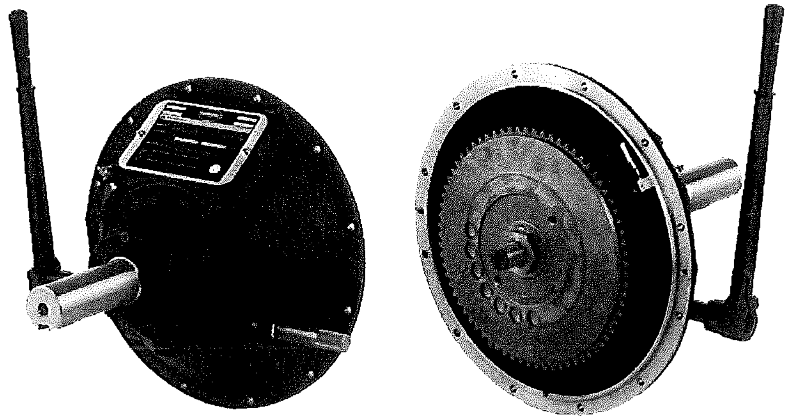
O&M

For all questions on your Perkins Engine refer to the attached Operation Manual and Assembly instructions.

Model SP111P and SP211P Series

STANDARD SP CLUTCH

SP111P • SP211P



QUALITY IS STANDARD

- AVAILABLE IN SIZES 11.5" THRU 21.0"
- TAPERED ROLLER MAIN BEARINGS
- OPTIONAL SINTERED IRON PLATES
- OPTIONAL BALL BEARING THROW OUT
- BUILT IN HEX NUT
- CREATES SUITABLE APPLICATION TORQUE CAPACITY
- MORE SUITABLE FOR SIDE LOAD APPLICATIONS
- CREATES 25% HIGHER TORQUE CAPACITY
- ALLOWS FOR MORE FREQUENT ENGAGEMENTS
- EASES ADJUSTMENT VERIFICATION

SPECIFICATIONS - SP111P & SP211P

Model Number	SAE HSG.	Max. Input Torque Nm (lb-ft)		Maximum Safe Speed				Weight kg (lbs)
				Solid Plates		Split Plates		
		Organic	Sintered	Cast Drive Ring	Nodular Drive Ring	Cast Drive Ring	Nodular Drive Ring	
SP111P1, SP111P2, SP111P3	1, 2, 3	617 (455)	746 (550)	2850	3600	2200	3200	58 (129)
SP211P1, SP211P2, SP211P3		1235 (910)	1493 (1100)		3000		3000	79 (175)

LOAD CLASSIFICATIONS BASED UPON AGMA LOAD CHARACTERISTICS

PRIME MOVER	DURATION OF SERVICE	DRIVEN MACHINE LOAD CLASSIFICATIONS		
		UNIFORM	MODERATE SHOCK	HEAVY SHOCK
Electric motor	Up to 3 hours per day	1.00	1.25	1.50
	3-10 hours per day	1.00	1.25	1.75
	Over 10 hours per day	1.25	1.50	2.00
Multi-cylinder internal combustion engine	Up to 3 hours per day	1.00	1.25	1.75
	3-10 hours per day	1.25	1.50	2.00
	Over 10 hours per day	1.50	1.75	2.25
Multi-cylinder internal combustion engine with high torque rise	Up to 3 hours per day	1.50	1.75	2.25
	3-10 hours per day	1.75	2.00	2.50
	Over 10 hours per day	2.00	2.25	2.75
Single cylinder internal combustion engine	Up to 3 hours per day	1.25	1.50	2.00
	3-10 hours per day	1.50	1.75	2.25
	Over 10 hours per day	1.75	2.00	2.50

All clutch engagements to be with prime mover below 1000 RPM. High inertia loads may require use of larger clutch. Contact Twin Disc application engineering department for assistance.

TO CALCULATE APPLICATION TORQUE:

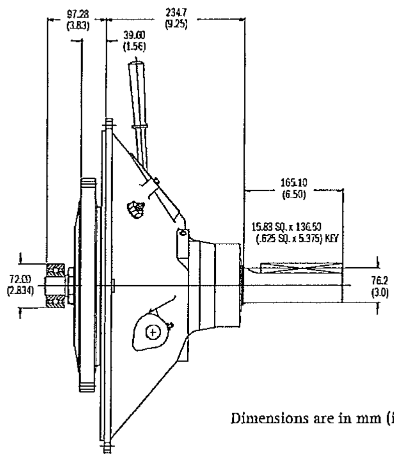
$$\frac{5252 \times HP}{\text{Engine RPM}} = \text{Torque}$$

Torque x Load Factor = Application Torque

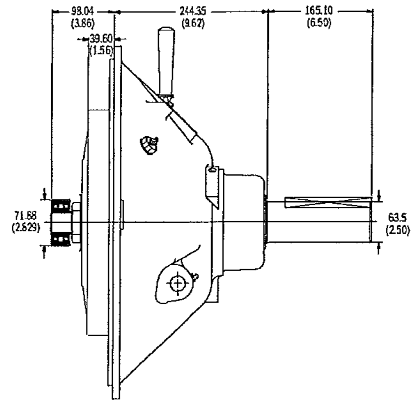
Use load factor from chart at left

Specifications subject to change without prior notice in the interest of continual product improvement. Contact your local Twin Disc representative for engineering specifications.

SP111P **SP211P**

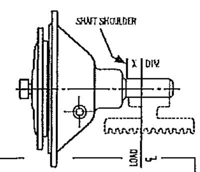


Dimensions are in mm (inches)



For nearly a century, we've been putting horsepower to work by designing, engineering and manufacturing rugged-duty industrial products. Our products and our reputation are bolted to the most renowned engine manufacturers and equipment OEMs in the world. Our mission is to make your machines and vehicles more productive, more durable, more operator-friendly, more cost-effective. From design and installation consultation through after-sale support, Twin Disc and its distributors are committed to your business. No one knows more about managing horsepower in more ways than Twin Disc.

TRANSMISSIONS • CLUTCHES • PTOS
PUMP DRIVES • TORQUE CONVERTERS
GEARBOXES • HYDRAULIC PTO PRODUCTS



SP111P & SP211P - ALLOWABLE SIDE LOAD, KG (LBS)

<table>
<tr><th rowspan="2">PTO MODEL</th><th rowspan="2">RPM</th><th colspan="6">X DISTANCE, mm (in) – see sketch</th></tr>
<tr><th>25.4 (1.0)</th><th>50.8 (2.0)</th><th>76.2 (3.0)</th><th>101.6 (4.0)</th><th>127.0 (5.0)</th><th>152.4 (6.0)</th></tr>
<tr><td rowspan="5">SP111P1
SP111P2
SP111P3</td><td>1000</td><td>1383 (3050)</td><td rowspan="2">1156 (2550)</td><td rowspan="4">907 (2000)</td><td rowspan="5">748 (1650)</td><td rowspan="5">635 (1400)</td><td rowspan="5">N/A</td></tr>
<tr><td>1200</td><td>1315 (2900)</td></tr>
<tr><td>1800</td><td>1161 (2560)</td><td>1075 (2370)</td></tr>
<tr><td>2400</td><td>1061 (2340)</td><td>984 (2170)</td></tr>
<tr><td>2800</td><td>1014 (2235)</td><td>938 (2070)</td><td>873 (1925)</td></tr>
<tr><td rowspan="5">SP211P1
SP211P2
SP211P3</td><td>1000</td><td>2059 (4540)</td><td rowspan="3">1540 (3395)</td><td rowspan="5">1229 (2710)</td><td rowspan="5">1159 (2555)</td><td rowspan="5">875 (1930)</td><td rowspan="5">766 (1690)</td></tr>
<tr><td>1200</td><td>1982 (4370)</td></tr>
<tr><td>1800</td><td>1769 (3900)</td></tr>
<tr><td>2400</td><td>1610 (3550)</td><td>1510 (3330)</td></tr>
<tr><td>2800</td><td>1538 (3390)</td><td>1436 (3165)</td></tr>
</table>

The following general formula should be used for determining the actual applied load: $L = \frac{126{,}000 \times HP}{N \times D} \times F \times LF$

WHERE L = Actual Applied Load (lbs)
N = Shaft Speed (RPM)
D = Pitch Diameter (in) of Sheave, etc.
F = Load Factor
1.0 for Chain or Gear Drive, 1.5 for Timing Belts, 2.5 for All V Belts, 3.5 for Flat Belts
LF = 2.1 for Reciprocating Compressors and other Severe Shock Drives and 1.8 for Large Inertia Type Drives (i.e. crushers, chippers, planers, etc.)

Compound Drives and Power Engaged Power Take-Off applications must have written factory review.

Twin Disc, Incorporated reminds users of these products that their safe operation depends on use in compliance with engineering information provided in our catalog. Users are also reminded that safe operation depends on proper installation, operation and routine maintenance and inspection under prevailing conditions. It is the responsibility of users (and not Twin Disc, Incorporated) to provide and install guards or safety devices which may be required by recognized safety standards or by the Occupational Safety and Health Act of 1970 and its subsequent provisions.

United States of America • Australia • Belgium • France • Italy • Singapore • Switzerland

Twin Disc, Incorporated
Racine, Wisconsin 53403 USA
Phone +1-262-638-4000
Fax +1-262-638-4482
www.twindisc.com

TD-Bulletin-SP111/211Series

Printed in the USA - 04/2007

IMPORTANT!

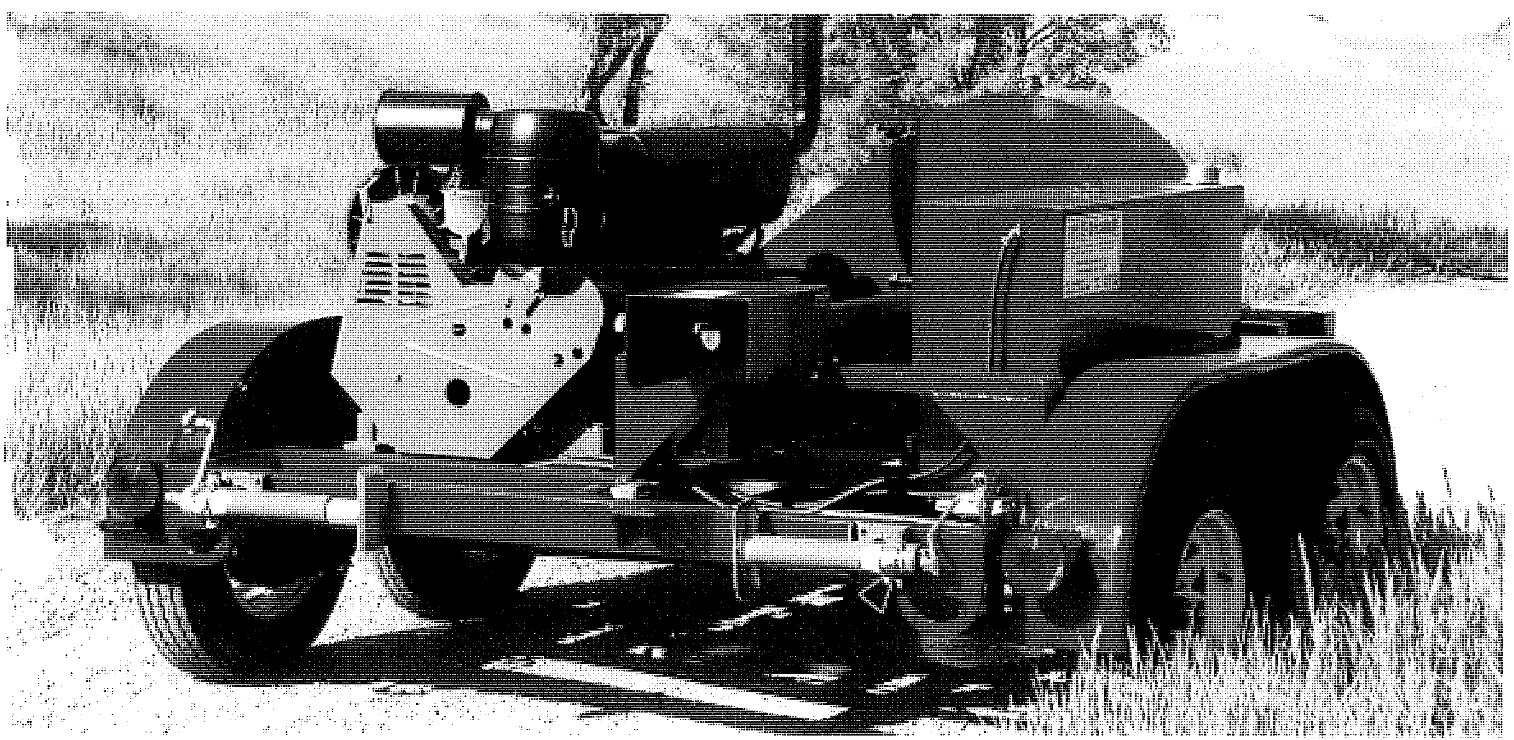
ENGINEERING NOTE

Maintaining the correct engagement pressure is the responsibility of the owner/operator. New clutches usually require several, frequent adjustments until the friction facing surfaces have "worn in". The clutch friction facing plates will become glazed, and possibly permanently damaged if the clutch is permitted to slip excessively.

Ensure the PTO manual is read and the engagement pressure is checked.

SRS CRISAFULLI
P.O. Box 1051
Glendive, MT 59330
1-800-442-7867

SECTION 7 – LUBRICATION & MAINTENANCE



SRS CRISAFULLI, INC.
P.O. Box 1051
Glendive, Montana 59330
1-800-442-7867

LUBRICATION and MAINTENANCE SCHEDULE

DIESEL ENGINE:

Frequency: According to Engine O&M

PTO:

Frequency: According to PTO O&M

SHAFT COUPLERS:

Frequency: Monthly or prior to each use.

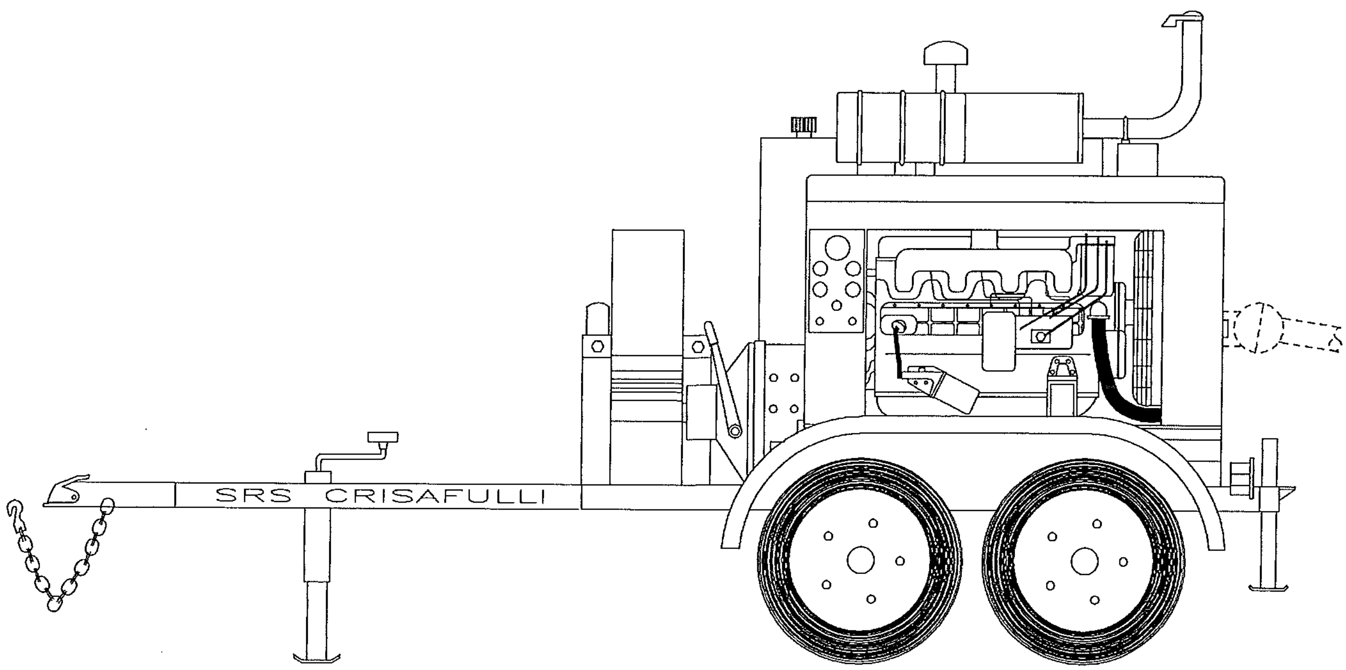
Apply Grease to shaft areas to prevent seizing

TRAILER AND FUEL TANK:

No lubrication required. Check all fasteners after transportation to ensure proper tightening.

SRS Crisafulli

DIESEL PTO POWER UNIT



P.O. Box 1051
1610 Crisafulli Drive
Glendive, MT 59330
www.crisafulli.com

Phone: 1-406-365-3393
Fax: 1-406-365-8088
Toll Free: 1-800-442-7867

TRANSMITTAL OF SHOP DRAWINGS, EQUIPMENT DATA, MATERIAL SAMPLES, OR MANUFACTURER'S CERTIFICATES OF COMPLIANCE

(Read instructions on the reverse side prior to initiating this form)

DATE: 01/29/2015

TRANSMITTAL NO.: 41 65 10-5

SECTION I - REQUEST FOR APPROVAL OF THE FOLLOWING ITEMS (This section will be initiated by the contractor)

TO: Eastern Area Office
926 SW Adams Street, Suite 110
Peoria, IL 61602

FROM: Kolb Grading, LLC
5731 Westwood Dr.
Saint Charles, MO 63304

CONTRACT NO.: W912EK-10-C-0122 NA

CHECK ONE:
[X] THIS IS A NEW TRANSMITTAL
[ ] THIS IS A RESUBMITTAL OF TRANSMITTAL ______

SPECIFICATION SEC. NO. (Cover only one section with each transmittal): 41 65 10

PROJECT TITLE AND LOCATION: 01-Main Register
Fox Island Division Habitat Rehab and En Fox Island Missouri

CHECK ONE: THIS TRANSMITTAL IS FOR [ ] FIO [X] GA [ ] DA [ ] CR

ITEM NO. a.	DESCRIPTION OF ITEM SUBMITTED (Type size, model number/etc.) b.	MFG OR CONTR. CAT., CURVE DRAWING OR BROCHURE NO. (See instruction no. 8) c.	NO. OF COPIES d.	CONTRACT REFERENCE DOCUMENT: SPEC. PARA. NO. e.	CONTRACT REFERENCE DOCUMENT: DRAWING SHEET NO. f.	FOR CONTRACTOR USE CODE g.	VARIATION (See Instruction No. 6) h.	FOR CE USE CODE i.
3	As-Built Drawings	SHOP DRAWINGS	4			A	N	A

REMARKS

RECEIVED
FEB 10 2015
BY EC-CE

I certify that the above submitted items have been reviewed in detail and are correct and in the strict conformance with the contract drawings and specifications except as otherwise stated.

D Mark Potts D Mark Potts

NAME AND SIGNATURE OF CONTRACTOR

SECTION II - APPROVAL ACTION

ENCLOSURES RETURNED (List by item No.)

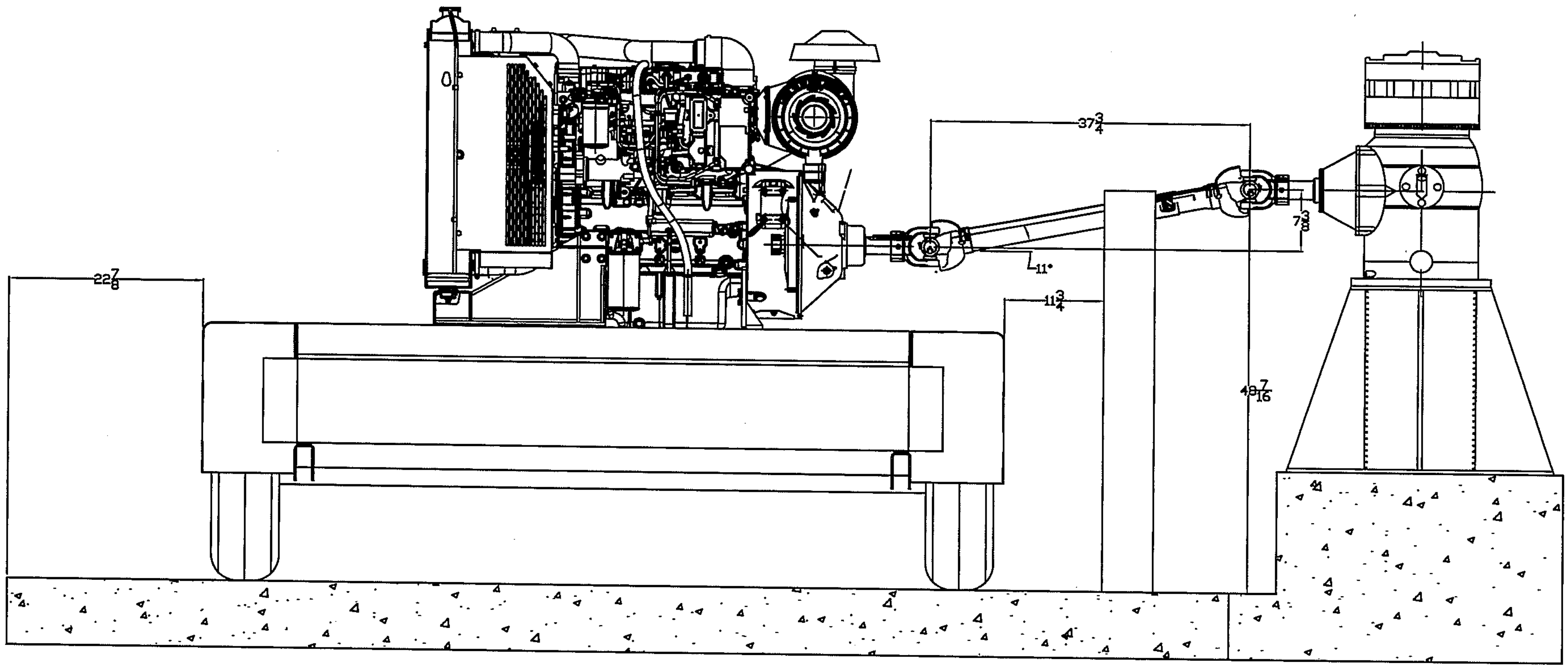
NAME, TITLE AND SIGNATURE OF APPROVING AUTHORITY

Jeffrey S. Sudman
JEFFREY S. [illegible], P.E. CONTRACTING OFFICER'S REPRESENTATIVE

DATE: 3/16/2015

SOME FEATURES INTENTIONALLY OMITTED FOR CLARITY

ALL DIMENSIONS MEASURED FROM MAXIMUM LOADING 330 GALLONS DIESEL 65 GALLONS WATER



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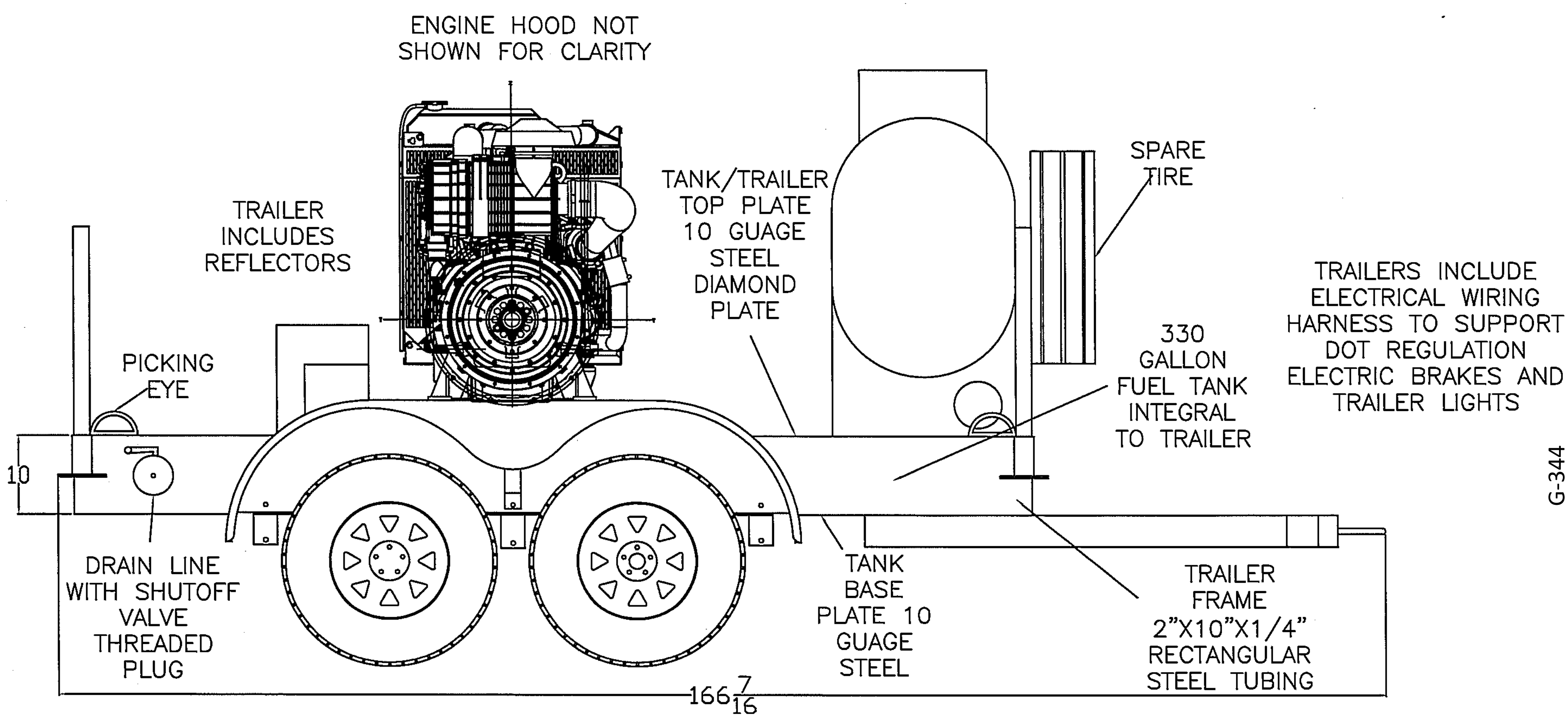
SRS Crisafulli

Sludge Removal Systems
1610 Crisafulli Drive
Glendive, MT 59330 USA

PHONE: 800-442-7867 www.crisafulli.com

POWER UNIT INSTALLATION
SHAFT ANGLE < 15 DEGREES

DATE: 07/25/12 | BY: BJW | DWG: 12246



G-344

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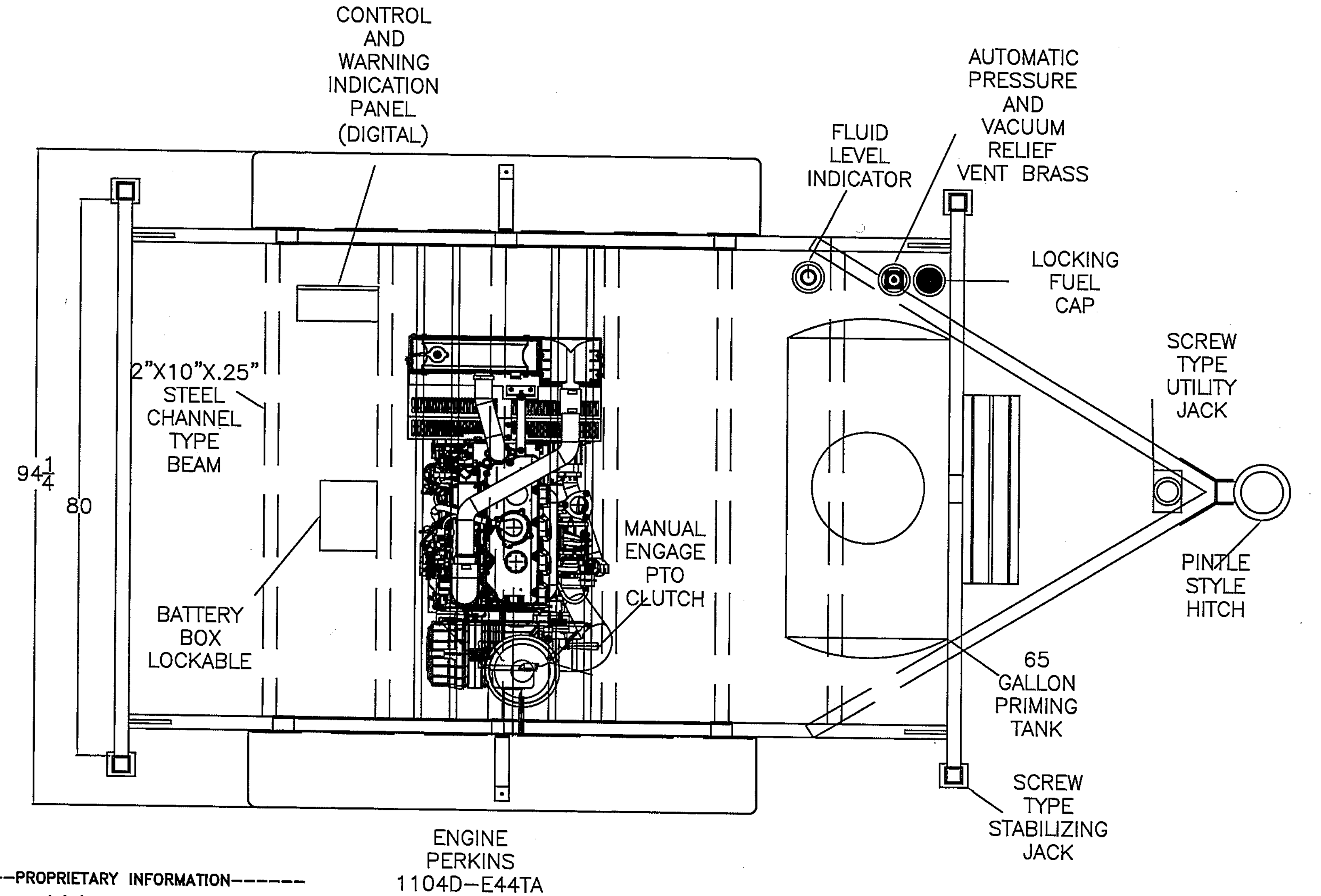
1610 Crisafulli Drive
Glendive, MT 59330 USA

PHONE: 800-442-7867 **www.crisafulli.com**

POWER UNIT
MATERIAL OF CONSTRUCTION

DATE: 07/25/12 | BY: BJW | DWG: 12246



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Sludge Removal Systems
1610 Crisafulli Drive
Glendive, MT 59330 USA
PHONE: 800–442–7867
www.crisafulli.com

POWER UNIT MATERIAL OF CONSTRUCTION		
DATE: 07/25/12	BY: BJW	DWG: 12246

TRANSMITTAL OF SHOP DRAWINGS, EQUIPMENT DATA, MATERIAL SAMPLES, OR MANUFACTURER'S CERTIFICATES OF COMPLIANCE

(Read instructions on the reverse side prior to initiating this form)

DATE: 02/02/2015

TRANSMITTAL NO.: 41 65 10-7

SECTION I - REQUEST FOR APPROVAL OF THE FOLLOWING ITEMS (This section will be initiated by the contractor)

TO: Eastern Area Office
926 SW Adams Street, Suite 110
Peoria, IL 61602

FROM: Kolb Grading, LLC
5731 Westwood Dr.
Saint Charles, MO 63304

CONTRACT NO.: W912EK-10-C-0122 NA

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SPECIFICATION SEC. NO. (Cover only one section with each transmittal): 41 65 10

PROJECT TITLE AND LOCATION: 01-Main Register
Fox Island Division Habitat Rehab and En Fox Island Missouri

CHECK ONE: THIS TRANSMITTAL IS FOR [X] FIO [ ] GA [ ] DA [ ] CR

ITEM NO. a.	DESCRIPTION OF ITEM SUBMITTED (Type size, model number/etc.) b.	MFG OR CONTR. CAT., CURVE DRAWING OR BROCHURE NO. (See instruction no. 8) c.	NO. OF COPIES d.	CONTRACT REFERENCE DOCUMENT: SPEC. PARA. NO. e.	CONTRACT REFERENCE DOCUMENT: DRAWING SHEET NO. f.	FOR CONTRACTOR USE CODE g.	VARIATION (See Instruction No. 6) h.	FOR CE USE CODE i.
4	Regulatory Requirements	PRODUCT DATA	4	1.3		A	N	F
	Diesel Engine							
	Mechanical Clutch							
	Right angle gear							

REMARKS

RECEIVED
FEB 10 2015
BY EC-CE

I certify that the above submitted items have been reviewed in detail and are correct and in the strict conformance with the contract drawings and specifications except as otherwise stated.

D. Mark Potts

NAME AND SIGNATURE OF CONTRACTOR

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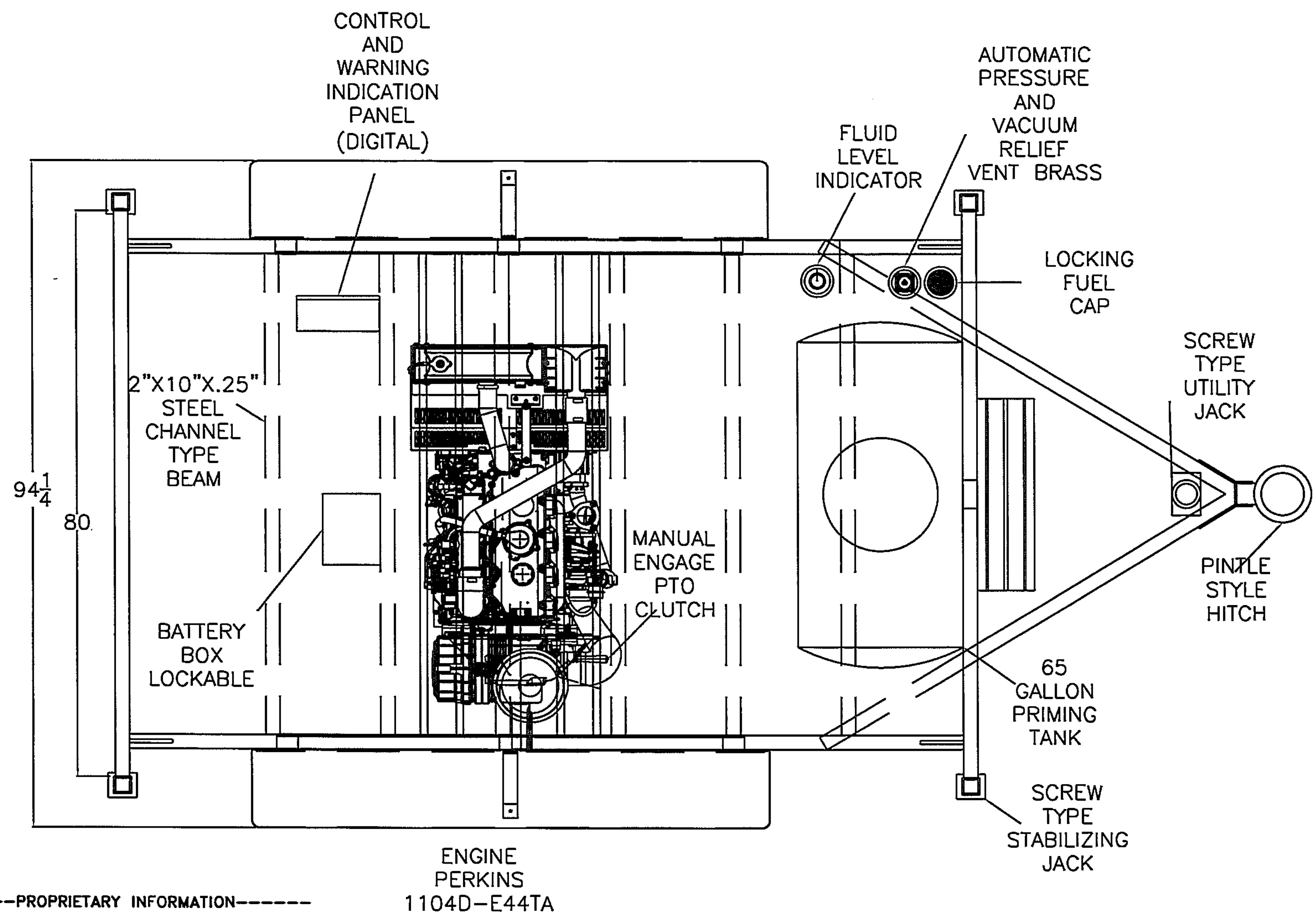
ENCLOSURES RETURNED (List by item No.)

NAME, TITLE AND SIGNATURE OF APPROVING AUTHORITY

CONTRACTING OFFICER'S REPRESENTATIVE

DATE: 3/16/2015

ENG FORM 4025, MAR 95 (ER 415-1-10) EDITION OF SEP 93 IS OBSOLETE. SHEET 1 OF 1 (Proponent: CEMP-CE)



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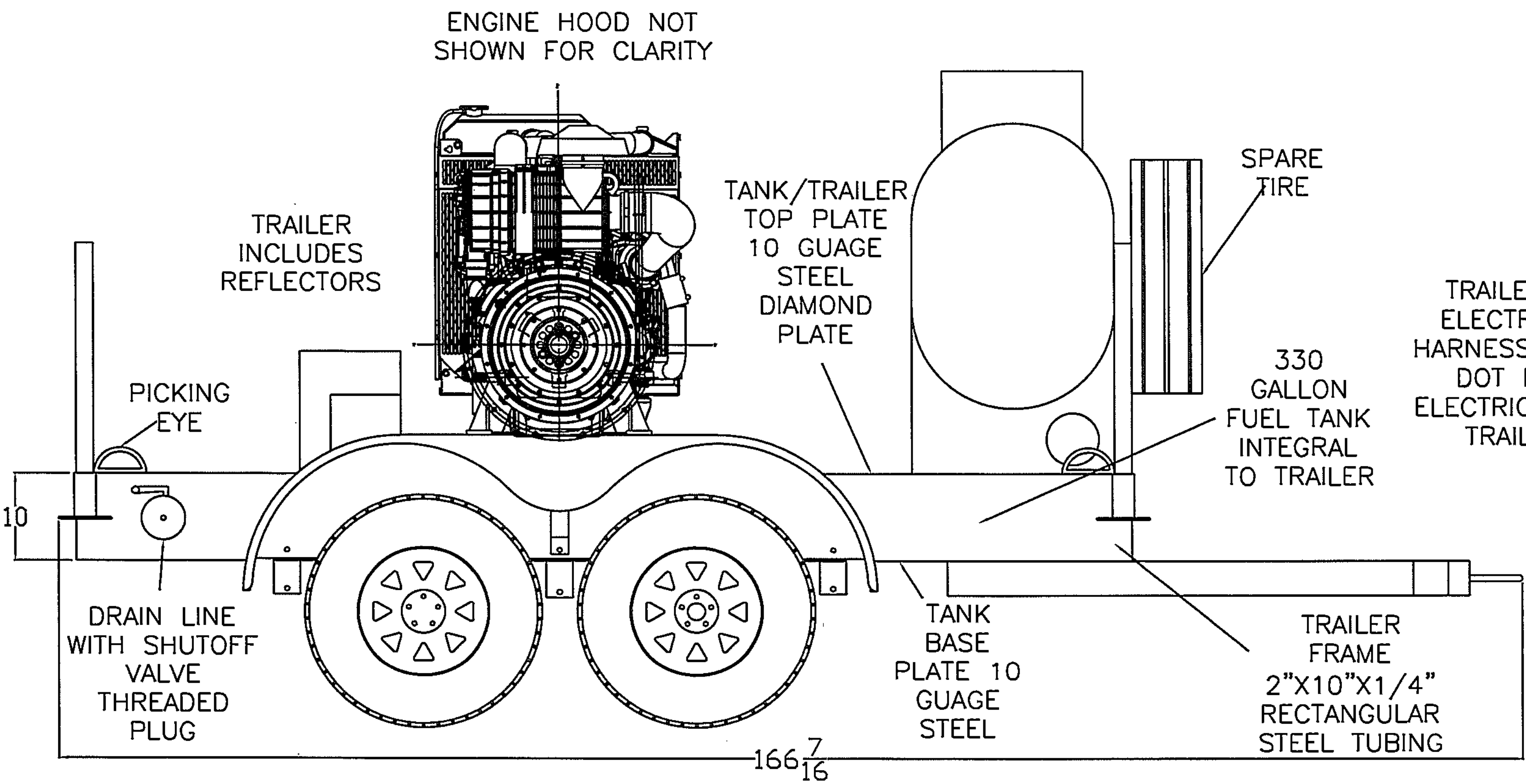
PHONE: 800–442–7867
www.crisafulli.com

POWER UNIT
MATERIAL OF CONSTRUCTION

DATE: 07/25/12	BY: BJW	DWG: 12246



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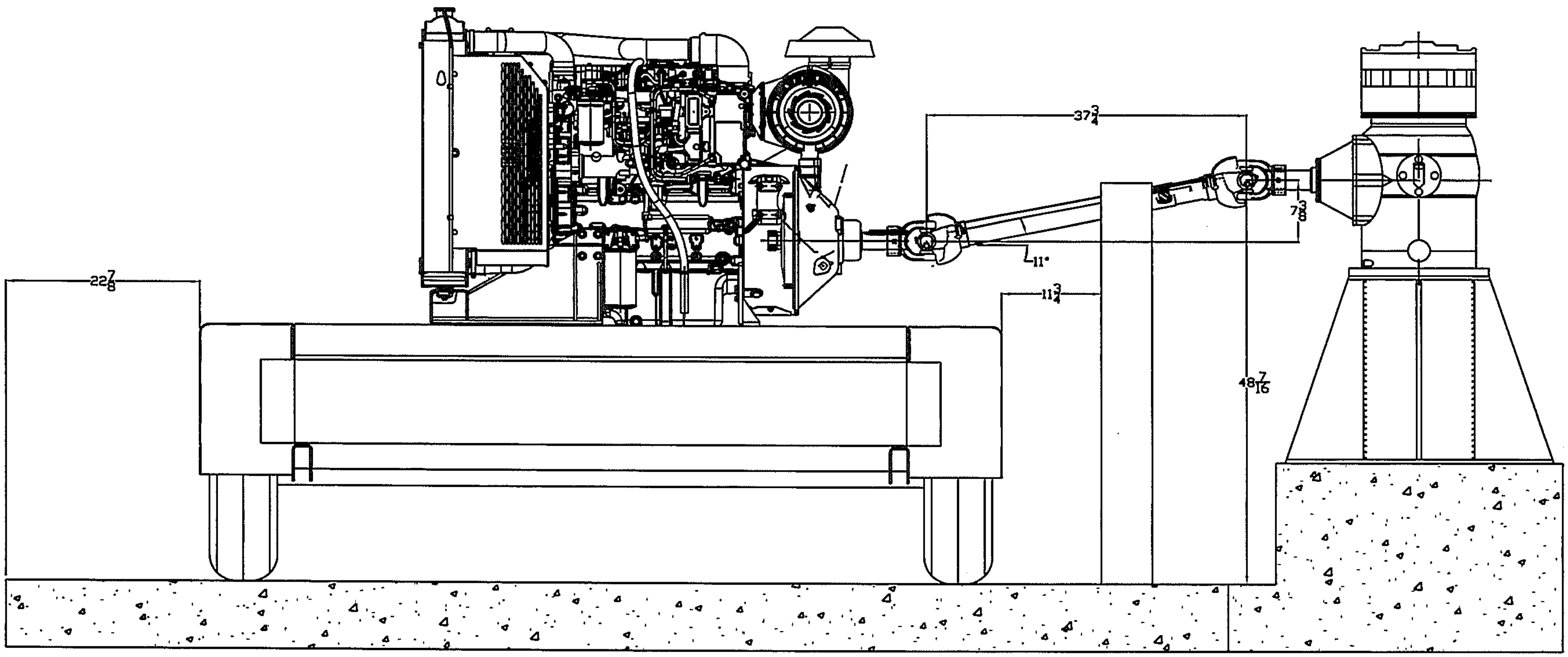
ALL DIMENSIONS MEASURED FROM MAXIMUM LOADING 330 GALLONS DIESEL 65 GALLONS WATER



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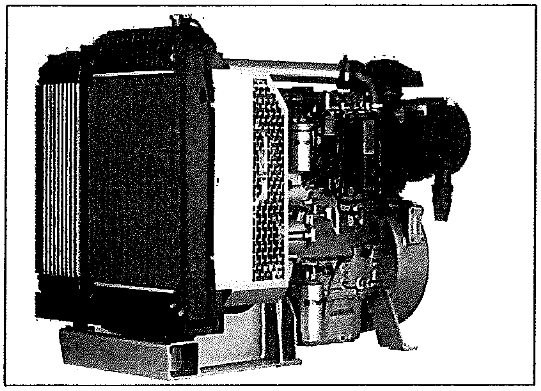
PHONE: 800-442-7867	www.crisafulli.com
POWER UNIT INSTALLATION SHAFT ANGLE < 15 DEGREES	
DATE: 07/25/12	BY: BJW	DWG: 12246

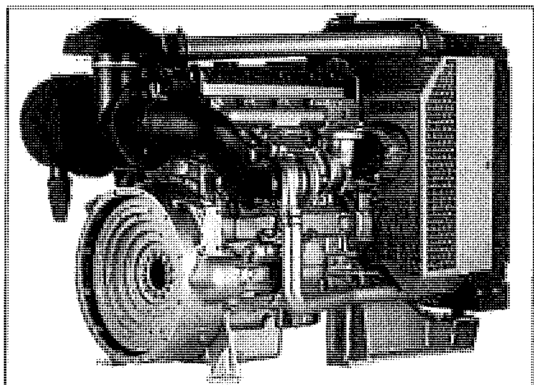


1100 Series

1104D-E44TA

Diesel Engine - Industrial Open Power Unit

100.2 kW/134.4 bhp



The 1104D-E44TA IOPU is a new addition to the 1100 Series range of IOPU engines. The 1100 Series electronic diesel engines are assembled on a new high technology production line, which makes frequent computerised checks during the production process ensuring high build quality/excellence is maintained.

The 1104D IOPU range of engines have a complete fuel system, air cleaner and radiator fitted as standard along with a choice of mechanical or electronic control system making these the ultimate power solution.

The 1100D range with their wide choice of build options, plus all the features and benefits, present a secure future for all our customers at Tier 3/Stage IIIA emissions legislation, and is the platform on which the long-term solution to Tier 4/Stage IIIB legislation will be built.

Powered by your Needs

- The 1104D-E44TA IOPU offers a choice of build configurations to match the power needs of customers for a diverse range of applications.

State of the Art Design

- The 1104D-E44TA IOPU incorporates the latest common-rail fuel system technologies with a closely optimised air-management system which is overseen by the latest generation of electronic engine control. This allows the 1104D range to deliver high power density and excellent fuel economy with low exhasut emissions and the minimum of heat rejection.

Reduced Noise

- Noise minimised at source - engine sound levels have been reduced by 2 dBA.
- Reduction in noise suppression costs.

Component Commonality

- Shared front and rear ends and 'repeated' components - pistons, con rods and valve gear.
- Rationalised inventory, streamlined training and consistent serviceability.

Lower Installation Costs

- Virtually identical hook-up points and envelope size as the 1104C-44TA.
- Customer enjoys a seamless transition during the emissions changeover process.

Lower Operating Costs

- The 1104D maintains Tier 2/Stage II fuel economy, allowing customers to keep existing fuel tanks.
- Service intervals are 500 hours standard.
- Perkins comprehensive warranty cover for two years with three years on major engine components.
- Low usage warranty package is also available.

Product Support

- Perkins actively pursues product support excellence by ensuring our distribution network invest in their territory - strengthening relationships and providing more value to you, our customer
- Through an experienced global network of distributors and dealers, fully trained engine experts deliver total service support around the clock, 365 days a year. They have a comprehensive suite of web based tools at their fingertips covering technical information, parts identification and ordering systems, all dedicated to maximising the productivity of your engine
- Throughout the entire life of a Perkins engine, we provide access to genuine OE specification parts and service. We give 100% reassurance that you receive the very best in terms of quality for lowest possible cost .. wherever your Perkins powered machine is operating in the world

Engines certified to Tier 3/Stage IIIA emissions legislation.

Engine Performance	Net Intermittent	Engine Speed	Pump Sets	Engine Speed
Max power (kW)	100.2	2200	85.1	2000
Max power (bhp)	134.4	2200	114.2	2000
Max torque (Nm)	556.0	1400	472.6	1400
Max torque (lbf ft)	410.1	1400	348.6	1400

Power for a run-in engine after 60 hours.
Net Intermittent = Intermittent service where maximum power and/or are, cyclic (time at full load not to exceed 50%).
Rating standard ISO/TR 14396.

All information in this document is substantially correct at time of printing and may be altered subsequently

Publication No.1907/05/09 Produced in England

1100 Series

1104D-E44TA IOPU

Standard IOPU Specification

Air inlet
- Mounted air filter and turbocharger

Cooling system
- Fan (pusher or puller)
- Fan drive
- Radiator
- Water pump

Electrical equipment
- Alternator (12 or 24 volt)
- Starter motor (12 or 24 volt)

Flywheel and housing
- Flywheel
- SAE 3 flywheel housing

Fuel system
- Fuel filter

Lubrication system
- Oil cooler and filter
- Timing case oil filler

Mountings
- Engine mounting brackets

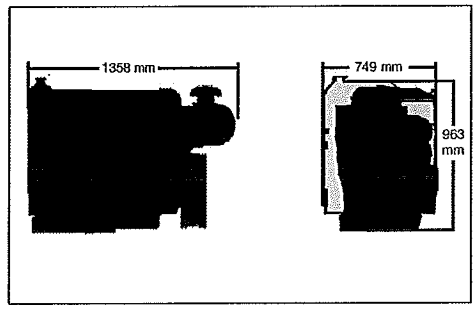
PTO
- SAE A or SAE B front PTO (142/280 Nm)

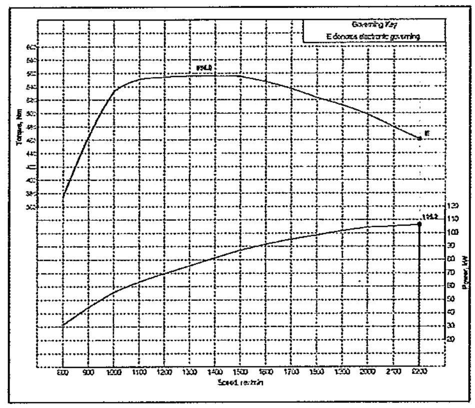
Starting aids
- Glow plugs

Literature
- User's Handbook

Option Groups

The 1104D-E44TA IOPU offers a wide choice of standard build specifications to meet specific customer needs:
- 12 or 24 volt alternator
- Pusher or puller fan
- SAE A or SAE B front PTO (142/280 Nm)
  SAE B provides 63 kW/85 hp
- Air compression





General Data

Number of cylinders	4 in-line
Bore and stroke	105 mm x 127 mm
Displacement	4.4 litres
Aspiration	Turbocharged air to air aftercooled
Cycle	4 stroke
Combustion system	Direct injection
Compression ratio	16:2
Direction of rotation	Anti-clockwise, viewed on flywheel
Cooling system	Liquid
Total lubrication system capacity	8.4 litres
Total coolant capacity	17 litres
Dimensions	Length 1358 mm Width 749 mm Height 963 mm
Dry weight (ElectropaK)	520 kg

Final weight and dimensions will depend on completed specification

Perkins®

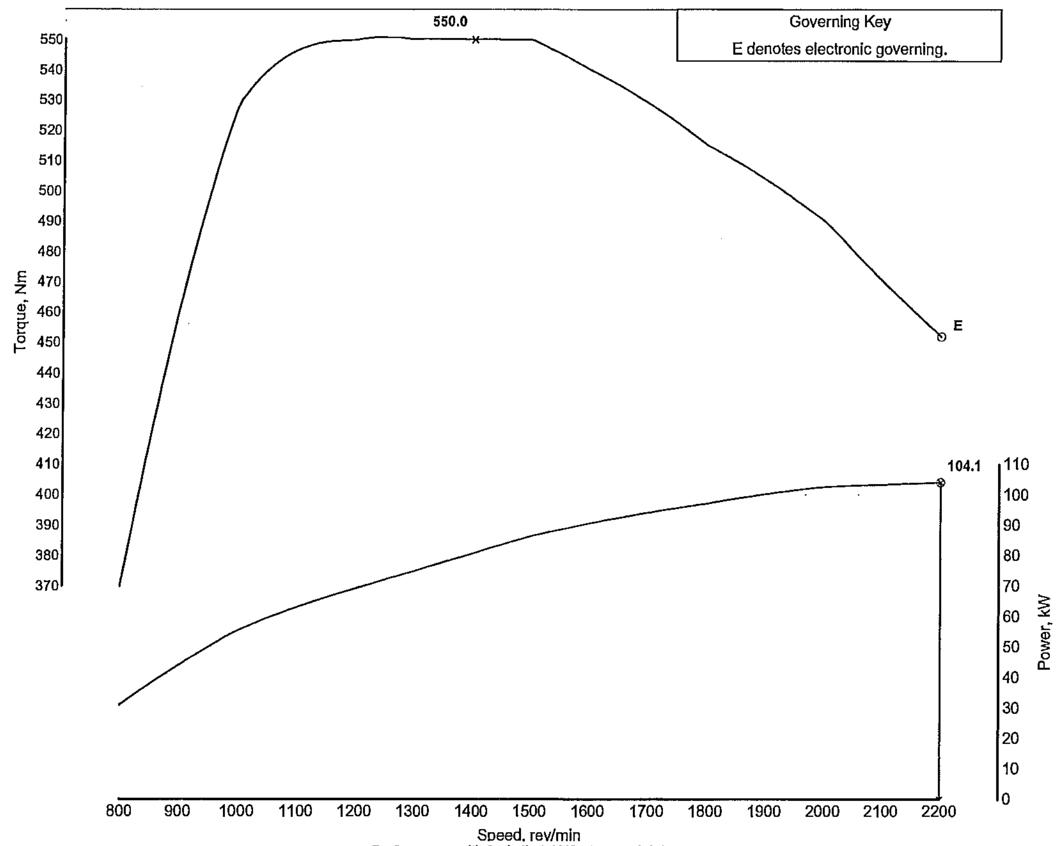
Perkins Engines Company Limited
Peterborough PE1 5NA
United Kingdom
Telephone +44 (0)1733 583000
Fax +44 (0)1733 582240
www.perkins.com

Distributed by

1104D-E44TA - T2894, with balancer

Perkins Perkins Engines Company Limited ©2006 Commercial in Confidence, proprietary information of Perkins Engines Company Ltd.	**Engine Model:** 1104D-E44TA	**Curve:** T 2894 **Sheet 1** **Issue:** 2 **Date:** 13-Feb-2006 **Development Target - May be Subject to Change**

Rating Standards:	ISO 14396: 2002	**Fuel Types:**	Europe Off Highway	USA FED Off Highway
Production Tolerance On Power Output:	+3%, -3%	Fuel Specification:	CEC RF-06-99	EPA 2D 89.330 1999
Total Barometric Pressure (kPa):	100	Density (kg/l @ 15°C):	0.833 - 0.837	0.845 - 0.85
Vapour Pressure (kPa):	1	Viscosity (mm²/s @ 40°C):	2.5 - 3.5	2.0 - 3.2
Air Inlet Temperature (°C):	25	Sulphur Content (% mass):	0.03 max	0.03 - 0.4
		Cetane No:	52 - 54	40 - 48



Performance with fuel oil at 40°C at pump inlet.

Notes:
1. For duty cycle refer to Perkins Engines (Peterborough) Limited statement on Product Duty Usage Limitations.

Auxiliaries fitted to engine:
Balancer - fitted.
Alternator - off load.
Fan - not fitted.

Exhaust Quality Standard — **Certification Refs (Rated Speeds)**

Smoke:
77/537/EEC- Includes FAS.

Emissions:
US EPA 40 CFR Part 89 Tier 3.
EU NRMM 97/68/EC Stage 3A.

Power Standard — **Certification Refs (Rated Speeds)**

Approved by:	**Accepted by:**	**Issued by:**
E. Hughes (Product Manager)	C. Herring (PE Manager)	P. Knight (Legislation Engineer)
Date: 2-Feb-2006	Date: 2-Feb-2006	

Rating Curves Data Sheet

Curve T 2894 Sheet 2

Note1: Unless otherwise specified, all stated data is for maximum rated speed and 100% load.

General Data

Engine Model:	1104D-E44TA
Number Of Cylinders:	4
Bore (mm):	105.0
Stroke (mm):	127.0
Configuration:	Vertical In Line
Displacement (litres):	4.4
Aspiration:	Turbocharged
Compression Ratio:	16.2 : 1
Combustion Bowl:	

Fuel System

Fuel Pump Model:	CAT FUEL SYSTEMS HEUI SF
Injection Timing (°BTDC) - Static:	T.D.C. No.1
- Dynamic:	
HP Rail Pressure (MPa):	
Fuel Pump Pressure (In) (kPa):	
Fuel Filter Max Particle Size (micron):	2
Fuel Return System Type:	Return to Tank

Lubrication System

Lubricating Oil Specification:	See Engine Specification Manual

Exhaust System

Exhaust Flow (kg/min):	10.06 (21.6 m³/min)
Exhaust Temperature (°C):	583 (ATC)

Cold Start Capability

Unaided Start Limit (°C):	-10
Aided Start Limit (°C):	-40
Start Aid (Optional):	Glowplugs fitted as standard
Minimum Cranking Speed (rev/min) - unaided:	Not applicable
- aided:	

Cooling System

Heat Rejected @ Rated Speed (kW):	61.0
Heat Rejected @ Peak Torque (kW):	
Coolant Flow (litres/min):	
Thermostat - Start To Open (°C):	
Thermostat - Fully Open (°C):	
Recommended Cap Pressure (kPa):	
Max Top Tank Pressure (kPa):	

Air System

Engine Air Flow (kg/min):	9.65 (8.29 m³/min)
Induction Manifold Pressure (kPa):	135.4

Charge Air Cooler System

Charge Air Cooling System:	Air-to-Air
Max Total Pressure Drop Inc Pipes (kPa):	10.0
Charge Air Cooler Heat Rejection (kW):	14.2
Manifold Charge Air Temperature (°C):	55.0

Turbocharger

Turbocharger Type:	Borg Warner B1 with wastegate
Maximum Altitude (m):	3000

Performance Data

Friction Power @ Rated Speed (kW):	
Friction Power @ Peak Torque (kW):	
Torque @ 800 rev/min (Nm):	370

For further performance data see table below.

Performance Data — Rating Standard: ISO 14396: 2002

Speed (rev/min)	Torque (Nm)	Power (kW)	Max Exhaust Back Pressure (kPa)	Max Inlet Restriction (kPa)	Governing Categories (key on sht 1)
2200	452	104.1	15.0	5.0	E
2100	470	103.4			
2000	490	102.6			
1800	515	97.1			
1600	540	90.5			
1500	550	86.4			
1400	550	80.6			
1300	550	74.9			
1200	550	69.1			
1000	529	55.4			
800	370	31.0			

Further Notes:

Internal References

Curve Issue No:	2	DCP Number(s):	05-1164
TAN Number:			
Curve Issue Date :	13-Feb-2006	FIE EDR Number	

Perkins®

Technical Data
1100 Series

1104D-E44TA

98,1 kW Nett @ 2200 rev/min
Balanced

IOPU (Industrial Open Power Unit)

Basic technical data

Number of cylinders ... 4
Cylinder arrangement ... vertical in-line
Cycle ... four stroke
Induction system ... turbocharged, air to air charge cooled
Compression ratio ... 16,2 : 1
Bore ... 105 mm
Stroke ... 127 mm
Cubic capacity ... 4,4 litres
Direction of rotation ... anti-clockwise when viewed from flywheel
Firing order ... 1, 3, 4, 2
Estimated IOPU weight (dry) ... 589 kg

Overall dimensions

-height ... 969 mm
-length ... 1358 mm
-width ... 749 mm

Moments of inertia (mk²)

-engine rotational components ... 0,12 kgm²
-flywheel ... 1,2 kgm²
-crank pulley ... 0.02 kgm²

Centre of gravity

-forward from rear of block ... tba mm
-above centre line of block ... tba mm
-offset to RHS of centre line ... tba mm

Performance

Note: All data based on operation to ISO/TR14396 2002, BS5514, ISO3046/1 and DIN 6271 standard reference conditions.

-all ratings certified to within ... ±3%

Test conditions

-air temperature ... 25 °C
-barometric pressure ... 100 kPa
-relative humidity ... 30%
-air inlet restriction at rated speed ... 5 kPa
-exhaust back pressure at rated speed (nominal) ... 15 kPa

Sound level

Estimated sound power level (exhaust piped away, cooling pack and air cleaner fitted) ... 112 dB(A)

Notes:

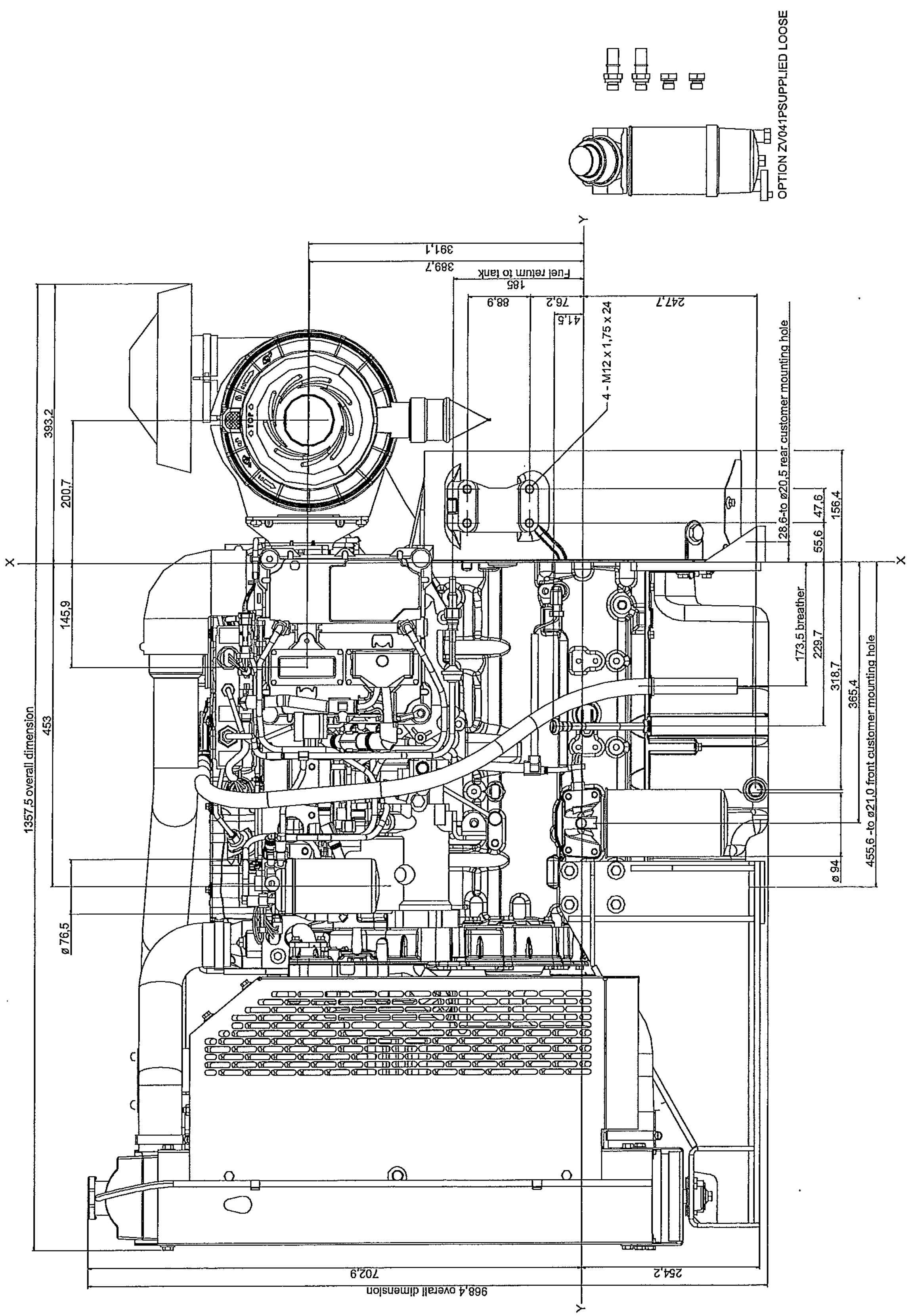
- Sound power level calculated from mean of 4 microphones, sited front, right, left and above engine
- If the engine is to operate in ambient conditions other than those of the test conditions, suitable adjustments must be made for these changes. For full details, contact Perkins Technical Service Department.

Emissions capability: Certified against the requirements of EU Stage IIIA & EPA Tier 3 legislation for non-road mobile machinery, powered by variable speed engines (EPA 40 CFR Part 89 Tier 3).

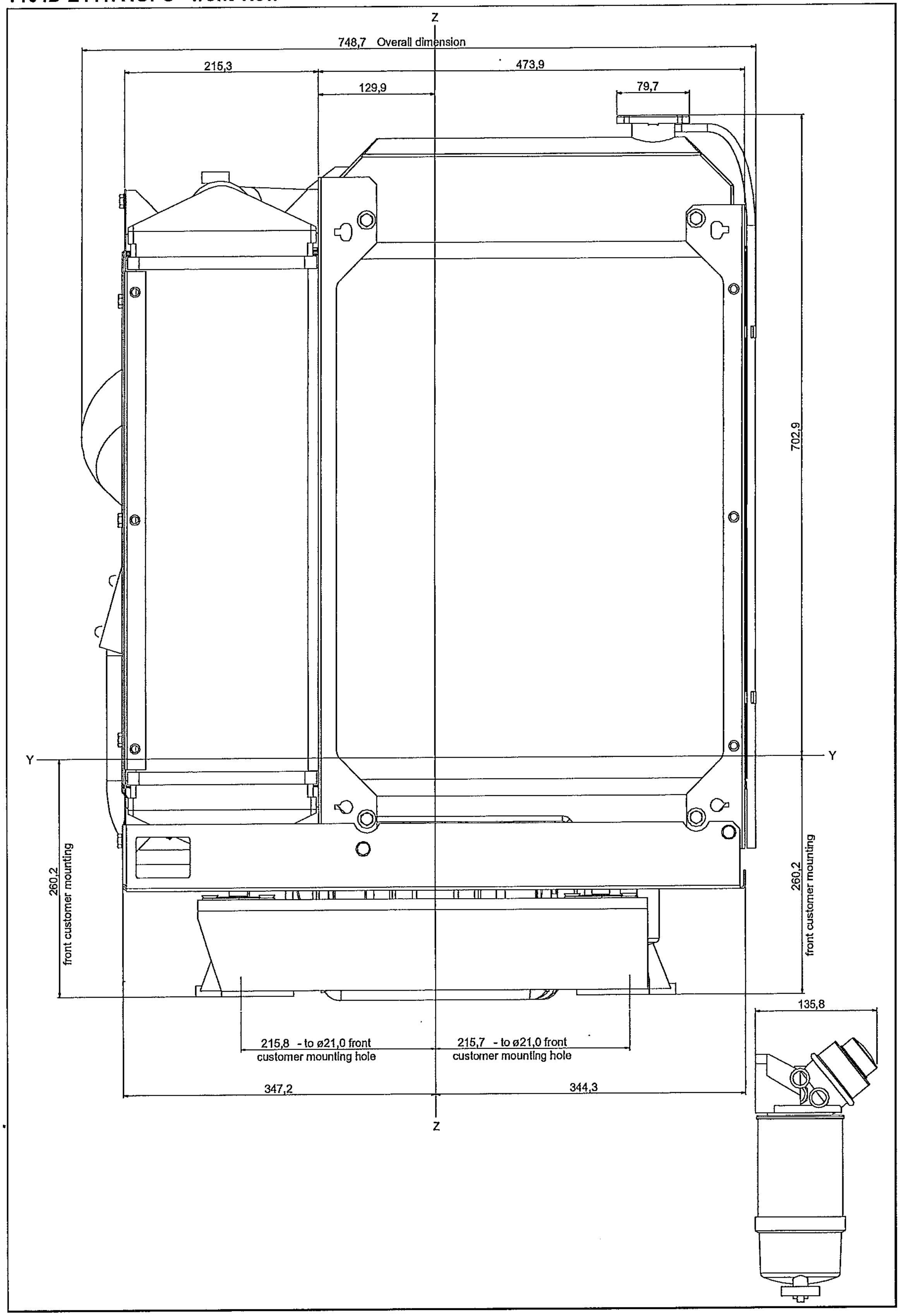
General installation

Designation	Units	Engine speed rev/min						
		1000	1200	1400	1600	1800	2000	2200
Gross engine power - intermittent	kWb	55,4	69,1	80,6	90,5	97,1	102,6	104.1
Gross torque	Nm	529	550	550	540	515	490	452
Brake mean effective pressure	kPa	1503	1564	1582	1544	1473	1392	1296
Engine coolant flow (against 35 kPa restriction)	l/min	94	113	132	151	169	188	207
Combustion air flow (wet)	m³/min	3,5	4,7	6,0	6,9	7,3	7,9	8,4
Exhaust gas flow (wet)	m³/min	9,5	12,3	15,2	16,7	18,0	19,0	20,1
Exhaust gas mass flow (wet)	kg/min	4,3	5,8	7,2	8,1	8,8	9,6	10,2
Exhaust gas temperature (turbo outlet)	°C	519	505	510	511	514	507	518
Cooling fan air flow (200 kPa external restriction)	m³/min	69,0	82,5	95,9	109,4	122,9	136,3	149,8
Radiator core resistance	kpa	0,11	0,16	0,24	0,30	0,35	0,41	0,47
Fuel consumption **(1)**	l/hr	14,3	17,5	21,2	23,8	25,9	27,7	29,4
(1) For 100% nett engine power								
Energy balance								
Energy in fuel	kWt	142,7	175,4	212,0	238,4	259,5	277,6	294,0
Energy in power output (gross)	kWt	55,4	69,1	80,6	90,5	97,1	102,6	104.1
Energy to cooling fan	kWm	0,8	1,5	2,0	3,0	4,0	5,0	6,0
Energy in power output (nett)	kWm	54,6	67,6	78,6	87,5	93,1	97,6	98,1
Energy to exhaust	kWt	37,0	48,2	61,4	69,3	75,9	81,1	88,6
Energy to coolant and oil	kWt	33,9	39,6	45,9	50,5	54,1	57,2	60,1
Energy to charge cooler	kWt	2,4	5,2	9,8	12,1	14,1	16,7	18,1
Energy to radiation	kWt	14,0	13,3	14,3	16,0	18,3	20,0	23,1

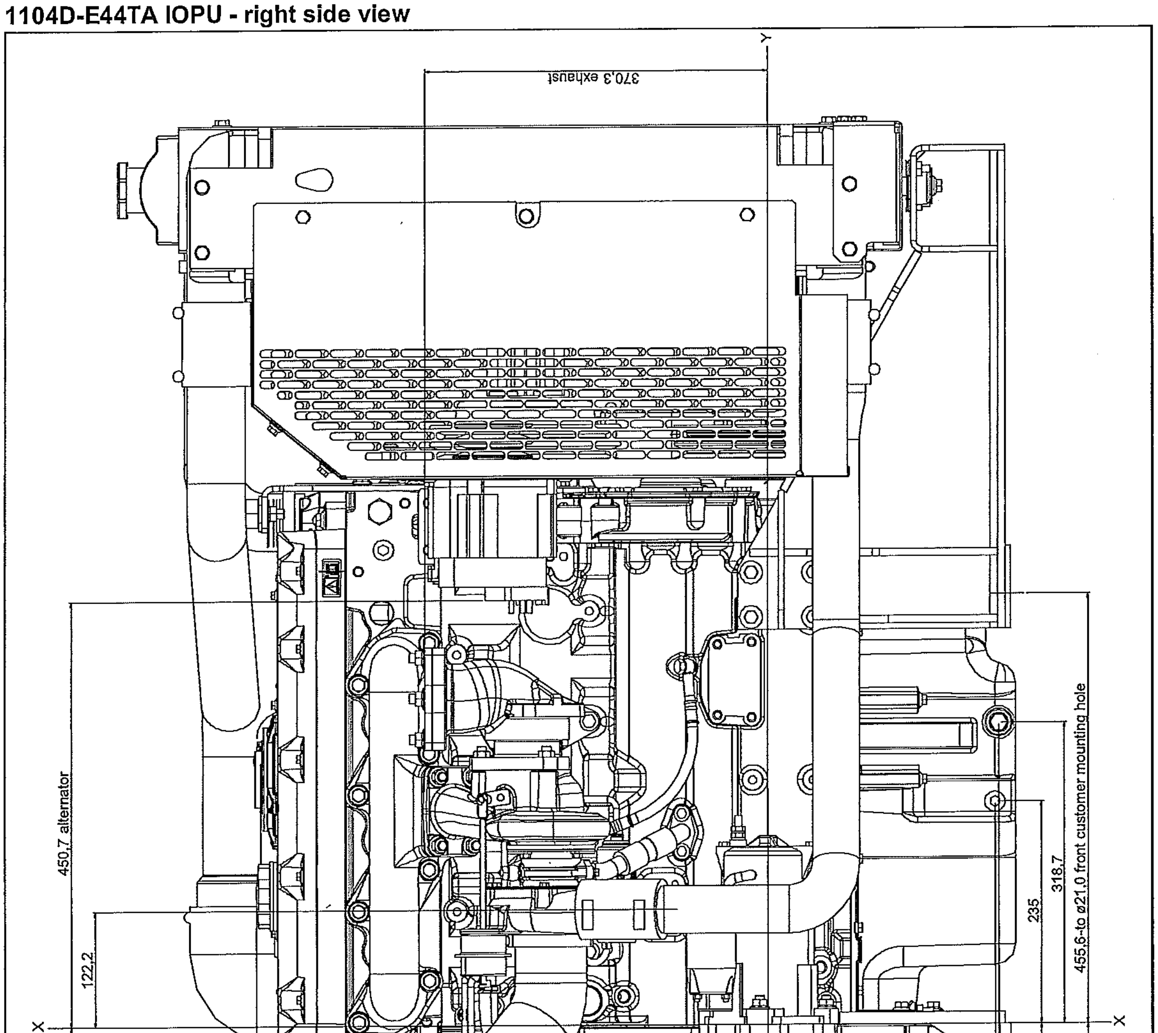
1104D-E44TA IOPU - left side view



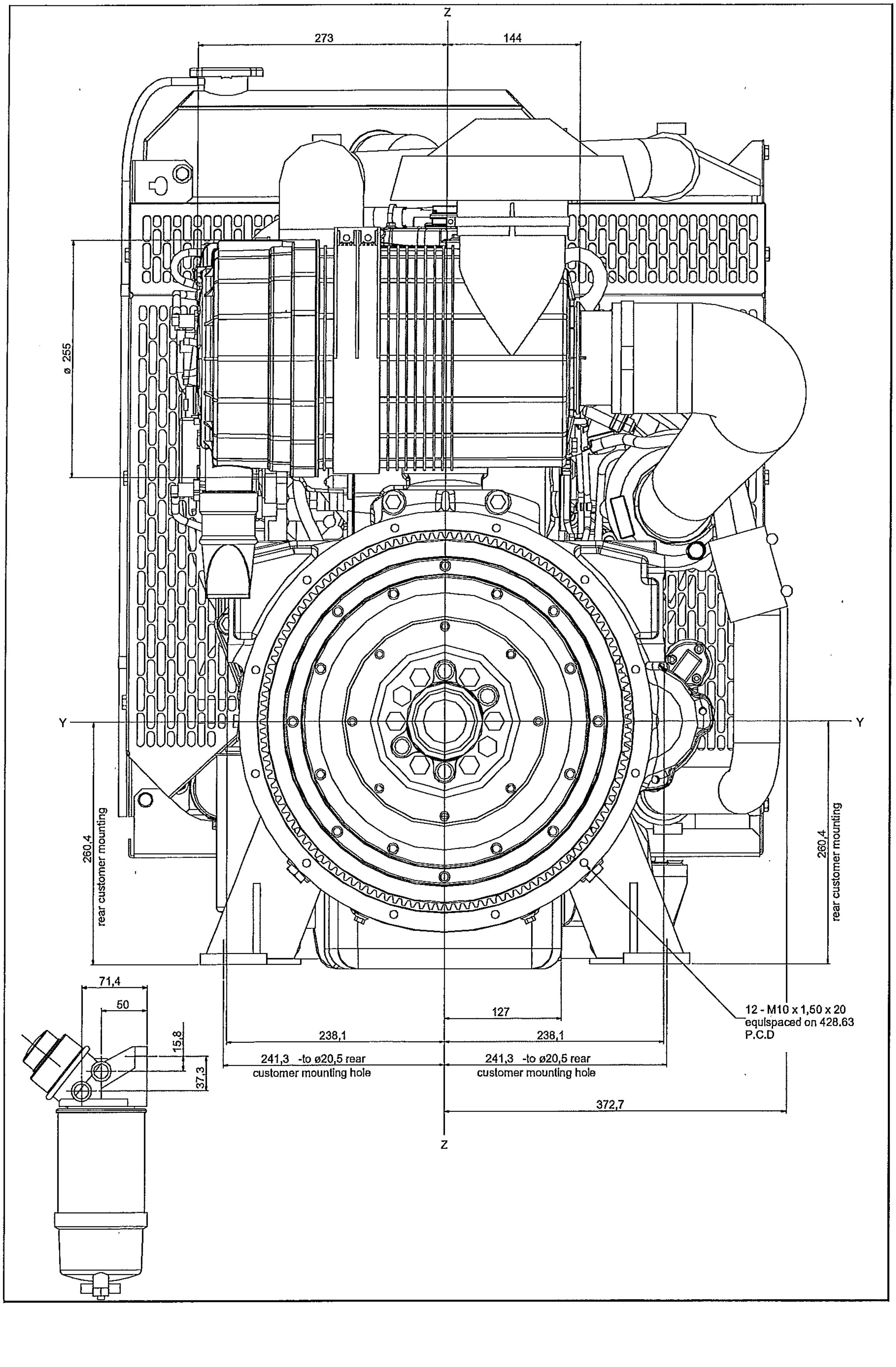
1104D-E44TA IOPU - front view



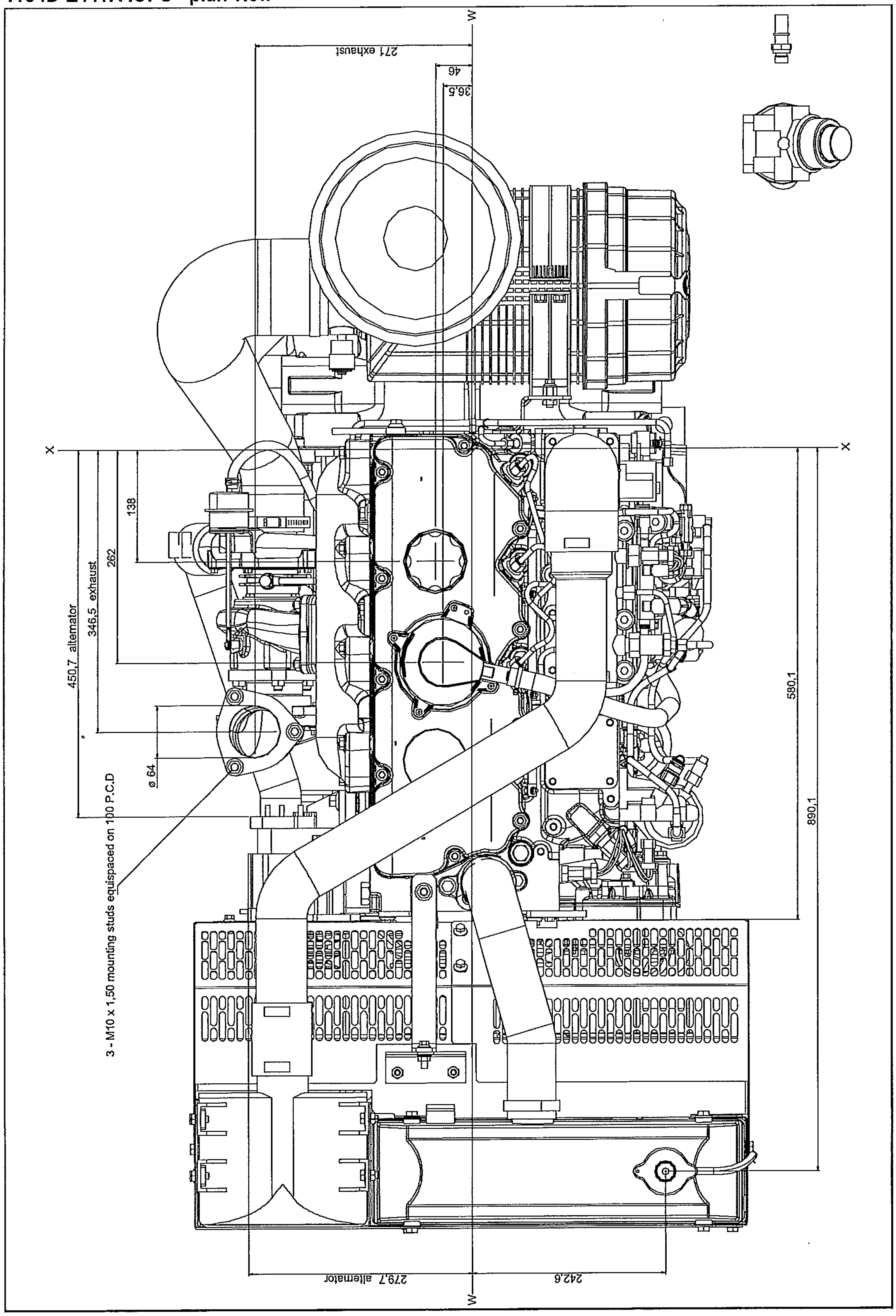
1104D-E44TA IOPU - right side view



1104D-E44TA IOPU - rear view



1104D-E44TA IOPU - plan view



Cooling system

Cooling pack

-overall weight (wet)... ... ... tba kg
-overall face area of matrix ... ...tba mm²
-width of matrix... ... ... tba mm
-height of matrix. ... ... tba mm

Radiator

-face area... ... ... 0,25 m²
-number of rows and material ... ... .5 aluminium
-matrix density and material... ... ... 9,4 aluminium fins per inch
-width of matrix... ... ...439 mm
-height of matrix. ... ...570 mm
-maximum top tank temperature ... ... 112 °C
-pressure cap setting. ... ...100 kPa

Charge cooler

-face area... ... ...tba mm²
-number of rows and material ... ...tba aluminium
-matrix density and material... ... ... tba aluminium fins per inch
-width of matrix... ... ... tba mm
-height of matrix. ... ... tba mm

Fan

-diameter ... ... 559 mm
-drive ratio.. ... ... 1:1
-number of blades. 10
-material. ... ... composite
-type... ... ... puller

Coolant

Total system capacity
-with radiator.. ... ... 17 litres
-without radiator. ... ...7,0 litres
Coolant pump drive ... ... gear
Coolant pump drive ratio 2:1
Temperature rise across engine (rating dependent).. ..6,6 - 7,0 °C
Thermostat operation range... ... ... 82 - 95 °C
Recommended coolant: 50% anti freeze / 50% water. For complete details of recommended coolant specifications, refer to the Operation and Maintenance Manual for this engine model.

Engine speed	Duct allowance with 50% glycol		
	Ambient clearance	Duct allowance	Cooling fan airflow
2200	53	120	150
2200	46	200	154

Electrical system

-type... ... ... 12 Volt negative earth
Alternator type ... ... Denso A115i
-alternator voltage.. ... ...12V
-alternator output ... ... .65 - 175A
Starter motor type .. .. Iskra
-starter motor voltage. 12V
-starter motor power AZE... ... ... .3,2 kW
-starter motor power AZF... ... ... .4,2 kW
Number of teeth on flywheel.. 126
Number of teeth on starter pinion 10
Minimum cranking speed... ... ... 100 rev/min
Starter solenoid maximum
-pull-in current @ 0°C 62A
-hold-in current @ 0°C 14A

Electronics

Electronic interfaces

ECM type. ... ... A4E2 (full authority control)
Connector type ... ... 64 pin plug-in
Voltage / current requirements - various (24V option) **(1)**
Control network - SAE J1939
Engine speed demand:
- PWM
- Analogue
- Multi-position
- PTO modes

Engine configurable options (1)

- High idle setting
- Low idle setting
- Engine monitoring systems
- Configurable input switches (e.g. air cleaner blockage)
- Cold start glow requirement (auto control)
- Speed control - electronic - via ECM
- Stop control - electronic - via ECM

Note: (1) For the full range of options and technical data, refer to the Electronics Applications and Installation Guide.

Diagnostics

- Two lamp fault indicators (mandatory)

- Warning (e.g. engine overheating)
- Shutdown (e.g. low oil pressure)

- Full engine diagnostics

- PDL
- J1939

Cold start recommendation

Starter model	At Temp. °C	Oil viscosity limit	Minimum Battery CCA (cold cranking amps)	
			With glow plugs (SAE)	Without glow plugs
AZE (1)	-5	15W40	750	750
AZE (1)	-10	15W40	850	950
AZF (2)	-15	15W40	1125	(3)
AZF (2)	-20	10W	1300	(3)
AZF (2)	-25	5W30	1300	(3)

1. AZE starter - Battery must not exceed 950 CCA.
2. AZF starter - Battery must not exceed 2400 CCA.
3. Glow plugs must be used.

The table above shows the recommended battery sizes against starter model, temperature and oil viscosity and is based on the test results from starting a 'bare' engine with batteries at a 75% state of charge and with a cable resistance of 0,0017 Ohms.

Exhaust system

Maximum back pressure. ... ... 15 kPa
Exhaust outlet size.. ... ... 64 mm

Induction system

Maximum air intake restriction
-clean filter... ... ...5 kPa
-dirty filter. ... ...8 kPa
-air filter type ... ... 2 stage cyclonic/paper element

Fuel system

Type of injection. ... ... .common rail / direct
Fuel injection pump ... ... HEUI SFI
Fuel atomiser. ... ... Unit injector / multi-hole
Fuel filter particle size (maximum). ... ... .2 microns

Fuel lift pump

-max flow through customer filter... ... ... 2,2 litres/min
-max fuel supply restriction at lift pump.. ... ... .40 kPa
-max fuel return restriction @ low idle ... ... 10 kPa
-max fuel return flow ... ... 0,8 m³/min
Maximum suction head.. ... ... .17 kPa (1.7 m)
Maximum static pressure head.. ... ... .10 kPa (1.0 m)
Governor type ... ... control by ECM
Speed control to. ... ... ISO 8528, G3

Fuel specification

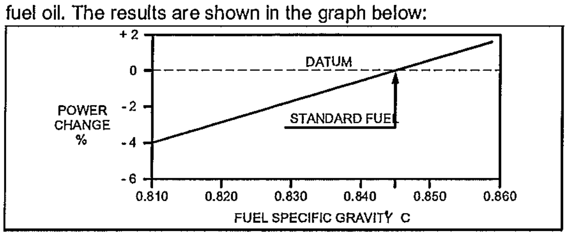
Perkins recommend the use of the following fuel specifications:

- EN590 DERV Grade A, B, C, E, F, Class 0, 1, 2, 3 & 4
- BS2869 Class A2 Off-highway Gas Oil Red Diesel
- ASTM D975, Class 1D and Class 2D.

Note: For further information on fuel specifications and restrictions, refer to the OMM, "Fluid Recommendations" for this engine model.

Fuel specific gravity

Engine power is affected by changes of the specific gravity of the fuel oil. The results are shown in the graph below:



Note: It is important to maintain extreme cleanliness when working on the fuel system, since even tiny particles can cause engine or fuel system problems. For further information on fuel system cleanliness, please refer to the Systems Operation Testing and Adjusting manual.

Lubrication system

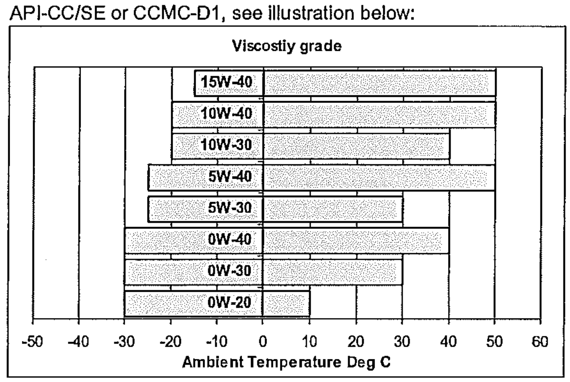
Lubricating oil sump option.. ... ... G0301
Lubricating oil capacity total system ... ... 7,9 litres
Maximum sump capacity. ... ... 6,4 litres
Minimum sump capacity.. ... ... 4,1 litres
Maximum engine operating angles
-front up, front down, right side or left side.. ... ... 25°

Lubricating oil pressure

-relief valve opens... ... ...450 kPa
-at maximum no-load speed ... ... .280 - 340 kPa
Oil temperature
-continuous operation.. ... ... 125 °C
-maximum intermittent operation. ... ... 135 °C
-oil consumption at full load as a % of fuel consumption. 0.15%

Recommended SAE viscosity

A single or multicoloured oil must be used which conforms to API-CC/SE or CCMC-D1, see illustration below:



Mountings

Standard PTO option... ... ... Q1000
Flywheel housing. ... ... SAE 3 156,4 mm
Maximum static bending moment at rear face of block... 1130 Nm

Perkins®

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Fax +44 (0) 1733 582240
www.perkins.com

Distributed by

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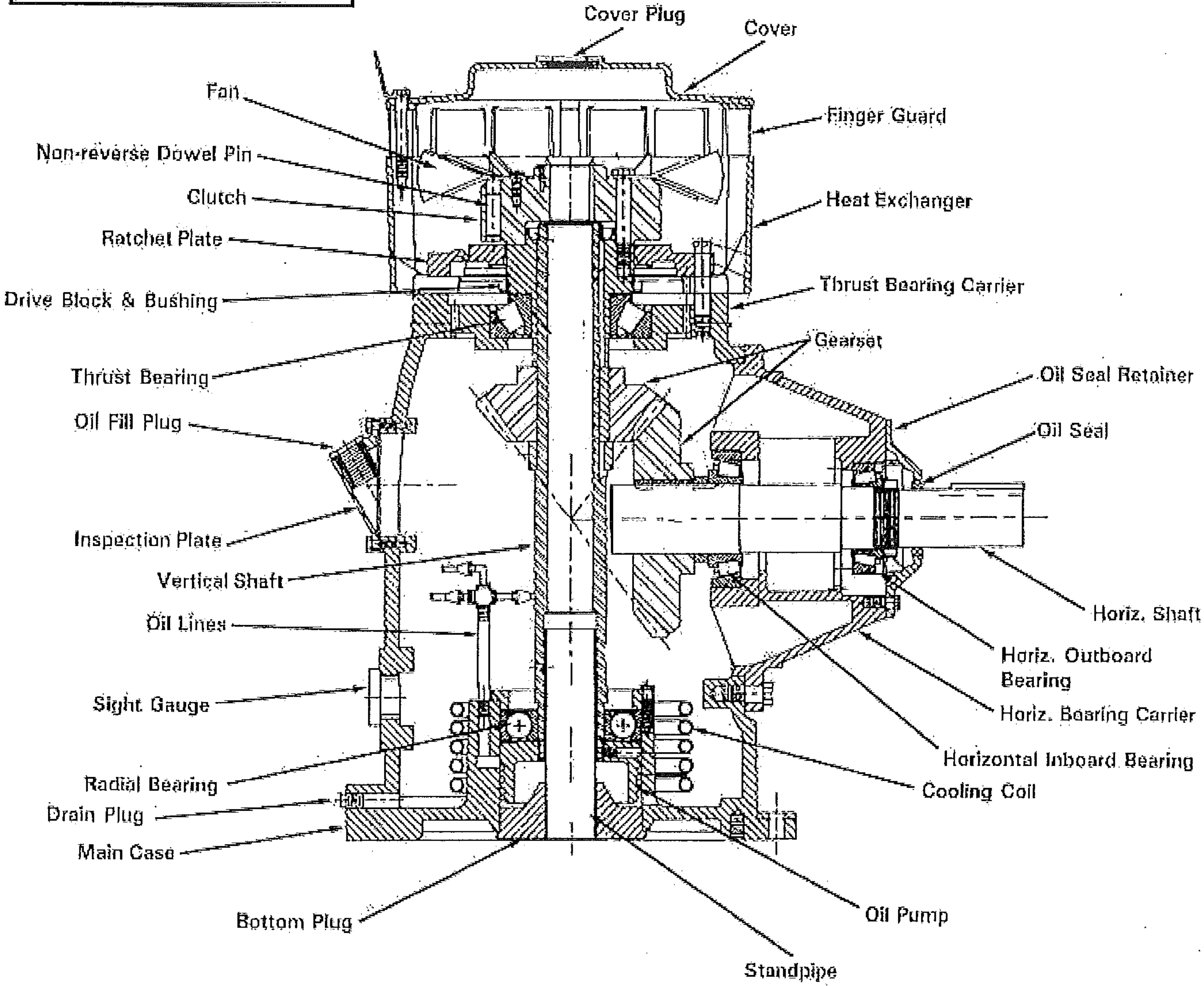
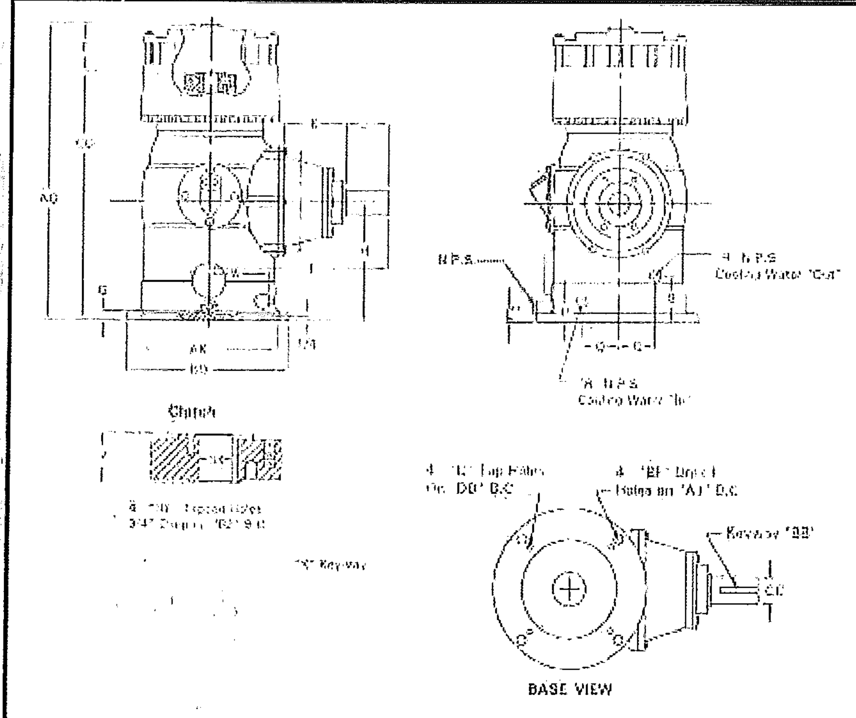
Model G200A Gear Drive



• *Contact Randolph Manufacturing For All Of Your Gear Drive Repair & Part Requirements* •

Typical Lubricants

AGMA Lubricant Number	3	4	5
Viscosity Range, cSt at 40°C./ISO	90-110	135-165	198-242
Max. Ambient Temperature F° / °C	40/5	80/30	140/60
ARCO	Duro 100	Duro 150	Duro 220
CITGO	Mystik JT-7 80-90	Mystik JT-7 80-90	Mystik JT-7 90-140
Conoco	Dectol 100 R & O	Dectol 150 R & O	Dectol 220 R & O
Exxon	Teresstic 100	Teresstic 150	Nuto 220
Mobil Oil	DTE Oil - Heavy	DTE Oil - Extra Heavy	DTE Oil - BB
Phillips	Magnus 100	Magnus 150	Magnus 220
Texaco	Meropa 100	Meropa 150	Meropa 220



Standard Clutch Dimensions

"BX"	"X"	"BY"	"BZ"
3/4	3/16 x 3/32	10-32	1.375
7/8	1/4 x 1/8	10-32	1.375
1	1/4 x 1/8	10-32	1.375
1-1/16	1/4 x 1/8	10-32	1.375
1-3/16	1/4 x 1/8	1/4-20	1.750
1-1/4	1/4 x 1/8	1/4-20	1.750
1-7/16	3/8 x 3/16	1/4-20	2.125
1-1/2	3/8 x 3/16	1/4-20	2.125
1-11/16	3/8 x 3/16	1/4-20	2.500
1-3/4	3/8 x 3/16	1/4-20	2.500
1-15/16	1/2 x 1/4	1/4-20	2.500
2	1/2 x 1/4	1/4-20	2.500
2-3/16	1/2 x 1/4	3/8-16	3.250
2-1/4	1/2 x 1/4	3/8-16	3.250
2-7/16	5/8 x 5/16	3/8-16	3.250
2-1/2	5/8 x 5/16	3/8-16	3.750
2-11/16	5/8 x 5/16	3/8-16	3.750
2-3/4	5/8 x 5/16	3/8-16	3.750
2-15/16	3/4 x 3/8	3/8-16	3.750

Table 3 - Dimensions

Contact factory for certified print when tolerances are required.

Model	M40/M60 M80/M100	G40/G60 G80	G100/G125 M100	M200	G150 G200A	G250 G300	G350 G400	G450	F600/F650 F750	F1000	F1200 F1500
AG (Fan)	22-1/4	26-11/16	26-11/16	29-15/16	34	34	36	37	45-7/16	45-7/16	46-1/6
AJ	14-3/4	14-3/4	14-3/4	14-3/4	18-1/4	18-1/4	18-1/4	18-1/4	23	23	28-3/4
AK	13.501	13.501	13.501	13.501	13.501	13.501	13.501	13.501	13.501	13.501	22.005
BB	3/8 x 3/16	3/8 x 3/16	5/8 x 5/16	5/8 x 5/16	5/8 x 5/16	3/4 x 3/8	3/4 x 3/8	3/4 x 3/8	7/8 x 7/16	7/8 x 7/16	7/8 x 7/16
BD	16-1/2	16-1/2	16-1/2	16-1/2	20	20	20	20	24-1/2	24-1/2	30-1/2
BF	11/16	11/16	11/16	11/16	11/16	11/16	11/16	11/16	13/16	13/16	13/16
BX max.	1-1/2	1-1/2	1-1/2	1-15/16	1-15/16	1-15/16	2-3/16	2-3/16	2-15/16	2-15/16	4-3/4
BX min.	3/4	3/4	3/4	1-3/16	1-3/16	1-3/16	1-1/2	1-1/2	1-11/16	1-11/16	2-15/16
Gtap	-	-		-	5/8-11	5/8-11	5/8-11	5/8-11	5/8-11	5/8-11	3/4-10
CC	1.874	1.874	2.249	2.437	2.437	2.937	2.937	2.937	3.749	3.749	3.749
CD	17-5/8	22-9/16	22-5/8	24-7/8	29-3/16	29-3/16	31-9/16	32-3/4	40-13/16	40-13/16	37-3/4
DD					14-3/4	14-3/4	14-3/4	14-3/4	14-3/4	14-3/4	28
F (Fan)	3-15/16	3-1/2	3-1/2	4-1/2	4-1/8	4-1/16	3-5/8	3-3/8	3-7/8	3-7/8	7-1/4
G	15/16	7/8	7/8	7/8	7/8	7/8	7/8	7/8	1-3/4	1-3/4	1-3/4
H	8-1/2	11-7/16	11-7/16	11-7/16	13-3/4	13-3/4	13-3/4	13-3/4	16-3/4	16-3/4	16
I	17	18	18	18	20-15/16	21-3/4	21-3/4	21-3/4	29	29	34
J (Sprag N.B.)	3-13/16	4-5/16	4-1/2	4-1/2	3-15/16	4-15/16	4-5/8	4-5/8	6-7/8	6-13/16	6
J (Pin type N.B.)	4-3/4	5	5-3/16	5-1/4	5-5/16	5-7/8	5-7/16	5-9/16	8-1/2		
K (Sprag N.B.)	4-9/16	5-7/16	6-3/16	6-3/16	8-1/4	8-1/4	8-1/4	8-1/4	8-3/4	9-13/16	12-1/2
K (Pin type N.B.)	5-5/8	5-3/4	5-1/2	5-1/2	7-3/16	7-3/16	7-5/8	7-1/8	7-1/2		-
L	1-1/4	1-1/2	1-1/2	1-1/2	1-3/4	1-3/4	1-3/4	1-3/4	1-1/4	1-1/4	2-3/8
Mnps	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
N	6-5/8	9-1/8	9-1/8	9-1/8	12-3/8	12-3/8	12-3/8	12-3/8	20	20	13
O	4-3/4	5-3/4	5-3/4	5-3/4	6-3/4	6-3/4	5-3/4	5-3/4	7-1/2	7-1/2	10
P	1-3/4	1-7/8	1-7/8	1-7/8	2-1/2	2-1/2	2-1/2	2-1/2	1-1/4	1-1/4	2-1/4
Q	3-1/8	3-3/4	3-3/4	3-3/4	4-1/2	4-1/2	4-1/2	4-1/2	3-5/16	3-5/16	11-7/16
Rnps	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
S	4-1/2	4-5/8	4-5/8	4-5/8	5-7/8	5-7/8	5-7/8	5-7/8	1-1/4	1-1/4	2-1/4
T	8-1/4	10-3/4	10-3/4	10-3/4	16-5/8	16-5/8	16-5/8	16-5/8	22	22	20
V	2	2	2	2-1/2	2-1/2	2-1/2	3	3	4	4	5
W	6-1/4	6-1/2	6-1/2	6-1/2	7-3/4	7-3/4	7-3/4	7-3/4	12	12	8-11/16
Net Wt.	250	320	335	380	600	680	740	745	1500	1810	3000
Domestic Wt. (lbs)	275	345	360	408	718	728	778	783	1547	1867	3100
Export Wt. (lbs)	340	420	435	480	820	820	880	885	1720	2090	3250
Export Cubic Ft.	9.5	9.5	9.5	10.3	17.5	17.5	17.5	17.5	38.9	38.9	66.0
Oil Cap Quarts	6	7	7	7	13	13	13	13	24	24	40

NOTE: Table is for standard gear drives only. For solid-shaft, opposed, or EHT bearings, contact factory for dimension print.

Water Well Solutions

Fox Island Division
Habitat Rehabilitation and Enhancement, Pool 20
Alexandria, Missouri

Wells "G" and "H"

Well & Pump Data

October 2012

Prepared For:

Kolb Grading, LLC
St. Charles, Missouri

Prepared By:

Water Well Solutions Illinois Division, LLC
Elburn, Illinois

Water Well Solutions Illinois Division * 44W158 Keslinger Road B * Elburn, Illinois 60119
Toll Free: (888) 769-9009 * Fax: (920) 474-4771 * Web: www.wwssg.com

Water Well Solutions

Table of Contents

Section 1

MISSOURI DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY PROGRAM

WELL PLUGGING REGISTRATION RECORD

OFFICE USE ONLY	
REFERENCE NO.	DATE RECEIVED
REVENUE NO.	CHECK NO.

STATE WELL NO.	ENTERED	APPROVED BY
	PH 1 PH2 PH3	ROUTE

INFORMATION SUPPLIED BY WELL OR PUMP INSTALLATION CONTRACTOR

OWNER NAME: Department of the Army		TELEPHONE NUMBER WITH AREA CODE: (309) 637-1321 Ext. 6803	
OWNER ADDRESS: Clock Tower Building - PO Box 2004	CITY: Rock Island	STATE: IL	ZIP CODE: 61204 - 2004
ADDRESS OF WELL SITE (IF DIFFERENT THAN ABOVE): Clark County Missoure	CITY: Alexandria	STATE: MO	ZIP CODE: 63430 -
SITE NAME: Fox Island Division Habitat, Pool 20	WELL NUMBER:	INFORMATION VERIFIED BY OWNER SIGNATURE (WELL OWNER):	DATE:

SMALLEST LARGEST
SW ¼ NW ¼ NW ¼
Sec. 19 Township 64 North 5 Range ☐ East ☑ West

LOCATION OF WELL
LAT. ____ ° ____ ' ____ "
LONG. ____ ° ____ ' ____ "

AREA
ELEV 488 ft.
COUNTY Clark

WELL CERTIFICATION NUMBER (IF APPLICABLE):
VARIANCE NUMBER (IF APPLICABLE):

ABANDONMENT INFORMATION

FORMER USE OF WELL
☐ Hand Dug ☑ Irrigation
☐ Domestic ☐ Multi-Family
☐ Public Water Supply ☐ Heat Pump
☐ Mineral Exploratory Test Hole
☐ Soil/Vapor Probe ☐ Other ____

ORIGINAL DRILLER (IF KNOWN):
DATE ORIGINALLY DRILLED (IF KNOWN):
STATIC WATER LEVEL: 6 ft.

DEPTH OF THE WELL: 48 ft.
LENGTH OF CASING: Unknown ft.
CASING DIAMETER: 12 in.
DRILL HOLE DIAMETER (IF KNOWN): in.

PUMP REMOVED FROM WELL? ☑ Yes ☐ No
WAS THE CASING CUT OFF THREE FEET BELOW GROUND SURFACE ☑ Yes ☐ No ☐ Removed
TYPE OF CASING ☐ Plastic ☐ Concrete ☑ Steel ☐ Other ____

GROUT INSTALLATION METHOD
☑ Gravity
☐ Tremie
☐ Excavation

GROUT MATERIAL USED
Neat Cement: ☐ Hi-Early ☐ Type 1
Bentonite: ☐ Slurry ☐ Granular ☐ Pellets ☑ Chips ☐ Other ____

HOW MANY GALLONS OF WATER MIXED PER BAG OF CEMENT OR BENTONITE? 5 gallons
NUMBER OF BAGS OF GROUT USED:
POUNDS OF GROUT PER BAG: 2,500 lbs.

TYPE OF FILL MATERIAL USED
☐ Gravel ☐ Ag-Lime
☐ Sand ☐ Other ____

AMOUNT OF FILL MATERIAL USED: 0 ☐ Cu. Yds. ☐ Tons
DEPTH TO TOP OF FILL MATERIAL FROM THE SURFACE: No fill used ft.

MULTIPLE WELLS
☐ Yes ☑ No

WAS THE WELL ABANDONED BECAUSE OF HOOKING UP TO A PUBLIC OR RURAL WATER SUPPLY DISTRICT? ☐ Yes ☑ No
IF YES, PROVIDE THE NAME OF THE WATER DISTRICT:

WELL CHLORINATED BEFORE PLUGGING? ☑ Yes ☐ No
AMOUNT USED FOR THE CHLORINATION
☐ Gallons of Chlorine
☑ Pounds of Chlorine 5 lbs.
☐ Tablets of Chlorine
DATE WELL WAS PLUGGED: 05/16/2012

REASON WELL WAS PLUGGED
No longer need as an irrigation well.

REMARKS
Well was sealed from the bottom to 3 feet below grade with bentonite chips.

I hereby certify that the well herein described was plugged in accordance with Missouri Department of Natural Resources requirements for the plugging of wells.

SIGNATURE	PERMIT NUMBER	DATE
SIGNATURE (PRIMARY CONTRACTOR): [signature]	001560-WPM	6/19/2012
SIGNATURE (CONTRACTOR)		
SIGNATURE (APPRENTICE)		

MO 780-1603 (04-12) DISTRIBUTION: WHITE – DIVISION CANARY – DRILLER PINK – OWNER
RETURN COMPLETED FORM TO: MISSOURI DEPARTMENT OF NATURAL RESOURCES, DIVISION OF GEOLOGY AND LAND SURVEY, WELLHEAD PROTECTION SECTION
PO BOX 250, ROLLA, MO 65402 PHONE: 573-368-2165

Section 2

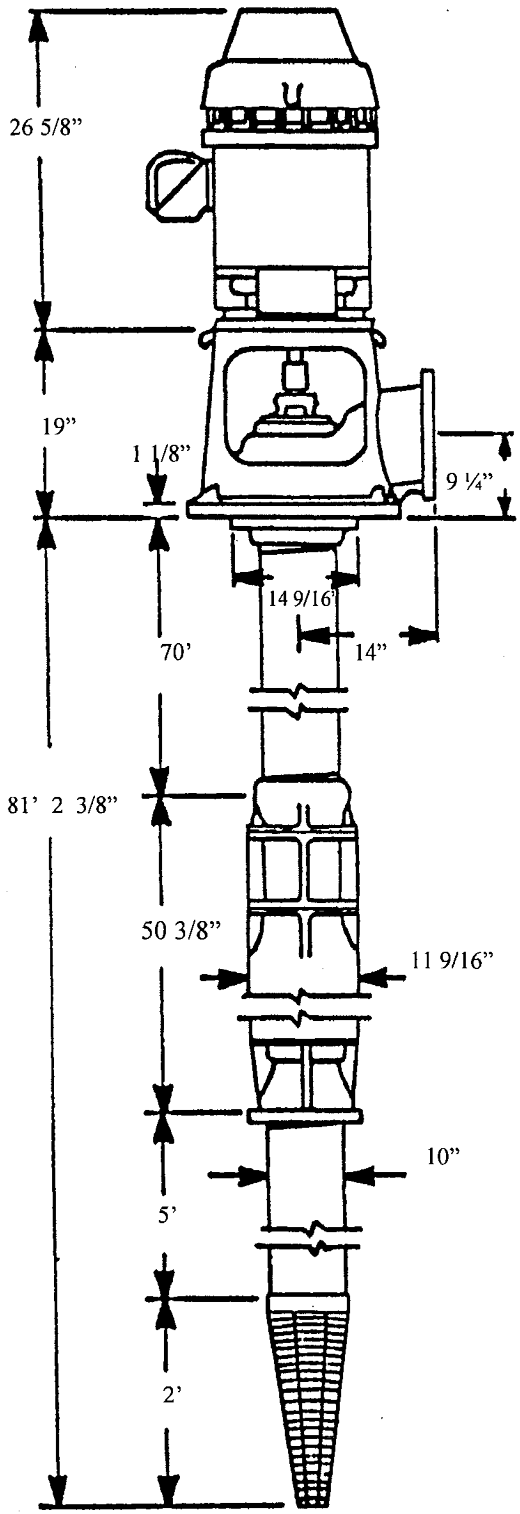
Water Well Solutions

Toll Free (888)769-9009 www.waterwellsolutions.com

VERTICAL TURBINE PUMP AND WELL DATA

Upper Brg. ______
Lower Brg. ______

Customer	Fox Island Refuge
Well No.	"G"
Project No.	WK10-331
Date	10/20/12



RIGHT ANGLE GEAR DRIVE

Make	Randolph		
Type	G125	NRR	Yes
HP	125	RPM	1760
Phase	N/A	CD	22 ½"
Voltage	N/A		
Ratio	1:1		
Serial #	R1210024		
HeadshaftSize	1 ½"		
Headshaft lgth	29 ¾"		

PUMP

C.I.Discharge HD	10" 16.5"		
Lineshaft	1 ½"	Col	10"
Shaft tube	N/A		
Prod lube	X	Oil lube	
Type	12 FDLC	Stage	3
GPM	1650	TDH	127'
Impeller	Enclosed 7.375"		
Suction case	Bell ☐	Case	☒
Mfg.	Goulds		
Serial #	3N762-1		

MATERIAL

Col pipe	Steel SCH.40 A53 GRD B	Pump bowl	Cast Iron
Line shaft	416 Stainless Steel	Impeller	Bronze
Shaft tube	N/A	Bearings (bowl)	Bronze
Bowl shaft	416 Stainless Steel	Bearings (lineshaft)	Rubber
Shaft packing	Graphite	Wear rings	Bronze

COL. DETAIL

Top	1 10" x 5'
Intermediate	5 – 10" x 9' 11 ¼"
Bottom	1 - 10' x 4' 11 ¼"
Spec coating	None
Strainer	304 Stainless Steel
Top lineshaft length	63"
Airline mat'l	¼" Plastic (2)
Length	70'
Sole plate	None
Size	
Installer	Andy B.

WELL DATA

Inside diameter	14"		
Well depth from grade	111 FT		
Pump setting above grade	18"		
Diameter of screen	14"		
Screen length	86' 4 3/8"		
Slot	.030" & .060"		
Gravel pack	X	Tubular	
Size of gravel pack	#40 & #80		

PUMP TEST DATA

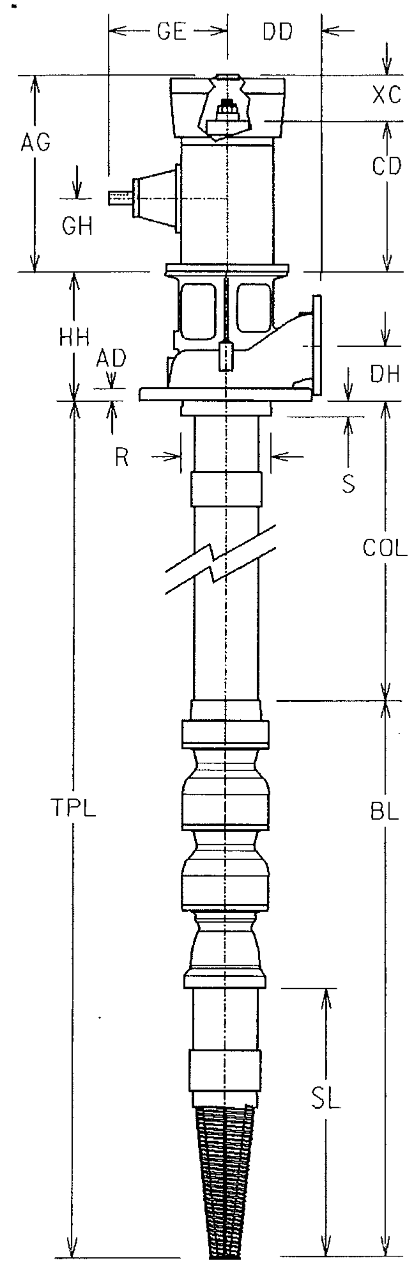
Static level 36 Ft.

Capacity (GPM)	Pumping level	
1650	45	Ft.
1650	45	Ft.
1650	45	Ft.
		Ft.

Comments Complete new installation

WATER WELL SOLUTIONS
WELL G

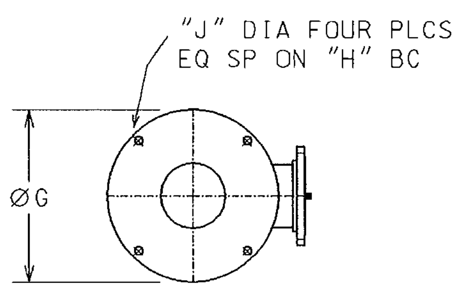
DIMENSIONAL OUTLINE
DWT-CATG
3 Stage 10x12FDLC



ELEV 390.0' BOTTOM OF WELL

Pump Data

AD:	1.13		
AG:	26.69	Size:	12FDLC
BD:	16.5	Stages:	3
BL:	50.38		
CD:	22.63	BowlShaft:	1.94"
CL:	N/A		
COL:	70.00'	LineShaft:	1.5"
DD:	14.00"	LineShaft Type:	Open
		Column:	Standard
DH:	9.25	Column:	10" Threaded
G:	25.00	Bearing Spacing:	10 feet
H:	22.75	Section Length:	10 feet
HH:	19.00	Head:	A:Cast
J:	0.75	Flange (Disch.):	10"-125# FF
R:	14.60	Inlet:	
S:	2.38		
SL:	60.00	Seal:	Packing
TPL:	79.2'	Strainer:	Cone
UG:	N/A	SubBase:	None
V:			
W:			
X:			
XC:			
GE:			
GH:			
MAX:	11.60		



DISC HEAD

Hydraulic Data

Flow (gpm):	1650
Pump Head (ft):	75.0
TDH (ft):	127.0
Speed (rpm):	1770
Fluid:	Water
Temperature (F):	60
Viscosity:	1.105
Spec.Grav:	1

Miscellaneous

Thrust At Design (lb):	2416
Thrust At Shutoff (lb):	3781
Min Water Level(in):	600

Weight

Pump (lb):	4213
Gear:	390
Total (lb):	4603

Gear Drive Data

Refer to gear drive dimension sheet

Mfg:	RANDOLPH
Model:	G125
Input RPM:	1770
Ratio:	1-1
Efficiency:	96
Non-Reverse:	Yes

Version: 3.53P

Customer:

Date: 07-10-2012

WATER WELL SOLUTIONS

HYDRAULIC ANALYSIS
DWT-CATG
3 Stage 10x12FDLC

Overall Pump Parameters

Size and Model:	12FDLC	Pump Operating Speed, RPM:	1770
Capacity, GPM:	1650	Total Dynamic Head, Ft.:	127.0
Total Pump Length, In.:	950.4	Impeller Trim, In.:	7.4
Pump Type:	Well	Head Type:	A:Cast
Pump K-Factor:	15	Number of Stages:	3
		Pumping Level, In.:	600.0

LineShaft-Related Data

Shaft Diameter, In.:	1.5	Shaft Limit, HP:	256
Shaft Material:	416SS	Matl Correction Fact:	1.18
LineShaft Length, In.:	840.00	Shaft Elongation, w/o Adder:	0.03
LineShaft Type:	Open	Impeller Running Clearance:	0.13

Bowl Data

Total Bowl Length, In.:	110.38	Bowl Diameter, In.:	11.6
Bowl Shaft Dia, In.:	1.94	Bowl Shaft Limit, HP:	588
		Bowl Shaft Material:	416SS

Column Data

Column Diameter, In.:	10	Column Load, Lb.:	1892.3
Wall Thickness, In:	0.365	Column Elongation, In.:	0.00

HorsePower Data

Shaft Friction Loss, Hp.:	0.77	Thrust Load Loss, Hp.:	0.32
Bowl HP At Design, Hp.:	63		

Head Data

Column Loss, Ft.:	1.53	Head Loss, Ft.:	0.52
		Total Loss, Ft.:	2.05

Other Data

Hydraulic Thrust, Lb.:	1905.0	Thrust at Design, Lb.:	2416.0
Thrust at Shutoff, Lb.:	3780.8	Design NPSH, Ft.:	19.6
Available Lateral, In.:	0.75	Design Lateral, In.:	0.16
Shutoff Lateral, In.:	0.18	Actual Head above Grade, Ft.:	74.95
Suction Pressure, psi:	0.0	Shutoff Disc Pressure, psi:	73.4

Efficiency Data (Efficiencies estimated not guaranteed)

Bowl Efficiency:	83.90	Pump Efficiency:	81.14
Gear Efficiency:	96.00	Overall Efficiency:	77.89
		KWH/1000 gallons:	0.51

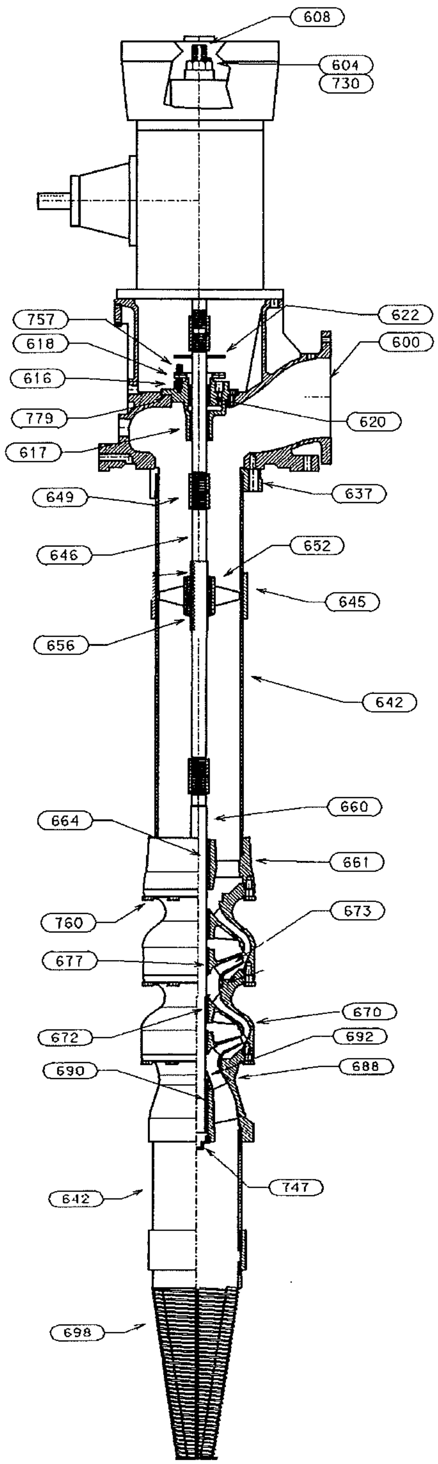
Component Weights

Bowl Weight, Lbs.:	663	Column Weight,Lbs.:	3010
Head Weight, Lbs.:	540	Can Weight,Lbs.:	0
Gear Weight, Lbs.:	390	Total Pump Weight,Lbs.:	4603

Version: 3.53P Customer: Date: 07-10-2012

WATER WELL SOLUTIONS

SECTIONAL
DWT-CATG
3 Stage 10x12FDLC



DISCHARGE HEAD ASSEMBLY

ITEM	NAME	Code	MATERIAL	ASTM
600	HEAD- DISCHARGE	1003	CAST IRON CL30	A48-94ae1
604	NUT- ADJUSTING	2130	BRASS C36000	B16M-00
608	HEADSHAFT	2227	SST 416	A582M-95b
616	HOUSING	1003	CAST IRON CL30	A48-94ae1
617	BEARING- HOUSING	1109	FEDERALLOY BISMUTH BRZ	B584-00
618	GLAND- SPLIT	1203	SST 316	A744M-00
620	PACKING	5026	GRAPHITE PACKING	ML402-99
622	SLINGER	5121	RUBBER EPDM	D3568-98
637	COLUMN FLANGE	1003	CAST IRON CL30	A48-94ae1
730	KEY- MOTOR GIB	2242	CARBON STEEL 1018	A108-99
757	SCREW- GLAND ADJUSTING	2229	SST 316	A276-00a
779	GASKET- HOUSING	5136	ACRYLIC/NITRILE	5136 REV 4

COLUMN AND LINESHAFT ASSEMBLY

642	COLUMN PIPE	6501	BLACK PIPE SCH 40	A 53-98
645	COLUMN COUPLING	6501	BLACK PIPE SCH 40	A 53-98
646	LINESHAFT	2227	SST 416	A582M-95b
649	LINESHAFT COUPLING	2265	SST 416	A582M-95b
652	RETAINER- BEARING	1102	SILICON BRONZE C87600	B584-00
656	LINESHAFT BEARING	5121	RUBBER EPDM	D3568-98

BOWL ASSEMBLY

642	COLUMN PIPE	6501	BLACK PIPE SCH 40	A 53-98
660	SHAFT- BOWL	2218	SST 416	A582M-95b
661	BOWL- DISCHARGE	1003	CAST IRON CL30	A48-94ae1
664	BEARING- DISC BOWL	1109	FEDERALLOY BISMUTH BRZ	B584-00
670	BOWL- INTERMEDIATE	6911	CAST IRON CL30 ENAMEL	A48-94e1
672	BEARING- INT BOWL	1109	FEDERALLOY BISMUTH BRZ	B584-00
673	IMPELLER	1102	SILICON BRONZE C87600	B584-00
677	COLLET- IMPELLER	2218	SST 416	A582M-95b
688	BOWL/BELL- SUCTION	1003	CAST IRON CL30	A48-94ae1
690	BEARING- SUCTION	1109	FEDERALLOY BISMUTH BRZ	B584-00
692	SANDCOLLAR	1109	FEDERALLOY BISMUTH BRZ	B584-00
698	STRAINER- SUCTION	6913	SST 316 XPND METAL FL	A555-97
747	PLUG- PIPE	1046	MALLEABLE IRON	A197
760	CAPSCREW- HEX	2229	SST 316	A276-00a

Version: 3.53P　　Customer:　　Date: 07-10-2012

WATER WELL SOLUTIONS
Tim Kelly

ADDERS
DWT-CATG
3 Stage 10x12FDLC

ADDITIONAL PUMP COMPONENTS

The following is a list of the additional components you ordered.
Consult factory for any other components or services.

Component

Strainer
SST Strainer
Bowl SS Bolting
Bronze Wear Rings
416SS Collets
Bowl Assembly Test
Head Hydro Test:
Performance Test

Version: 4.08NO | Customer: Alexandria MO Well G | Date: 11-05-2010

GICON PUMPS & EQUIPMENT®

Engineered Products Division

Pumping Solutions Icon

Customer: WATER WELL SOLUTIONS
PO: WK10-331
Project: 12FDLC-3STG
Order #: 3N76Z
Date: 9/20/2012 10:05:13AM

Pump Model:	12FDLC	**Design Flow (GPM):**	1650.0	**Specific Gravity:**	1.00
Pump Type:	LINESHAFT	**Design Head (Ft):**	127.0	**Viscosity (SSU):**	1.1
Pump Number:	3N76Z-PUMP 2	**Efficiency (%):**	76.0	**Water Temp (F):**	74.0
Stages:	3	**Motor:**	North American	**Test Line:**	6"
Upper Impeller Dia:	7.7200	**Motor SN:**	1006008	**Upper Bowl Material:**	CI
Upper Impeller Qty:	3	**Motor HP:**	75.0	**Lower Bowl Material:**	N/A
Lower Impeller Dia:	0.0000	**Nominal RPM:**	1770.0	**Upper Imp Material:**	SB
Lower Impeller Qty:	0	**Design RPM:**	1770.0	**Lower Imp Material:**	N/A

Test Data

GPM	RPM	PSI	Head (ft)	Vel Head Loss (ft)	Pipe Friction (ft)	Total TDH (ft)	kW Input	Brake HP*	EFF (%)	
0	1779	106.75	252.09	0.00	0.00	252.09	62.91	77.29	0.00	
535	1780	92.47	219.11	0.07	0.01	219.19	60.07	73.84	40.10	
1000	1779	81.25	193.19	0.26	0.02	193.46	64.21	79.01	61.83	
1397	1779	69.67	166.45	0.50	0.03	166.98	65.51	80.67	73.02	
1658	1778	62.49	149.85	0.71	0.05	150.61	66.88	82.40	76.53	**
1934	1778	52.68	127.19	0.96	0.06	128.21	66.82	82.38	76.01	
2037	1778	48.59	117.74	1.07	0.07	118.88	66.24	81.67	74.87	

Converted Data

GPM	RPM	PSI	Head (ft)	Vel Head Loss (ft)	Pipe Friction (ft)	Total TDH (ft)	kW Input	Brake HP*	EFF (%)	
0	1770	106.75	249.42	0.00	0.00	249.42	62.91	76.07	0.00	
532	1770	92.47	216.54	0.07	0.01	216.62	60.07	72.55	40.10	
995	1770	81.25	191.24	0.25	0.02	191.51	64.21	77.82	61.82	
1390	1770	69.67	164.85	0.50	0.03	165.38	65.51	79.52	73.01	
1650	1770	62.49	148.50	0.70	0.05	149.24	66.88	81.29	76.52	**
1925	1770	52.68	126.03	0.95	0.06	127.05	66.82	81.26	76.00	
2028	1770	48.59	116.65	1.06	0.07	117.77	66.24	80.54	74.86	

* Motor HP from manufacturer's curve minus losses.
** Design Point.

NPSH Typical Catalog Data

NPSHr	16.2	17.3	18.4	19.6	22.4	22.4	22.4
Flow	660.0	990.0	1320.0	1650.0	1980.0	1980.0	1980.0

Customer Approval

By: D. Mal Bake
Title: QC Kolb Grading
Date: 9-20-12

Certified Test

By: Eddie Jaramillo
Title: Engineer
Date: 9-20-12

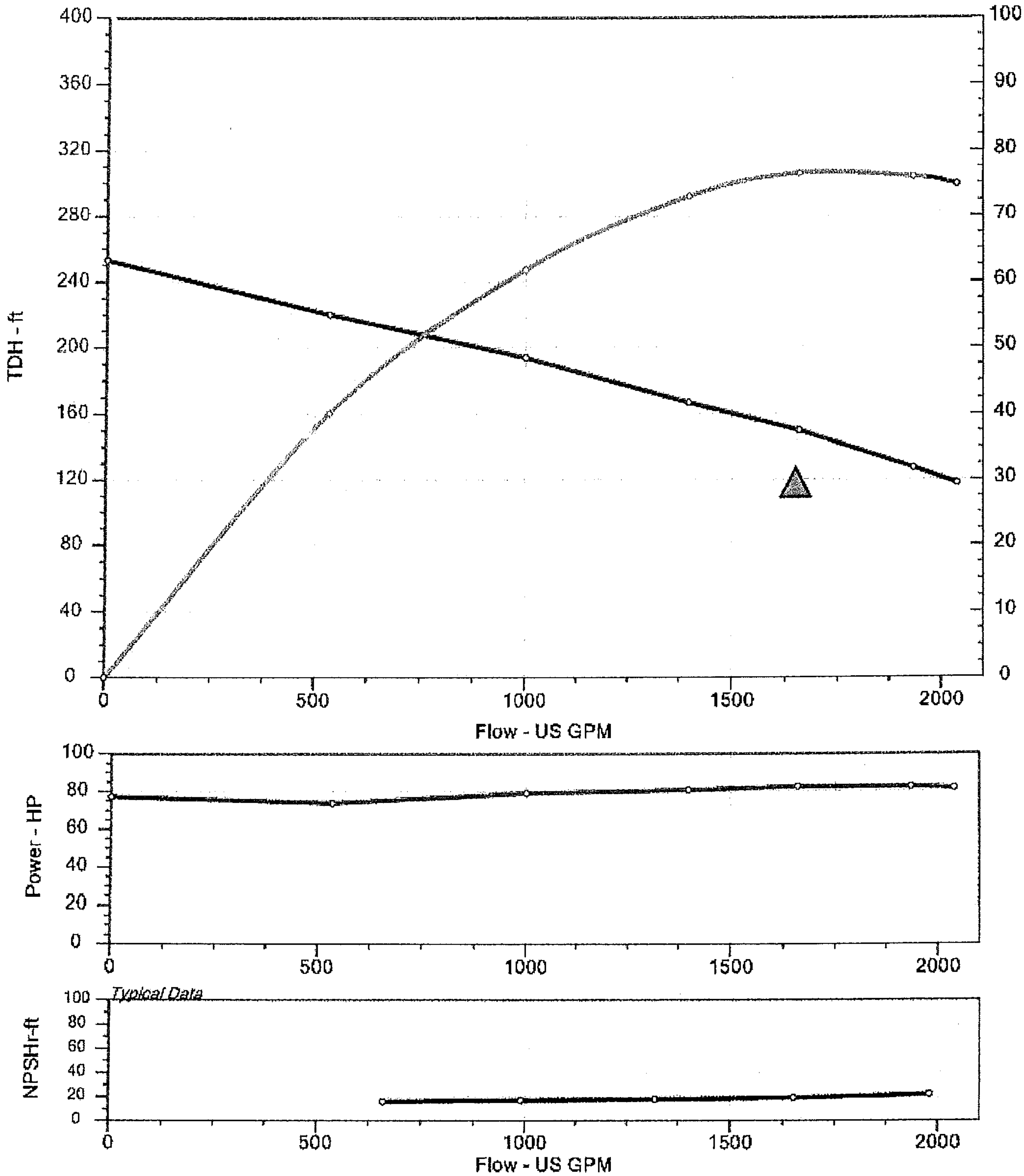
GICON PUMPS & EQUIPMENT®

Engineered Products Division

Pumping Solutions Icon

Customer: WATER WELL SOLUTIONS
PO: WK10-331 **Project:** 12FDLC-3STG
Order #: 3N76Z
Date: 9/20/2012 10:05:13AM

Raw Data



Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project	Fox Island Refuge				Date Tested	10/23/2012	
Location	Well "G"				Job No.	WK10-331	
Depth of Well (ft)	111	Well Diameter (in)	14.0	Pump Size	12 FDLC	Orifice	8 x 7
Ground Elev. (ft)	503	Measuring Point Elevation(ft)	Top of Casing	Well Type	Gravel Packed		
Airline Length (ft)	70	Non-Pumping Water Level (ft)	36	Tested By	Tim Kelly		

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
1:15	39.0	1650	25.0	45.0	9.0	46.0	151.3	183.3	Drive Eng. 1800 RPM
1:45	39.0	1650	25.0	45.0	9.0	46.0	151.3	183.3	
2:00	39.0	1650	25.0	45.0	9.0	46.0	151.3	183.3	
2:15	39.0	1650	25.0	45.0	9.0	46.0	151.3	183.3	

NOTE: 1 hour pump test on new pump in well.

Section 3

Water Well Solutions

Toll Free (888)769-9009 www.waterwellsolutions.com

VERTICAL TURBINE PUMP AND WELL DATA

Upper Brg. ____________

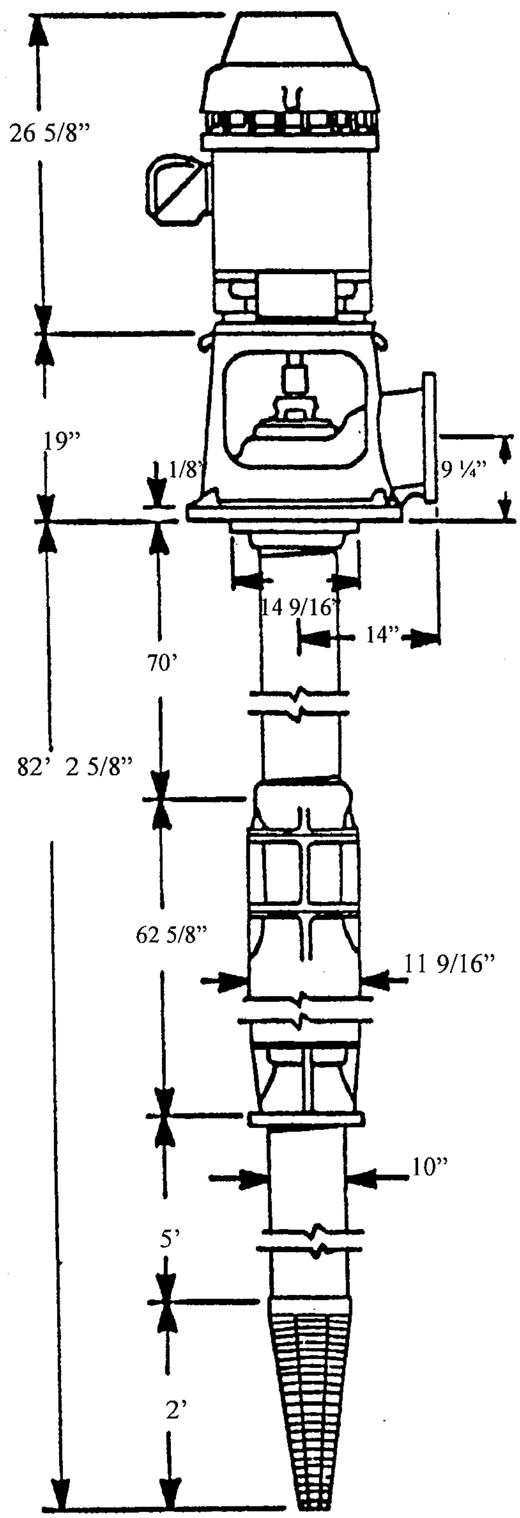
Lower Brg. ____________

Customer: Fox Island Refuge

Well No.: "H"

Project No.: WK10-331

Date: 10/20/12



MOTOR

Right Angle Gear Drive

Make	Randolph		
Type	G125	NRR	Yes
HP	125	RPM	1760
Phase	N/A	CD	22 ½"
Voltage	N/A		
Ratio	1:1		
Serial #	R1210025		
HeadshaftSize	1 ½"		
Headshaft lgth	29 ¾"		

PUMP

C.I.Discharge HD	10" x 16.5"		
Lineshaft	1 ½"	Col	10"
Shaft tube	N/A		
Prod lube	X	Oil lube	
Type	12 FDLC	Stage	4
GPM	1700	TDH	147'
Impeller	Enclosed 7.125"		
Suction case	Bell ☐	Case	☒
Mfg.	Goulds		
Serial #	3N762-2		

MATERIAL

Col pipe	Steel SCH 40 A53 GRD B	Pump bowl	Cast Iron
Line shaft	416 Stainless Steel	Impeller	Bronze
Shaft tube	N/A	Bearings (bowl)	Bronze
Bowl shaft	416 Stainless Steel	Bearings (lineshaft)	Rubber
Shaft packing	Graphite	Wear rings	Bronze

COL. DETAIL

Top	1 – 10" x 5'
Intermediate	5-10" x 9' 11 1/4
Bottom	1 – 10" x 4' 11 1/4
Spec coating	None
Strainer	304 Stainless Steel
Top lineshaft length	63"
Airline mat'l	¼" Plastic (2)
Length	70 FT
Sole plate	None
Size	
Installer	Andy B

WELL DATA

Inside diameter	14"		
Well depth from grade	116 FT		
Pump setting above grade	18"		
Diameter of screen	14"		
Screen length	95' 8"		
Slot	.030" & .060"		
Gravel pack	X	Tubular	
Size of gravel pack	#40 & #80		

PUMP TEST DATA

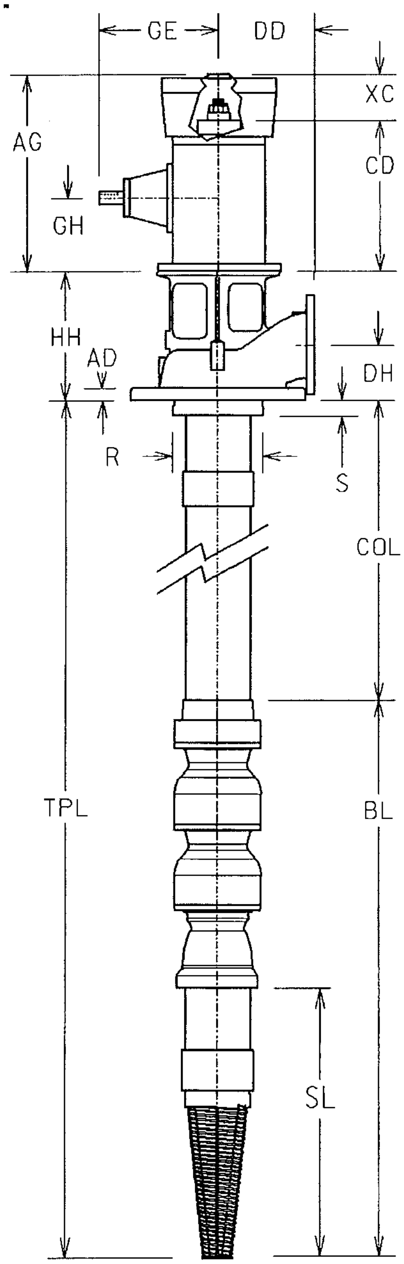
Static level 36 Ft.

Capacity (GPM)	Pumping level
1700	38 Ft.
1700	38 Ft.
1700	38 Ft.
	Ft.

Comments: Complete new installation

WATER WELL SOLUTIONS
WELL H

DIMENSIONAL OUTLINE
DWT-CATG
4 Stage 10x12FDLC

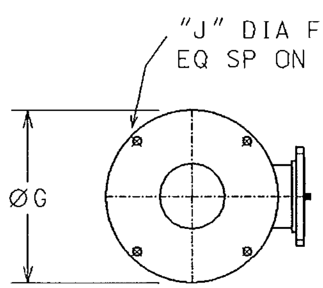


ELEV 371.6' BOTTOM OF WELL

AD:	1.13
AG:	26.69
BD:	16.5
BL:	62.63
CD:	22.63
CL:	N/A
COL:	70.00'
DD:	14.00
DH:	9.25
G:	25.00
H:	22.75
HH:	19.00
J:	0.75
R:	14.60
S:	2.38
SL:	60.00
TPL:	80.2'
UG:	N/A
V:	
W:	
X:	
XC:	
GE:	
GH:	
MAX:	11.60

Pump Data

Size:	12FDLC
Stages:	4
BowlShaft:	1.94"
LineShaft:	1.5"
LineShaft Type:	Open
Column:	Standard
Column:	10" Threaded
Bearing Spacing:	10 feet
Section Length:	10 feet
Head:	A:Cast
Flange (Disch.):	10"-125# FF
Inlet:	
Seal:	Packing
Strainer:	Cone
SubBase:	None



DISC HEAD

Hydraulic Data

Flow (gpm):	1700
Pump Head (ft):	94.8
TDH (ft):	147.0
Speed (rpm):	1770
Fluid:	Water
Temperature (F):	60
Viscosity:	1.105
Spec.Grav:	1

Miscellaneous

Thrust At Design (lb):	2744
Thrust At Shutoff (lb):	4649
Min Water Level(in):	600

Weight

Pump (lb):	4342
Gear:	390
Total (lb):	4732

Gear Drive Data

Refer to gear drive dimension sheet

Mfg:	RANDOLPH
Model:	G125
Input RPM:	1770
Ratio:	1-1
Efficiency:	96
Non-Reverse:	Yes

Version: 3.53P

Customer:

Date: 07-10-2012

WATER WELL SOLUTIONS

HYDRAULIC ANALYSIS
DWT-CATG
4 Stage 10x12FDLC

Overall Pump Parameters

Size and Model:	12FDLC	Pump Operating Speed, RPM:	1770
Capacity, GPM:	1700	Total Dynamic Head, Ft.:	147.0
Total Pump Length, In.:	962.6	Impeller Trim, In.:	7.1
Pump Type:	Well	Head Type:	A:Cast
Pump K-Factor:	15	Number of Stages:	4
		Pumping Level, In.:	600.0

LineShaft-Related Data

Shaft Diameter, In.:	1.5	Shaft Limit, HP:	256
Shaft Material:	416SS	Matl Correction Fact:	1.18
LineShaft Length, In.:	840.00	Shaft Elongation, w/o Adder:	0.04
LineShaft Type:	Open	Impeller Running Clearance:	0.13

Bowl Data

Total Bowl Length, In.:	122.63	Bowl Diameter, In.:	11.6
Bowl Shaft Dia, In.:	1.94	Bowl Shaft Limit, HP:	588
		Bowl Shaft Material:	416SS

Column Data

Column Diameter, In.:	10	Column Load, Lb.:	2190.3
Wall Thickness, In:	0.365	Column Elongation, In.:	0.01

HorsePower Data

Shaft Friction Loss, Hp.:	0.77	Thrust Load Loss, Hp.:	0.36
Bowl HP At Design, Hp.:	75.4		

Head Data

Column Loss, Ft.:	1.62	Head Loss, Ft.:	0.55
		Total Loss, Ft.:	2.17

Other Data

Hydraulic Thrust, Lb.:	2205.0	Thrust at Design, Lb.:	2744.0
Thrust at Shutoff, Lb.:	4649.4	Design NPSH, Ft.:	19.9
Available Lateral, In.:	0.75	Design Lateral, In.:	0.16
Shutoff Lateral, In.:	0.19	Actual Head above Grade, Ft.:	94.83
Suction Pressure, psi:	0.0	Shutoff Disc Pressure, psi:	97.9

Efficiency Data (Efficiencies estimated not guaranteed)

Bowl Efficiency:	83.60	Pump Efficiency:	81.14
Gear Efficiency:	96.00	Overall Efficiency:	77.90
		KWH/1000 gallons:	0.59

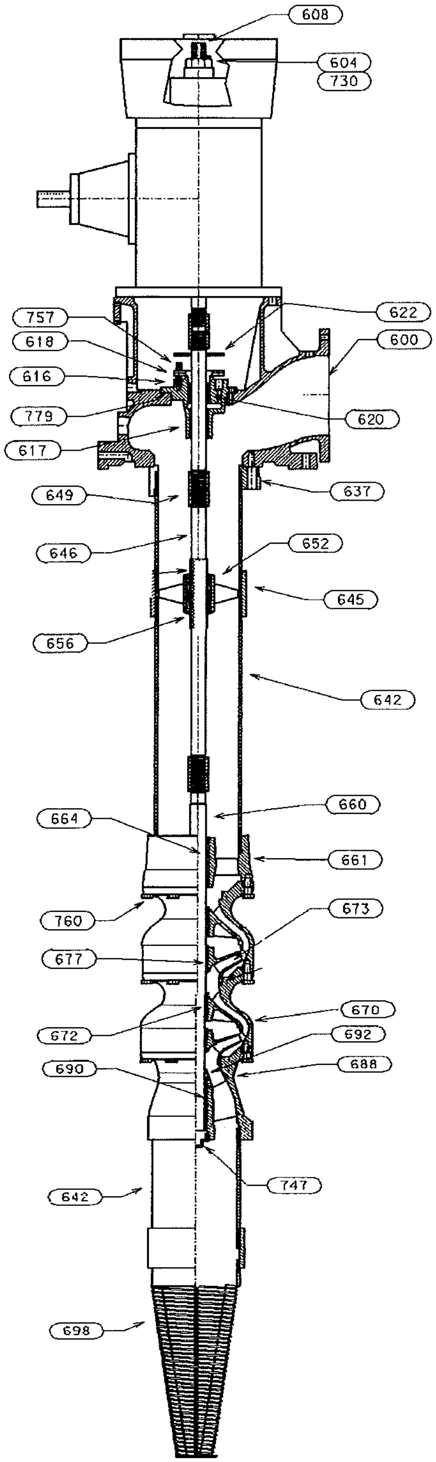
Component Weights

Bowl Weight, Lbs.:	792	Column Weight,Lbs.:	3010
Head Weight, Lbs.:	540	Can Weight,Lbs.:	0
Gear Weight, Lbs.:	390	Total Pump Weight,Lbs.:	4732

Version: 3.53P   Customer: Date: 07-10-2012

WATER WELL SOLUTIONS

SECTIONAL
DWT-CATG
4 Stage 10x12FDLC



DISCHARGE HEAD ASSEMBLY

ITEM	NAME	Code	MATERIAL	ASTM
600	HEAD- DISCHARGE	1003	CAST IRON CL30	A48-94ae1
604	NUT- ADJUSTING	2130	BRASS C36000	B16M-00
608	HEADSHAFT	2227	SST 416	A582M-95b
616	HOUSING	1003	CAST IRON CL30	A48-94ae1
617	BEARING- HOUSING	1109	FEDERALLOY BISMUTH BRZ	B584-00
618	GLAND- SPLIT	1203	SST 316	A744M-00
620	PACKING	5026	GRAPHITE PACKING	ML402-99
622	SLINGER	5121	RUBBER EPDM	D3568-98
637	COLUMN FLANGE	1003	CAST IRON CL30	A48-94ae1
730	KEY- MOTOR GIB	2242	CARBON STEEL 1018	A108-99
757	SCREW- GLAND ADJUSTING	2229	SST 316	A276-00a
779	GASKET- HOUSING	5136	ACRYLIC/NITRILE	5136 REV 4

COLUMN AND LINESHAFT ASSEMBLY

642	COLUMN PIPE	6501	BLACK PIPE SCH 40	A 53-98
645	COLUMN COUPLING	6501	BLACK PIPE SCH 40	A 53-98
646	LINESHAFT	2227	SST 416	A582M-95b
649	LINESHAFT COUPLING	2265	SST 416	A582M-95b
652	RETAINER- BEARING	1102	SILICON BRONZE C87600	B584-00
656	LINESHAFT BEARING	5121	RUBBER EPDM	D3568-98

BOWL ASSEMBLY

642	COLUMN PIPE	6501	BLACK PIPE SCH 40	A 53-98
660	SHAFT- BOWL	2218	SST 416	A582M-95b
661	BOWL- DISCHARGE	1003	CAST IRON CL30	A48-94ae1
664	BEARING- DISC BOWL	1109	FEDERALLOY BISMUTH BRZ	B584-00
670	BOWL- INTERMEDIATE	6911	CAST IRON CL30 ENAMEL	A48-94e1
672	BEARING- INT BOWL	1109	FEDERALLOY BISMUTH BRZ	B584-00
673	IMPELLER	1102	SILICON BRONZE C87600	B584-00
677	COLLET- IMPELLER	2218	SST 416	A582M-95b
688	BOWL/BELL- SUCTION	1003	CAST IRON CL30	A48-94ae1
690	BEARING- SUCTION	1109	FEDERALLOY BISMUTH BRZ	B584-00
692	SANDCOLLAR	1109	FEDERALLOY BISMUTH BRZ	B584-00
698	STRAINER- SUCTION	6913	SST 316 XPND METAL FL	A555-97
747	PLUG- PIPE	1046	MALLEABLE IRON	A197
760	CAPSCREW- HEX	2229	SST 316	A276-00a

Version: 3.53P   Customer: Date: 07-10-2012

WATER WELL SOLUTIONS
Tim Kelly

ADDERS
DWT-CATG
4 Stage 10x12FDLC

ADDITIONAL PUMP COMPONENTS

The following is a list of the additional components you ordered.
Consult factory for any other components or services.

Component

Strainer
SST Strainer
Bowl SS Bolting
Bronze Wear Rings
416SS Collets
Bowl Assembly Test
Head Hydro Test:
Performance Test

Version: 4.08NO | Customer:Alexandria MO Well H | Date: 11-04-2010

GICON PUMPS & EQUIPMENT®

Engineered Products Division

Pumping Solutions Icon

Customer: WATER WELL SOLUTIONS
PO: WK10-331
Project: 12FDLC-4STG
Order #: 3N76Z
Date: 9/20/2012 8:23:11AM

Pump Model:	12FDLC	**Design Flow (GPM):**	1700.0	**Specific Gravity:**	1.00
Pump Type:	LINESHAFT	**Design Head (Ft):**	147.0	**Viscosity (SSU):**	1.1
Pump Number:	3N76Z-PUMP 1	**Efficiency (%):**	78.0	**Water Temp (F):**	74.0
Stages:	4	**Motor:**	North American	**Test Line:**	6"
Upper Impeller Dia:	7.7200	**Motor SN:**	1107127	**Upper Bowl Material:**	CI
Upper Impeller Qty:	4	**Motor HP:**	150.0	**Lower Bowl Material:**	N/A
Lower Impeller Dia:	0.0000	**Nominal RPM:**	1780.0	**Upper Imp Material:**	SB
Lower Impeller Qty:	0	**Design RPM:**	1770.0	**Lower Imp Material:**	N/A

Test Data

GPM	RPM	PSI	Head (ft)	Vel Head Loss (ft)	Pipe Friction (ft)	Total TDH (ft)	kW Input	Brake HP*	EFF (%)	
0	1789	140.07	329.06	0.00	0.00	329.06	74.30	92.24	0.00	
510	1789	125.09	294.45	0.07	0.01	294.52	74.76	92.89	40.84	
1042	1788	108.08	255.17	0.28	0.02	255.47	80.76	100.47	66.91	
1426	1788	92.00	218.02	0.52	0.04	218.58	81.80	101.83	77.29	
1717	1788	75.87	180.76	0.76	0.05	181.57	80.50	100.29	78.50	**
1936	1788	62.31	149.44	0.96	0.06	150.46	78.14	97.40	75.52	
2024	1788	55.95	134.75	1.05	0.07	135.87	76.71	95.64	72.61	

Converted Data

GPM	RPM	PSI	Head (ft)	Vel Head Loss (ft)	Pipe Friction (ft)	Total TDH (ft)	kW Input	Brake HP*	EFF (%)	
0	1770	140.07	322.20	0.00	0.00	322.20	74.30	89.39	0.00	
505	1770	125.09	288.34	0.07	0.01	288.41	74.76	90.03	40.83	
1032	1770	108.08	250.08	0.27	0.02	250.37	80.76	97.49	66.90	
1412	1770	92.00	213.71	0.51	0.03	214.25	81.80	98.84	77.28	
1700	1770	75.87	177.15	0.74	0.05	177.94	80.50	97.31	78.49	**
1916	1770	62.31	146.40	0.94	0.06	147.41	78.14	94.46	75.50	
2003	1770	55.95	131.99	1.03	0.07	133.09	76.71	92.73	72.59	

* Motor HP from manufacturer's curve minus losses.

** Design Point.

NPSH Typical Catalog Data

NPSHr	16.3	17.4	18.5	19.9	23.6	23.6	23.6
Flow	680.0	1020.0	1360.0	1700.0	2040.0	2040.0	2040.0

Customer Approval

By: S. Mark Pott

Title: QC Kolb Grading

Date: 9-20-12

Certified Test

By: Eddie [illegible]

Title: Engineer

Date: 9-20-12

GICON PUMPS & EQUIPMENT®

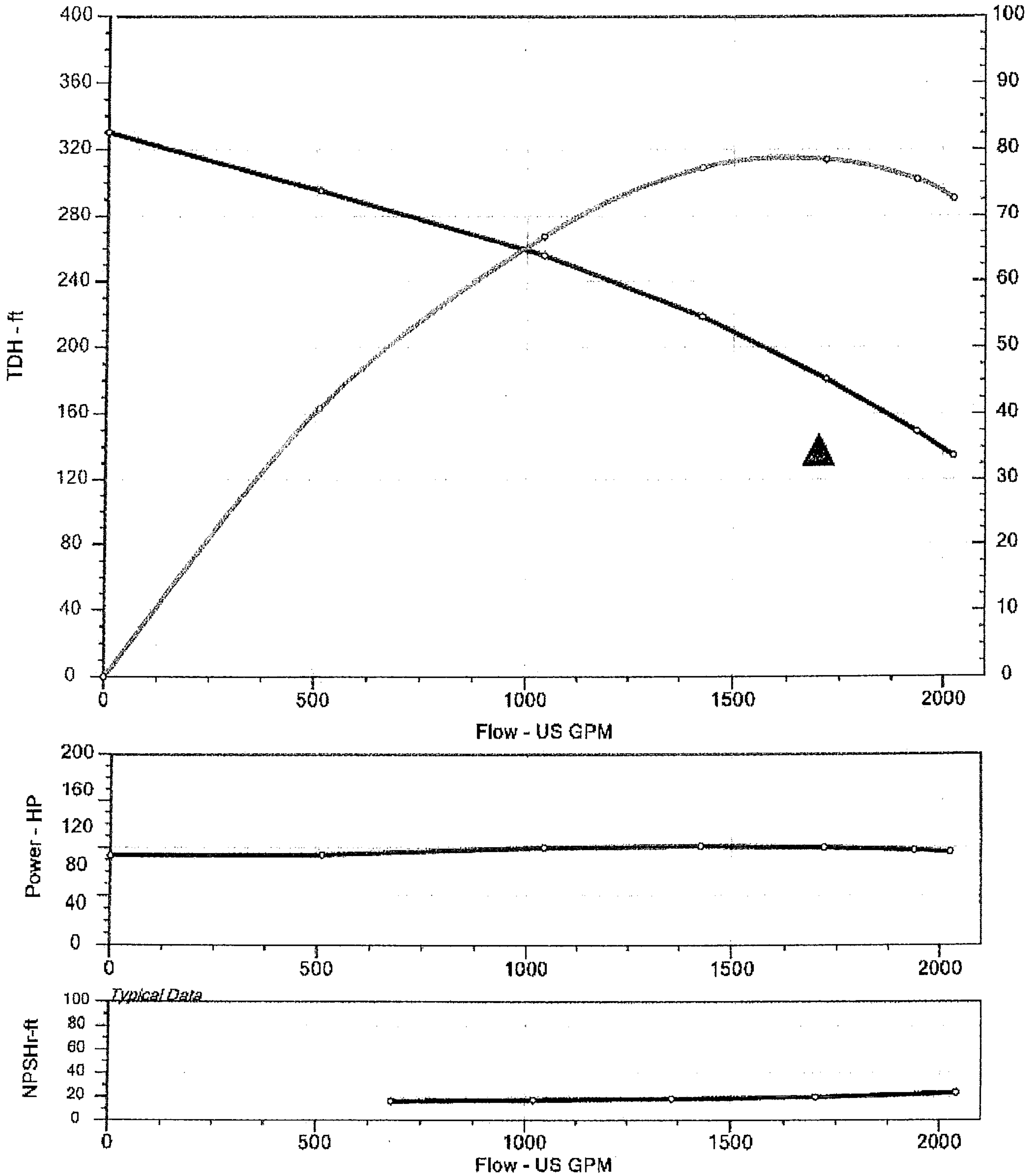
Engineered Products Division

Pumping Solutions Icon

Customer: WATER WELL SOLUTIONS **Order #:** 3N76Z

PO: WK10-331 **Project:** 12FDLC-4STG **Date:** 9/20/2012 8:23:11AM

Raw Data



Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

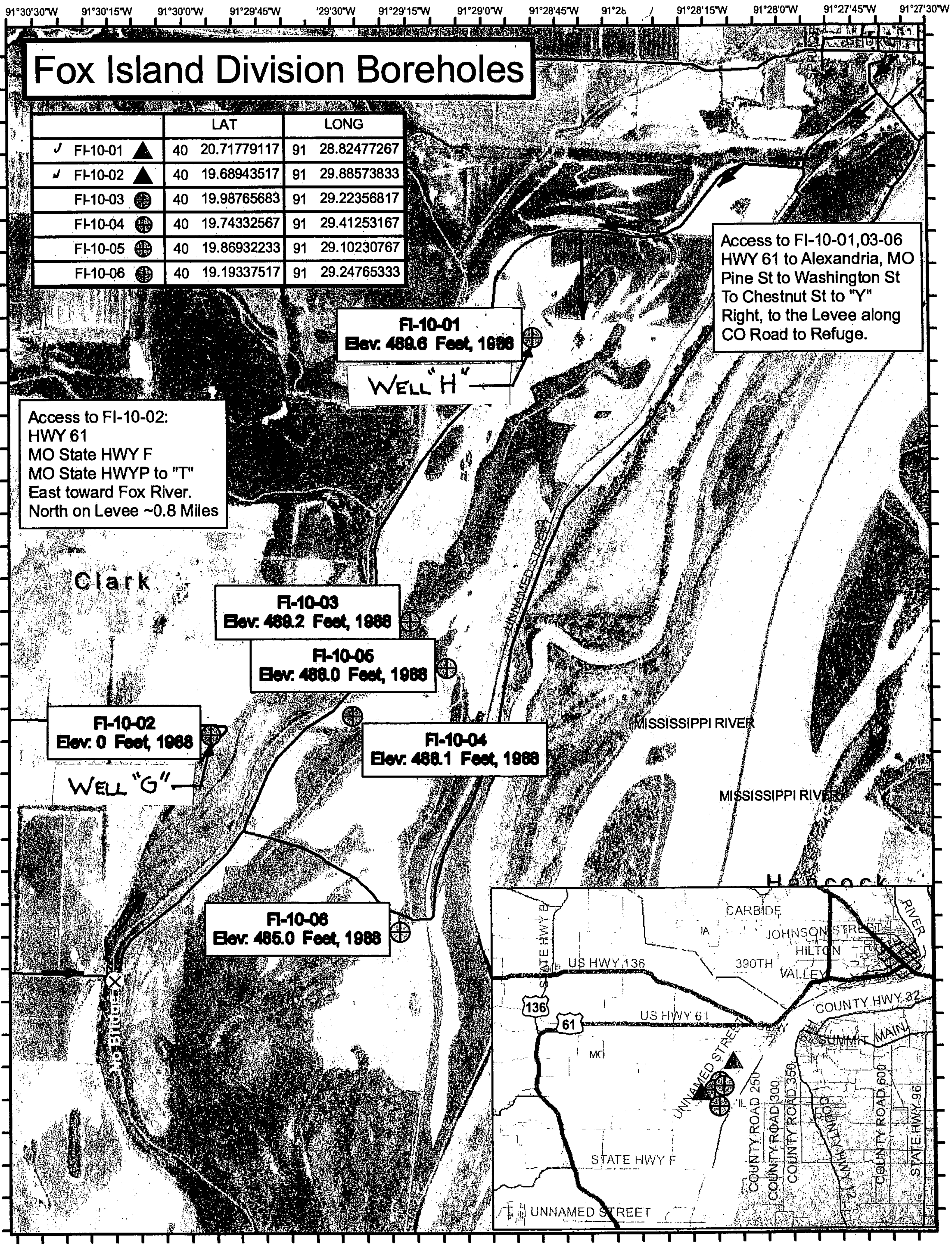
PUMPING TEST DATA SHEET

Project	Fox Island Refuge				Date Tested	10/23/2012	
Location	Well "H"				Job No.	WK10-331	
Depth of Well (ft)	116	Well Diameter (in)	14"	Pump Size	12 FDLC	Orifice	8 x 7
Ground Elev. (ft)	503	Measuring Point Elevation(ft)	Top of Casing	Well Type	Gravel Packed		
Airline Length (ft)	70	Non-Pumping Water Level (ft)	36	Tested By	Tim Kelly		

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
10:15	41.5	1700	32.0	38.0	2.0	55.0	165.1	850.0	Drive Eng. 1800 RPM
10:30	41.5	1700	32.0	38.0	2.0	54.0	162.7	850.0	
11:00	41.5	1700	32.0	38.0	2.0	54.0	162.7	850.0	
11:10	41.5	1700	32.0	38.0	2.0	54.0	162.7	850.0	

NOTE: 1 hour pump test on new pump in well.

Section 4


Fox Island Division Boreholes
LAT LONG
✓ FI-10-01 40 20.71779117 91 28.82477267
✓ FI-10-02 40 19.68943517 91 29.88573833
FI-10-03 40 19.98765683 91 29.22356817
FI-10-04 40 19.74332567 91 29.41253167
FI-10-05 40 19.86932233 91 29.10230767
FI-10-06 40 19.19337517 91 29.24765333
Access to FI-10-01,03-06
HWY 61 to Alexandria, MO
Pine St to Washington St
To Chestnut St to "Y"
Right, to the Levee along
CO Road to Refuge.
FI-10-01
Elev: 489.6 Feet, 1988
WELL "H"
Access to FI-10-02:
HWY 61
MO State HWY F
MO State HWYP to "T"
East toward Fox River.
North on Levee ~0.8 Miles
Clark
FI-10-03
Elev: 489.2 Feet, 1988
FI-10-05
Elev: 488.0 Feet, 1988
FI-10-02
Elev: 0 Feet, 1988
WELL "G"
FI-10-04
Elev: 488.1 Feet, 1988
MISSISSIPPI RIVER
MISSISSIPPI RIVER
UNNAMED STREET
FI-10-06
Elev: 485.0 Feet, 1988
CARBIDE
IA
JOHNSON STREET
HILTON
390TH
VALLEY
US HWY 136
136
US HWY 61
61
COUNTY HWY 32
SUMMIT
MAIN
MO
IL
STATE HWY F
UNNAMED STREET
COUNTY ROAD 250
COUNTY ROAD 300
COUNTY ROAD 350
COUNTY ROAD 600
STATE HWY 96
91°30'30"W
91°30'15"W
91°30'0"W
91°29'45"W
91°29'15"W
91°29'0"W
91°28'45"W
91°28'15"W
91°28'0"W
91°27'45"W
91°27'30"W
40°21'25"N
40°21'15"N
40°21'5"N
40°20'55"N
40°20'45"N
40°20'35"N
40°20'25"N
40°20'15"N
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40°19'55"N
40°19'45"N
40°19'35"N
40°19'25"N
40°19'15"N
40°19'5"N
40°18'55"N
40°18'45"N
40°18'35"N
40°18'25"N

MISSOURI DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY PROGRAM

PUBLIC WELL/HIGH YIELD RECORD

OFFICE USE ONLY	
REF. NO.	DATE RECEIVED
ENTERED	
PH1 PH2 PH3	
CHECK NO.	REVENUE NO.

ROUTE	APPROVED	DATE	STATE CERT. NO.
/ /			

NAME OF BUSINESS, FACILITY OR SITE THE WELL SERVES (REQUIRED)	PHYSICAL ADDRESS OF THE WELL
Corp of Engineers (Well "G")	Fox Island Division Habitat, Pool 20, Alexandria, MO

OWNER NAME	OWNER TELEPHONE NUMBER WITH AREA CODE		
Department of the Army	(309) 637-1321		
OWNER ADDRESS	**CITY**	**STATE**	**ZIP CODE**
Clock Tower Building - Box 2004	Rock Island	Illinois	63430

SEE BACK OF FORM FOR WELL CLASSIFICATIONS

TYPE OF WELL

- ☐ PUBLIC WATER WELL (APPROVAL MUST BE OBTAINED IN ADVANCE BY DNR REGIONAL OFFICE)
- ☐ HIGH YIELD/IRRIGATION BEDROCK WELL (YIELD > 70 GPM MUST HAVE CASING DEPTH DETERMINED BY WELLHEAD PROTECTION SECTION)
- ☑ UNCONSOLIDATED MATERIAL IRRIGATION WELL
- ☐ OPEN LOOP HEAT PUMP (YIELD >70 GPM MUST HAVE CASING DEPTH DETERMINED BY WELLHEAD PROTECTION SECTION)
  - ☐ SUPPLY WELL ☐ RETURN WELL
- ☐ PILOT HOLE FOR PUBLIC WELL

ATTACH COPY OF THE CASING DEPTH LETTER

DNR VARIANCE NUMBER

CASING DETAILS	CASING LENGTH	O.D.	WEIGHT	CASING MATERIAL	DIAMETER OF DRILL HOLE	WELL SCREEN	LENGTH OF SCREEN	POSITION OF GROUT SEAL
	30 ft.	14 in.	54.57 lb.	☑ STEEL ☐ PLASTIC	20 in.	☑ STEEL ☐ PLASTIC	86.33 ft.	☐ BOTTOM ☑ TOP ☐ FULL LENGTH

CASING GROUT MATERIAL			NUMBER OF BAGS USED	METHOD OF GROUT INSTALLATION (MARK ONLY ONE)	DRILLING SUSPENDED
	☐ TYPE 1 CEMENT ☐ HI-EARLY CEMENT ☐ BENTONITE SLURRY	☑ BENTONITE CHIPS ☐ BENTONITE PELLETS ☐ BENTONITE GRANULAR	12	☐ PRESSURE THRU CASING ☐ PRESSURE THRU TREMIE	☐ NO ☑ YES
			POUNDS PER BAG 50	☐ OPEN HOLE ☐ TREMIE ☑ GRAVITY ☐ POS. DISPLACEMENT	72 HRS

LINER DETAILS	LENGTH	O.D. OF LINER	LINER MATERIAL	POSITION OF SEAL	PACKER DEPTHS
	ft.	in.	☐ STEEL ☐ PLASTIC	☐ FULL LENGTH ☐ BOTTOM ☐ TOP	____ FT. ____ FT.

LINER GROUT MATERIAL			NUMBER OF BAGS USED	METHOD OF GROUT INSTALLATION	LINER USED TO (MARK ONLY ONE)	ABANDONED WELL ON-SITE?
	☐ TYPE 1 CEMENT ☐ HI-EARLY CEMENT ☐ BENTONITE SLURRY	☐ BENTONITE CHIPS ☐ BENTONITE PELLETS ☐ BENTONITE GRANULAR	POUNDS PER BAGS	☐ GRAVITY ☐ DISPLACEMENT ☐ AS LINER INSTALLED ☐ TREMIE	☐ HOLD BACK FORMATION ☐ PREVENT RUST ☐ SEAL OUT UNDESIRABLE CONDITIONS	☐ Yes; PLUGGED? ☐ Yes ☐ No

GPS LOCATION OF WELL
LAT. 40 19.68 ° 9435 ' 17 "
LONG. 91 29.88 ° 573833 ' "
COUNTY Clark

DEPTH TO FIRST GROUNDWATER	24.58 FEET	PUMP RATE	1650 GPM
WELL YIELD	2521 GPM	PUMP SET DEPTH	70 FEET
STATIC WATER LEVEL	24.58 FEET	PUMP INSTALLATION DATE	10/20/2012
WELL COMPLETION DATE	05/16/2012	✓ CENTRIFUGAL PUMP	

ELEVATION (OPTIONAL): 503 ft.

LEGAL LOCATION (OPTIONAL): ¼ ¼ ¼ SEC. 24 TWN. 64 N RNG. 5 ☐ East ☑ West

AREA

OTHER INFORMATION OR LOCATION DATA (OPTIONAL)

DEPTH FROM	DEPTH TO	FORMATION DESCRIPTION
0	15	Fill
15	25	Brown Silty Sand
25	46	Brown Fine-Med Sand
46	70	Brown Med-Crs Sand
70	85	Grey Fine Sand
85	90	Grey Medium Sand
90	100	Grey Med-Fine Sand
100	110	Grey Fine Sand
110	120	Brown Gravel

I hereby certify the well/pump information described herein is true and accurate.

	PERMIT NUMBER	DATE
PRIMARY CONTRACTOR SIGNATURE	001560-WPM	11/14/2012
WELL DRILLER SIGNATURE	001560-WPM	11/14/2012
PUMP INSTALLER SIGNATURE	001560-WPM	11/14/2012
APPRENTICE SIGNATURE		
APPRENTICE SIGNATURE		

DEPTH TO BEDROCK FT.
TOTAL DEPTH 122 FT.

DISTRIBUTION: WHITE – DIVISION CANARY – DRILLER PINK - OWNER

SUBMIT COMPLETED FORM TO: MISSOURI DEPARTMENT OF NATURAL RESOURCES, DIVISION OF GEOLOGY AND LAND SURVEY, WELLHEAD PROTECTION SECTION, PO BOX 250, ROLLA, MO 65402-0250 PHONE: 573-368-2165

MO 780-1901 (04-12)

Water Well Solutions

WELL CONSTRUCTION REPORT

1. Customer: Kolb Grading,LLC (Fox Island Refuge)
2. Address: Pool 20 Mississippi River Bottoms
   City: Alexandria State: MO Zip:
3. Well No.: G At Test Hole No.: FI-10-02
4. Well Location (attached map):
   See attached

5. Supt.: Jack Bark (Traut Drilling)
6. Date: 10/20/2012
7. Date Started: 12/15/2011
8. Drill Crew Man Hrs.:
9. Working Days:
   Drilling: Other:

10. MATERIAL IN WELL

	Length	Dia. (Inches)	Wall Thickness (Inches)	Material	Type	Slot Size
Screen	86' 4"	14"		304 S.S.	Johnson	.030 & .060"
Inner Casing	31'	14"	.375"	304 S.S.		
Outer Casing						

11. GRAVEL PACK

Size: #40 & #80 Tons: 17

12. SEALING CASING

Bentonite: X Yes ___ No 35 Bags

Cement: ___ Yes ___ No ___ Bags

Seal Material Placed in Well With: Poured

Bottom of Well Screen Sealed With: .375" S.S. Plate

13. WELL DIMENSIONS

A. Total Depth: 113 Ft.
(From top of inner casing to bottom of well)

B. Height of Inner Casing: 6"
(Above ground level)

C. Distance to Top of Gravel: 23 Ft.
(From ground level)

D. Diameter of Drill Hole: 20"

COMMENTS: Well Constructed using due rotary.

Water Well Solutions Illinois Division, LLC * 44W158 Keslinger Road B * Elburn, Illinois 60119
Toll Free: (888) 769-9009 * Fax: (920) 474 4771 * Web: www.wwssg.com

Water Well Solutions

14. PUMPING TEST

A. Test Pump

Model 12THC Size 12" Stages 3

Permanent Pump

Length of Column 70 Ft.

Length of Bowl 4' 2 3/8" Ft.

Length of Suction 5 Ft.

B. Measured Water Level 9.58 Ft. from top of 14" Casing

Dia. Casing which is 4 Ft. above ground level (487') Orifice 10 x 8

C. Length of Airline 50 Ft. from top of casing

TIME	IN. ORIFICE MANOMETER	GPM	ALT. GAUGE READING	PUMPING LEVELS	DRAWDOWN
8:01	69.0	2503		15.50	5.92
10:00	70.0	2521		17.45	7.87
12:00	70.0	2521		17.70	8.12
1:00	70.0	2521		17.79	8.21
2:00	70.0	2521		18.04	8.46
3:00	70.0	2521		18.04	8.50

15. Permanent Goulds Model No. 12 FDLC Installed By Andy Burbach

Airline Length 70 Ft. Date 10 (Month) 20 (Day) 2012 (Year)

Water Well Solutions

LOG OF WELL

Ft.	In.	To	Ft.	In.	Formation
0			1		Topsoil
1			5		Brown Fine Sand
5			15		Brown Fine to Medium Sand
15			31		Brown Medium Sand
31			66		Brown Coarse Sand w/Large Gravel
66			70		Brown Fine Sand
70			85		Brown Medium to Coarse Sand w/Large Gravel
85			99		Grey Fine Sand
99			100		Grey Clay and Large Gravel
100			107		Gray Clay and Gravel

G-391

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project: Fox Island Refuge | Date Tested: 5/16/12

Location: Well "G" | Job No.: WK10-331

Depth of Well: 105.3 FT | Dia. of Well: 14" | Pump Size: 12 THC T.P. | Orifice: 10X8

Measuring Point Elevation: 48" Above Grade | Ground Elevation: ± 487 FT. | Well Type: Gravel Packed

Airline Length: 60 FT. | Non-Pumping Water Level: 9.58 FT. | Tested By: Jack B.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
6:00	0.0	0		9.58	0.0	0			
6:15	0.0	0		9.58	0.0	0			
6:30	0.0	0		9.58	0.0	0			
6:45	0.0	0		9.58	0.0	0			
7:00	0.0	0		9.58	0.0	0			
7:15	0.0	0		9.58	0.0	0			
7:30	0.0	0		9.58	0.0	0			
7:45	0.0	0		9.58	0.0	0			
8:00	0.0	0		9.58	0.0	0			
8:01	69.0	2503		15.50	5.92	18		422.80	
8:02	69.0	2503		16.08	6.5	18		385.07	
8:03	69.0	2503		16.41	6.83	18		366.47	
8:04	69.0	2503		16.50	6.92	18		361.70	
8:05	70.0	2521		16.58	7	18		360.14	
8:06	70.0	2521		16.66	7.08	20		356.07	
8:07	70.0	2521		16.75	7.17	20		351.66	
8:08	70.0	2521		16.79	7.21	20		349.65	
8:09	70.0	2521		16.79	7.21	20		349.65	
8:10	70.0	2521		17.00	7.42	20		339.75	
8:15	70.0	2521		17.00	7.42	22		339.75	No Sand
8:20	70.0	2521		17.04	7.46	22		337.93	
8:25	70.0	2521		17.04	7.46	22		337.93	

Note: 8 Hour Constant Rate Test

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project Fox Island Refuge **Date Tested** 5/16/12

Location Well "G" **Job No.** WK10-331

Depth of Well 105.3 FT **Dia. of Well** 14" **Pump Size** 12 THC T.P. **Orifice** 10X8

Measuring Point Elevation 48" Above Grade **Ground Elevation** ± 487 FT. **Well Type** Gravel Packed

Airline Length 60 FT. **Non-Pumping Water Level** 9.58 FT. **Tested By** Jack B.

Pump Set at 60 FT.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
8:30	70.0	2521		17.04	7.46	22		337.93	
8:40	70.0	2521		17.12	7.54	22		334.35	
8:50	70.0	2521		17.16	7.58	22		332.58	
9:00	70.0	2521		17.25	7.67	22		328.68	
9:20	70.0	2521		17.33	7.75	22		325.29	
9:40	70.0	2521		17.41	7.83	22		321.96	
10:00	70.0	2521		17.45	7.87	23		320.33	
10:20	70.0	2521		17.5	7.92	23		318.30	
10:40	70.0	2521		17.54	7.96	23		316.70	
11:00	70.0	2521		17.58	8.00	23		315.13	
11:20	70.0	2521		17.63	8.04	23		313.56	
11:40	70.0	2521		17.67	8.08	24		312.00	
12:00	70.00	2521		17.70	812	24		310.47	
12:20	70.0	2521		17.75	8.17	24		308.57	No Sand
12:40	70.0	2521		17.75	8.17	24		308.57	
1:00	70.0	2521		17.79	8.21	24		307.06	
1:20	70.0	2521		18.00	8.42	24		299.41	
1:40	70.0	2521		18.00	8.42	24		299.41	
2:00	70.0	2521		18.04	8.46	24		297.96	COE Collected Sample
2:20	70.0	2521		18.04	8.46	24		297.95	
2:40	70.0	2521		18.08	8.50	24		296.48	
3:00	70.0	2521		18.08	8.50	24		296.48	COE Collected Sample

Note: 8 Hour Constant Rate Test

Page 2 of 4

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project: Fox Island Refuge
Date Tested: 5/16/12
Location: Well "G"
Job No.: WK10-331
Depth of Well: 105.3 FT
Dia. Of Well: 14"
Pump Size: 12 THC T.P.
Orifice: 10X8
Measuring Point Elevation: 48" Above Grade
Ground Elevation: ± 487 FT.
Well Type: Gravel Packed
Airline Length: 60 FT.
Non-Pumping Water Level: 9.58 FT.
Tested By: Jack B.

Pump Set at 60 FT.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
3:20	70.0	2521		18.13	8.55	24		295.03	
3:40	70.0	2521		18.17	8.59	24		293.62	
4:00	70.0	2521		18.17	8.59	24		293.62	COE Collected Sample
4:01	0.0	0		11.66	2.08				
4:02	0.0	0		11.92	2.34				
4:03	0.0	0		11.33	1.75				
4:04	0.0	0		11.33	1.75				
4:05	0.0	0		11.33	1.75				
4:06	0.0	0		11.29	1.71				
4:07	0.0	0		11.29	1.71				
4:08	0.0	0		11.25	1.67				
4:09	0.0	0		11.25	1.67				
4:10	0.0	0		11.20	1.62				
4:15	0.0	0		11.17	1.59				
4:20	0.0	0		11.13	1.55				
4:25	0.0	0		11.08	1.50				
4:30	0.0	0		11.04	1.46				
4:40	0.0	0		11.00	1.42				
4:50	0.0	0		10.75	1.17				
5:00	0.0	0		10.70	1.12				
5:20	0.0	0		10.70	1.12				
5:40	0.0	0		10.67	1.09				

Note: 8 Hour Constant Rate Test

Page 3 of 4

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project Fox Island Refuge Date Tested 5/16/12

Location Well "G" Job No. WK10-331

Depth of Well 105.3 FT Dia. Of Well 14" Pump Size 12 THC T.P. Orifice 10X8

Measuring Point Elevation 48" Above Grade Ground Elevation $\pm$ 487 FT. Well Type Gravel Packed

Airline Length 60 FT. Non-Pumping Water Level 9.58 FT. Tested By Jack B.

Pump Set at 60 FT.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
6:00	0.0	0		10.63	1.05				
6:20	0.0	0		10.63	1.05				
6:40	0.0	0		10.50	.92				
7:00	0.0	0		10.50	.92				
7:20	0.0	0		10.50	.92				
7:40	0.0	0		10.50	.92				
8:00	0.0	0		10.50	.92				
6:00	0.0	0		10.25	.67				5/17/12

Note: Recovery After 8 Hour Test

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project: Fox Island Refuge
Date Tested: 5/15/12
Location: Well "G"
Job No.: WK10-331
Depth of Well: 105.3 FT. Dia. of Well: 14" Pump Size: 12THC T.P Orifice: 10X8
Measuring Point Elevation: 48" Above Grade Ground Elevation: ± 487 FT. Well Type: Gravel Packed
Airline Length: 50 FT. Non-Pumping Water Level: 9.5 FT. Tested By: Jack B.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
1:15	0.0	0			0.00	0	0	0	
1:20	6.0	738		11.58	2.08	90		354.80	Clearing
1:30	6.0	738		11.50	2.00	90		369.00	No Sand
1:50	6.0	738		11.41	1.91	90		386.39	Clear
2:10	6.0	738		11.50	2.00	90		369.00	
2:15	10.5	976		11.75	2.25	88		328.00	
2:20	10.5	976		11.75	2.25	88		328.00	No Sand
2:30	16.0	1205		12.79	3.29	80		366.26	No Sand
2:35	16.0	1205		13.00	3.50	80		344.28	
2:45	22.0	1413		13.58	4.08	72		346.32	
2:50	22.0	1413		13.58	4.08	72		346.32	No Sand
3:00	22.0	1413		13.63	4.13	72		342.54	
3:15	35.0	1783		14.66	5.16	66		345.54	
3:35	49.0	2109		15.50	6.00	50		351.50	
3:40	49.0	2109		15.63	6.13	50		344.32	
3:55	69.0	2503		16.66	7.16	28		349.58	
4:00	69.0	2503		16.70	7.20	28		347.63	No Sand
4:15	70.0	2521		16.79	7.29	26		345.81	

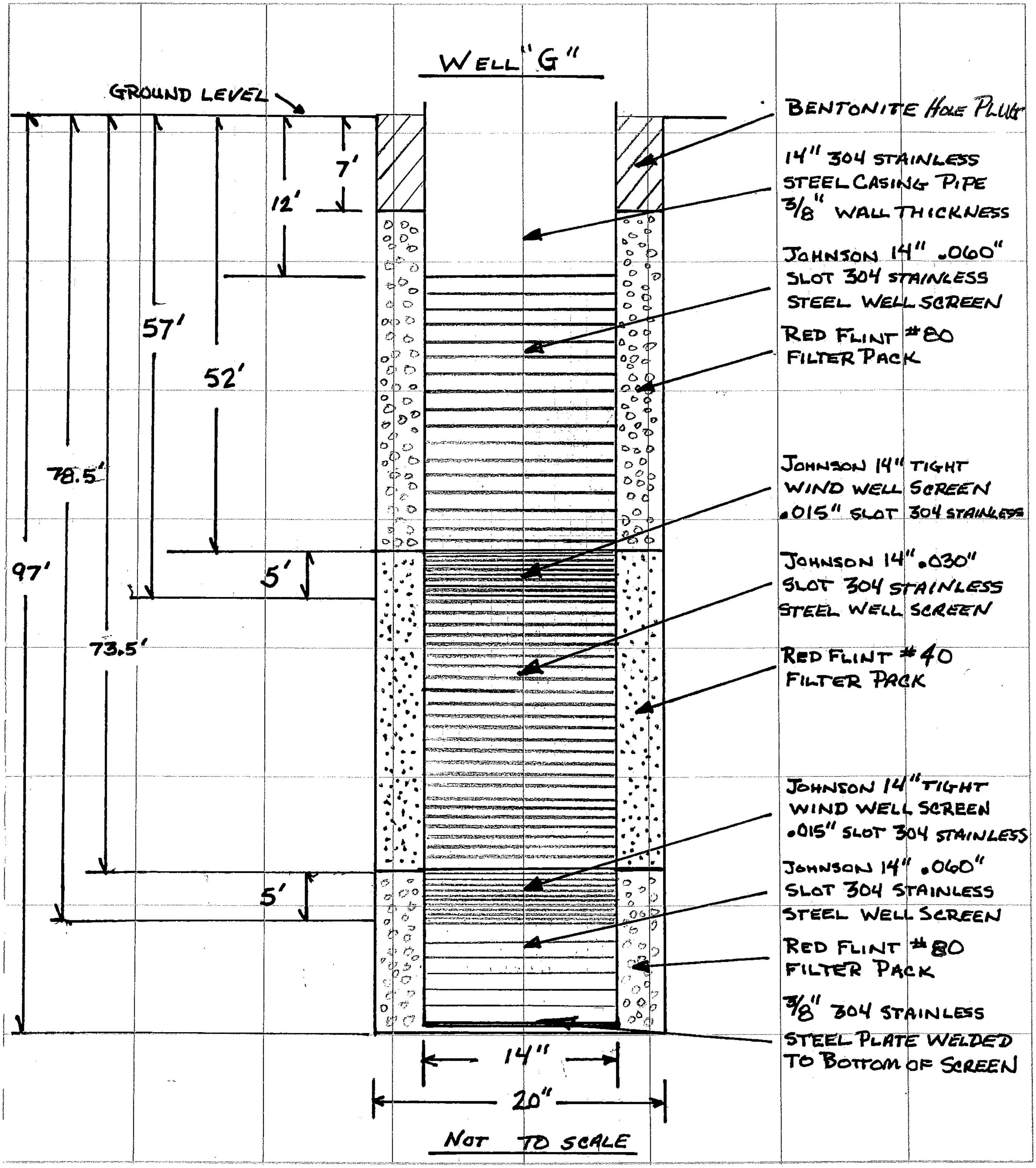
Note: Development

Page 1 of 1

Water Well Solutions

Project: FOX ISLAND DIVISION HABITAT REHABILITATION AND ENHANCEMENT

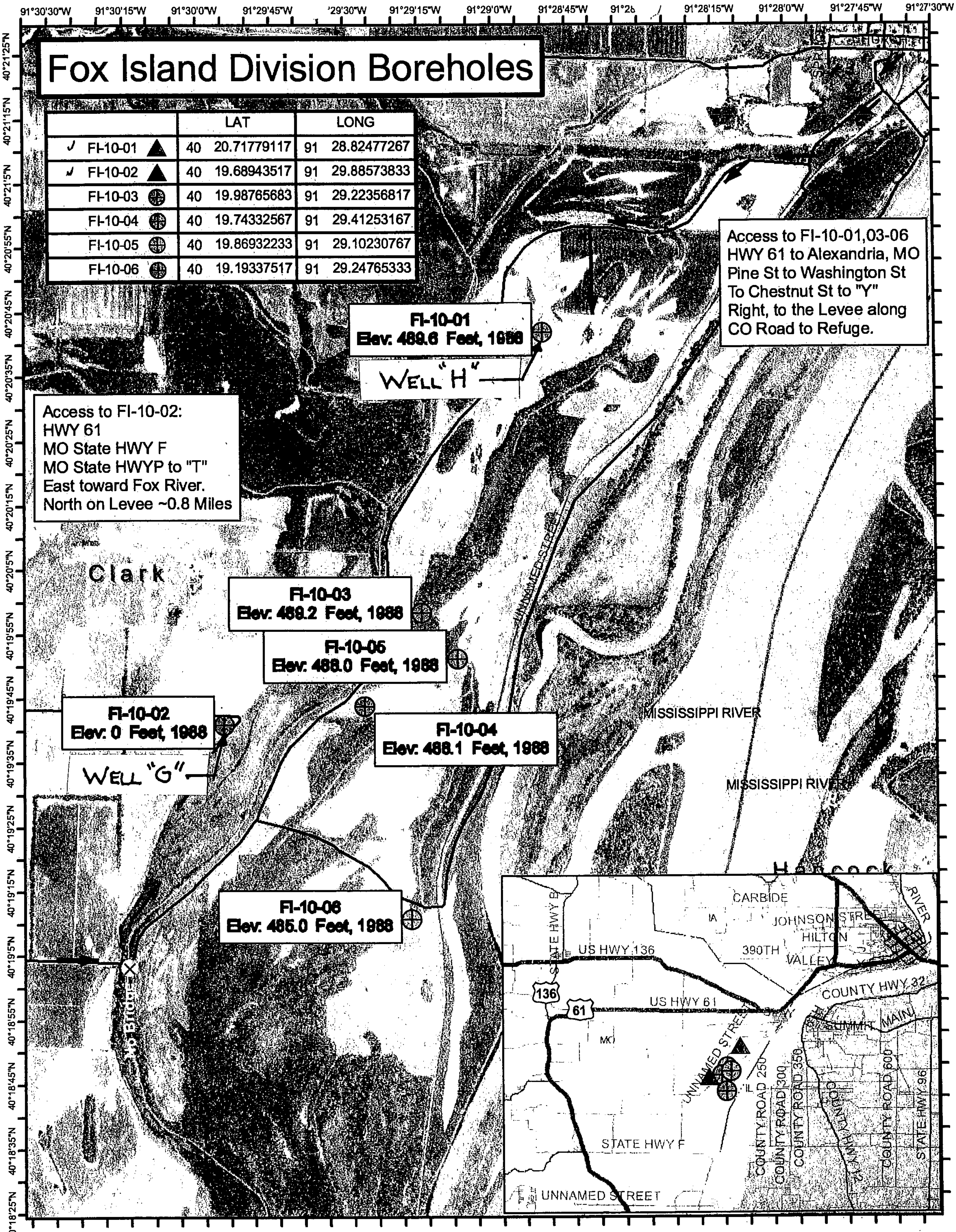
Job # W912EK-10-B-0025   Date: 11/2/2010   10/20/12 AS-BUILT



Wisconsin -- Illinois
(888) 769-9009 • FAX (920) 474-4771

Fox Island Division Boreholes

	LAT		LONG	
✓ FI-10-01 ▲	40	20.71779117	91	28.82477267
✓ FI-10-02 ▲	40	19.68943517	91	29.88573833
FI-10-03 ⊕	40	19.98765683	91	29.22356817
FI-10-04 ⊕	40	19.74332567	91	29.41253167
FI-10-05 ⊕	40	19.86932233	91	29.10230767
FI-10-06 ⊕	40	19.19337517	91	29.24765333



Section 5

MISSOURI DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY PROGRAM
PUBLIC WELL/HIGH YIELD RECORD

OFFICE USE ONLY

REF. NO.	DATE RECEIVED
ENTERED	
PH1 PH2 PH3	
CHECK NO.	REVENUE NO.

ROUTE	APPROVED	DATE	STATE CERT. NO.
/ /			

NAME OF BUSINESS, FACILITY OR SITE THE WELL SERVES (REQUIRED)	Corp of Engineers (Well "H")
PHYSICAL ADDRESS OF THE WELL	Fox Island Division Habitat, Pool 20, Alexandria, MO
OWNER NAME	Department of the Army
OWNER TELEPHONE NUMBER WITH AREA CODE	(309) 637-1321
OWNER ADDRESS	Clock Tower Building - Box 2004
CITY	Rock Island
STATE	Illinois
ZIP CODE	63430

SEE BACK OF FORM FOR WELL CLASSIFICATIONS

TYPE OF WELL

- ☐ PUBLIC WATER WELL (APPROVAL MUST BE OBTAINED IN ADVANCE BY DNR REGIONAL OFFICE)
- ☐ HIGH YIELD/IRRIGATION BEDROCK WELL (YIELD > 70 GPM MUST HAVE CASING DEPTH DETERMINED BY WELLHEAD PROTECTION SECTION)
- ☑ UNCONSOLIDATED MATERIAL IRRIGATION WELL
- ☐ OPEN LOOP HEAT PUMP (YIELD >70 GPM MUST HAVE CASING DEPTH DETERMINED BY WELLHEAD PROTECTION SECTION)
  - ☐ SUPPLY WELL ☐ RETURN WELL
- ☐ PILOT HOLE FOR PUBLIC WELL

ATTACH COPY OF THE CASING DEPTH LETTER

DNR VARIANCE NUMBER

CASING DETAILS

CASING LENGTH	O.D.	WEIGHT	CASING MATERIAL	DIAMETER OF DRILL HOLE	WELL SCREEN	LENGTH OF SCREEN	POSITION OF GROUT SEAL
25 ft.	14 in.	54.57 lb.	☑ STEEL ☐ PLASTIC	20 in.	☑ STEEL ☐ PLASTIC	95.67 ft.	☐ BOTTOM ☑ TOP ☐ FULL LENGTH

CASING GROUT MATERIAL

- ☐ TYPE 1 CEMENT
- ☐ HI-EARLY CEMENT
- ☐ BENTONITE SLURRY
- ☑ BENTONITE CHIPS
- ☐ BENTONITE PELLETS
- ☐ BENTONITE GRANULAR

NUMBER OF BAGS USED: 12

POUNDS PER BAG: 50

METHOD OF GROUT INSTALLATION (MARK ONLY ONE): ☐ PRESSURE THRU CASING ☐ PRESSURE THRU TREMIE ☐ OPEN HOLE ☐ TREMIE ☑ GRAVITY ☐ POS. DISPLACEMENT

DRILLING SUSPENDED: ☐ NO ☑ YES 72 HRS

LINER DETAILS

LENGTH ft. | O.D. OF LINER in. | LINER MATERIAL ☐ STEEL ☐ PLASTIC | POSITION OF SEAL ☐ FULL LENGTH ☐ BOTTOM ☐ TOP | PACKER DEPTHS ____ FT. ____ FT.

LINER GROUT MATERIAL

- ☐ TYPE 1 CEMENT
- ☐ HI-EARLY CEMENT
- ☐ BENTONITE SLURRY
- ☐ BENTONITE CHIPS
- ☐ BENTONITE PELLETS
- ☐ BENTONITE GRANULAR

NUMBER OF BAGS USED

POUNDS PER BAGS

METHOD OF GROUT INSTALLATION: ☐ GRAVITY ☐ DISPLACEMENT ☐ AS LINER INSTALLED ☐ TREMIE

LINER USED TO (MARK ONLY ONE): ☐ HOLD BACK FORMATION ☐ PREVENT RUST ☐ SEAL OUT UNDESIRABLE CONDITIONS

ABANDONED WELL ON-SITE? ☐ Yes

PLUGGED? ☐ Yes ☐ No

GPS LOCATION OF WELL
LAT. 40 20.71 ° 7791 ' 17 "
LONG. 91 28.82 ° 477267 ' "
COUNTY Clark

DEPTH TO FIRST GROUNDWATER	25.21 FEET	PUMP RATE	1700 GPM
WELL YIELD	2503 GPM	PUMP SET DEPTH	70 FEET
STATIC WATER LEVEL	25.21 FEET	PUMP INSTALLATION DATE	10/20/2012
WELL COMPLETION DATE	05/01/2012	✓ CENTRIFUGAL PUMP	

ELEVATION (OPTIONAL): 503 ft.

LEGAL LOCATION (OPTIONAL): ¼ ¼ ¼ SEC. 18 TWN. 64 N RNG. 5 ☐ East ☑ West

AREA

DEPTH FROM	DEPTH TO	FORMATION DESCRIPTION
0	16	Fill
16	20	Brown Fine Sand
20	30	Brown Fine-Med Sand
30	46	Brown Medium Sand
46	81	Brown Coarse Sand
81	85	Brown Fine Sand
85	90	Brwn Med-Crs Sand
90	114	Grey Fine Sand
114	115	Grey Clay & Rocks
115	122	Grey Clay & Gravel

OTHER INFORMATION OR LOCATION DATA (OPTIONAL)

I hereby certify the well/pump information described herein is true and accurate.

	PERMIT NUMBER	DATE
PRIMARY CONTRACTOR SIGNATURE [signature]	001560-WPM	11/14/2012
WELL DRILLER SIGNATURE [signature]	001560-WPM	11/14/2012
PUMP INSTALLER SIGNATURE [signature]	001560-WPM	11/14/2012
APPRENTICE SIGNATURE		
APPRENTICE SIGNATURE		

DEPTH TO BEDROCK FT.
TOTAL DEPTH 122 FT.

DISTRIBUTION: WHITE – DIVISION CANARY – DRILLER PINK - OWNER

SUBMIT COMPLETED FORM TO: MISSOURI DEPARTMENT OF NATURAL RESOURCES, DIVISION OF GEOLOGY AND LAND SURVEY, WELLHEAD PROTECTION SECTION, PO BOX 250, ROLLA, MO 65402-0250 PHONE: 573-368-2165

MO 780-1901 (04-12)

Water Well Solutions

WELL CONSTRUCTION REPORT

1. Customer: Kolb Grading,LLC (Fox Island Refuge)	5. Supt.: Jack Bark (Traut Drilling)
2. Address: Pool 20 Mississippi River Bottoms	6. Date: 10/20/2012
City: Alexandria State: MO Zip:	7. Date Started: 12/15/2011
3. Well No.: H At Test Hole No.: FI-10-01	8. Drill Crew Man Hrs.:
4. Well Location (attached map):	9. Working Days:
See attached	Drilling: Other:

10. MATERIAL IN WELL

	Length	Dia. (Inches)	Wall Thickness (Inches)	Material	Type	Slot Size
Screen	95' 8"	14"		304 S.S.	Johnson	.030 & .060"
Inner Casing	29'	14"	.375"	304 S.S.		
Outer Casing						

11. GRAVEL PACK

Size: #40 & #80 Tons: 16

12. SEALING CASING

Bentonite: X Yes ____ No 35 Bags

Cement ____ Yes ____ No ____ Bags

Seal Material Placed in Well With: Poured

Bottom of Well Screen Sealed With: .375" S.S. Plate

13. WELL DIMENSIONS

A. Total Depth: 116 Ft.
(From top of inner casing to bottom of well)

B. Height of Inner Casing: 6"
(Above ground level)

C. Distance to Top of Gravel: 23 Ft.
(From ground level)

D. Diameter of Drill Hole: 20"

COMMENTS: Well Constructed using due rotary.

Water Well Solutions Illinois Division, LLC * 44W158 Keslinger Road B * Elburn, Illinois 60119
Toll Free: (888) 769-9009 * Fax: (920) 474-4771 * Web: www.wwssg.com

Water Well Solutions

14. PUMPING TEST

A. Test Pump

Model 12THC Size 12" Stages 3

Permanent Pump

Length of Column 70 Ft.

Length of Bowl 5' 2 5/8" Ft.

Length of Suction 5 Ft.

B. Measured Water Level 10.21 Ft. from top of 14" Casing

Dia. Casing which is 2 Ft. above ground level (487') Orifice 10 x 8

C. Length of Airline 50 Ft. from top of casing

TIME	IN. ORIFICE MANOMETER	GPM	ALT. GAUGE READING	PUMPING LEVELS	DRAWDOWN
8:00	69.0	2503		12.63	2.42
10:00	69.0	2503		12.67	2.46
12:00	69.0	2503		12.67	2.46
1:00	69.0	2503		12.67	2.46
2:00	69.0	2503		12.67	2.46
3:00	69.0	2503		12.67	2.46

15. Permanent Goulds Model No. 12 FDLC Installed By Andy Burbach

Airline Length 70 Ft. Date 10 (Month) 20 (Day) 2012 (Year)

Water Well Solutions

LOG OF WELL

Ft.	In.	To	Ft.	In.	Formation
0			1		Topsoil
1			5		Brown Fine Sand
5			15		Brown Fine to Medium Sand
15			31		Brown Medium Sand
31			66		Brown Coarse Sand w/Large Gravel
66			70		Brown Fine Sand
70			85		Brown Medium to Coarse Sand w/Large Gravel
85			99		Grey Fine Sand
99			100		Grey Clay and Large Gravel
100			107		Gray Clay and Gravel

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project	Fox Island Refuge			**Date Tested**	5/1/2012		
Location	Well "H"			**Job No.**	WK10-331		
Depth of Well	109 FT	**Diameter Of Well**	14"	**Pump Size**	12THC T.P.	**Orifice**	10x8
Ground Elevation	487 FT	**Measuring Point Elevation**	46" Above Grade			**Well Type**	Gravel Packed
Airline Length	50 FT	**Non-Pumping Water Level**	10.21 FT	**Tested By**	Jack B.		

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
4:45				10.21	0	0	0	0	
5:00				10.21	0	0	0	0	
5:15				10.21	0	0	0	0	
5:30				10.21	0	0	0	0	
5:45				10.21	0	0	0	0	
6:00				10.21	0	0	0	0	
6:15				10.21	0	0	0	0	
6:30				10.21	0	0	0	0	
6:45				10.21	0	0	0	0	Raining Hard
7:00				10.21	0	0	0	0	got 3/4 of an inch
7:00	69.0	2503		12.25	2.04	32			
7:01	69.0	2503		12.29	2.08	32			Clear
7:02	69.0	2503		12.33	2.12	32			
7:03	69.0	2503		12.38	2.17	32			
7:04	69.0	2503		12.38	2.17	32			
7:05	69.0	2503		12.42	2.21	32			
7:06	69.0	2503		12.42	2.21	32			Clear
7:07	69.0	2503		12.46	2.25	32			
7:08	69.0	2503		12.46	2.25	32			
7:09	69.0	2503		12.46	2.35	32			
7:15	69.0	2503		12.50	2.29	32			Clear
7:20	69.0	2503		12.54	2.33	32			
7:25	69.0	2503		12.75	2.54	32			
7:30	69.0	2503		12.58	2.30	32			
7:40	69.0	2503		12.58	2.38	32			Clear (blue)
7:50	69.0	2503		12.58	2.38	32			

NOTE: 8 Hour Constant Rate Pump Test

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project	Fox Island Refuge				Date Tested	5/1/2012	
Location	Alexanria, MO - Well "H"				Job No.	WK10-331	
Depth of Well	109 FT	Diameter Of Well	14"	Pump Size	12THC T.P.	Orifice	10x8
Ground Elevation	487 FT	Measuring Point Elevation	46" Above Grade			Well Type	Gravel Packed
Airline Length	50 FT	Non-Pumping Water Level	10.21 FT	Tested By		Jack B.	

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
8:00	69.0	2503		12.63	2.42	32			
8:10	69.0	2503		12.63	2.42	32			
8:20	69.0	2503		12.63	2.42	32			
8:40	69.0	2503		12.63	2.42	32			
9:00	69.0	2503		12.63	2.42	32		1035.58	Clear
9:20	69.0	2503		12.67	2.46	32			
9:40	69.0	2503		12.67	2.46	32			Clear
10:00	69.0	2503		12.67	2.46	32		1018.31	Clear
10:20	69.0	2503		12.67	2.46	32			
10:40	69.0	2503		12.67	2.46	32			No Sand
11:00	69.0	2503		12.67	2.46	32		1018.31	
11:20	69.0	2503		12.67	2.46	32			Clear
11:40	69.0	2503		12.67	2.46	33		1018.31	
12:00	69.0	2503		12.67	2.46	33			
12:20	69.0	2503		12.67	2.46	33		1018.31	
12:40	69.0	2503		12.67	2.46	33			
1:00	69.0	2503		12.67	2.46	33			Clear
1:20	69.0	2503		12.67	2.46	32			
1:40	69.0	2503		12.67	2.46	32		1018.31	
2:00	69.0	2503		12.67	2.46	32			Clear
2:20	69.0	2503		12.67	2.46	32			
2:40	69.0	2503		12.67	2.46	32			
3:00	69.0	2503		12.67	2.46	32		1018.31	Clear
3:01				11.29	1.08				
3:02				11.04	0.83				
3:03				10.75	0.54				

NOTE: 8 Hour Constant Rate Pump Test. Only can run at 2500 G.P.M.
The ditch won't hold anymore water than that.

Page 2 of 3

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project	Fox Island Refuge			**Date Tested**	5/1/2012		
Location	Well "H"			**Job No.**	WK10-331		
Depth of Well	109 FT	**Diameter Of Well**	14"	**Pump Size**	12THC T.P.	**Orifice**	10x8
Ground Elevation	487 FT	**Measuring Point Elevation**	46" Above Grade			**Well Type**	Gravel Packed
Airline Length	50 FT	**Non-Pumping Water Level**	10.21 FT	**Tested By**	Jack B.		

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
3:04				10.67	0.46				
3:05				10.63	0.42				
3:06				10.58	0.37				
3:07				10.54	0.33				
3:08				10.54	0.33				
3:09				10.50	0.29				
3:10				10.46	0.25				
3:15				10.42	0.21				
3:20				10.38	0.17				
3:25				10.33	0.12				
3:30				10.29	0.08				
3:40				10.25	0.04				
3:50				10.23	0.02				
4:17				10.21	0.00				

NOTE: Recovery after 8 hour pump test.

Page 3 of 3

Water Well Solutions

Toll Free: (888) 769-9009 www.waterwellsolutions.com

PUMPING TEST DATA SHEET

Project	Fox Island Refuge				Date Tested	4/26/2012	
Location	Well "H"				Job No.	WK11-331	
Depth of Well	109 FT	Diameter Of Well	14"	Pump Size	12THC T.P.	Orifice	10x8
Ground Elevation	487 FT	Measuring Point Elevation	Top of Casing			Well Type	Gravel Packed
Airline Length	90 FT	Non-Pumping Water Level	10.33 FT	Tested By	Jack B.		

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
1:15	0.0	0		10.40	0.00	0	0	0	NPWL
1:20	5.5	707		11.00	0.67	90		1059.97	
1:50	5.0	674		11.00	0.67	90		1010.49	Sand < 1PPM
2:05	9.0	953		11.13	0.80	85		1191.25	
2:20	8.5	879		11.17	0.84	85		1046.43	Clear
2:45	13.0	1086		11.29	0.96	75		1131.25	<1.0PPM
2:50	13.0	1086		11.33	1.00	75		1086.00	
3:00	52.0	2173		12.13	1.80	35		1207.22	Sand 78PPM
3:25	31.5	1691		12.00	1.67	60		1012.57	
3:50	18.5	1296		11.46	1.13	70		1146.90	
4:00	18.5	1296		11.55	1.21	70		1071.07	
4:10	20.0	1348		11.63	1.30	68		1036.92	Sand 5.28 PPM
4:25	20.0	1348		11.63	1.30	68		1036.92	
6:30	63.0	2392		12.24	1.88	20		1272.34	
6:35	69.0	2503		12.38	2.05	10		1220.98	
6:45	63.0	2392		12.45	2.13	20		1123.00	
7:15	63.0	2392		12.50	2.17	20		1102.30	Sand 156 PPM

NOTE: Development

Page 1

Water Well Solutions

Toll Free: (888) 769-9009 **www.waterwellsolutions.com**

PUMPING TEST DATA SHEET

Project	Fox Island Refuge			**Date Tested**	April 27th & 30th
Location	Alexandria MO			**Job No.**	WK11-331
Depth of Well	109 FT	**Diameter Of Well** 14"	**Pump Size** 12THC T.P.	**Orifice**	10x8
Ground Elevation	487 FT	**Measuring Point Elevation**	42" Above Grade	**Well Type**	Gravel Packed
Airline Length	50 FT	**Non-Pumping Water Level**	10.17 FT	**Tested By**	Jack B.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
10:00	0.0	0		10.33	0.00	0			4/27/2012
10:15	0.0	0		10.33	0.00	0			4/27/2012
10:30	0.0	0		10.33	0.00	0			4/27/2012
12:00	0.0	0		10.17	0.00	0			4/27/2012
4/30/2012									
2:40	0.0	0		10.12	0.00	0			
2:45	13.0	1086		11.13	0.97	80		1119.59	Clear
2:55	13.0	1086		11.21	1.04	80		1044.23	
3:00	13.0	1086		11.29	1.12	80		969.64	
3:05	14.0	1127		11.29	1.12	80		1006.25	No Sand
3:15	14.0	1127		11.33	1.16	80		971.55	
3:30	18.0	1278		11.46	1.29	75		990.70	
3:45	18.0	1278		11.50	1.16	75		1101.72	No Sand
3:50	18.0	1278		11.50	1.16	75		1101.72	
3:55	23.0	1445		11.58	1.13	73		1278.76	No Sand
4:05	23.0	1445		11.63	1.46	73		989.73	
4:10	23.0	1445		11.63	1.46	73		989.73	No Sand
4:11	28.0	1594		11.75	1.58	71		1008.86	
4:15	28.0	1594		11.75	1.58	71		1008.86	
4:20	28.0	1594		11.75	1.58	71		1008.86	
4:30	28.0	1594		11.79	1.63	71		977.91	No Sand
4:33	34.0	1757		12.08	1.92	66		915.10	
4:40	34.0	1757		12.13	1.96	66		896.89	
									Shut Down - restart in 10 min.
5:00	0.0	0		0.00	0.00	0			
5:10	34.0	1757		0.00	0.00	0			

NOTE: Development with pump raised 50 ft. off of well bottom. Page 2

Water Well Solutions

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PUMPING TEST DATA SHEET

Project	Fox Island Refuge			**Date Tested**	4/30/2012
Location	Alexandria MO			**Job No.**	WK11-331
Depth of Well	109 FT	**Diameter Of Well**	14"	**Pump Size** 12THC T.P.	**Orifice** 10x8
Ground Elevation	487 FT	**Measuring Point Elevation**	42" Above Grade	**Well Type**	Gravel Packed
Airline Length	50 FT	**Non-Pumping Water Level**	10.166 FT	**Tested By**	Jack B.

Time	Orifice Reading	G.P.M.	Airline Reading	Pumping Level	Drawdown	Discharge Pressure (psi)	Total Dynamic Head	Specific Capacity	Remarks
5:15	34.0	1757		12.00	1.83	66		960.11	
5:20	34.0	1757		12.08	1.92	66		915.10	
5:30	34.0	1757		12.13	1.95	66		896.43	No Sand
5:45	38.0	1857		12.00	1.83	62		1014.75	
5:50	38.0	1857		12.13	1.96	62		947.45	
5:55	38.0	1857		12.17	2.00	62		928.5	
6:00	38.0	1857		12.21	2.04	62		910.29	
6:08	48.5	2098		12.38	2.21	55		949.32	No Sand
6:16	48.5	2098		12.42	2.25	55		932.44	
6:35	69.0	2503		12.71	2.54	35		985.43	
6:40	69.0	2503		12.79	2.63	32		951.71	
6:45	69.0	2503		12.79	2.63	33		951.71	No Sand
6:50	69.0	2503		12.79	2.63	33		953.52	

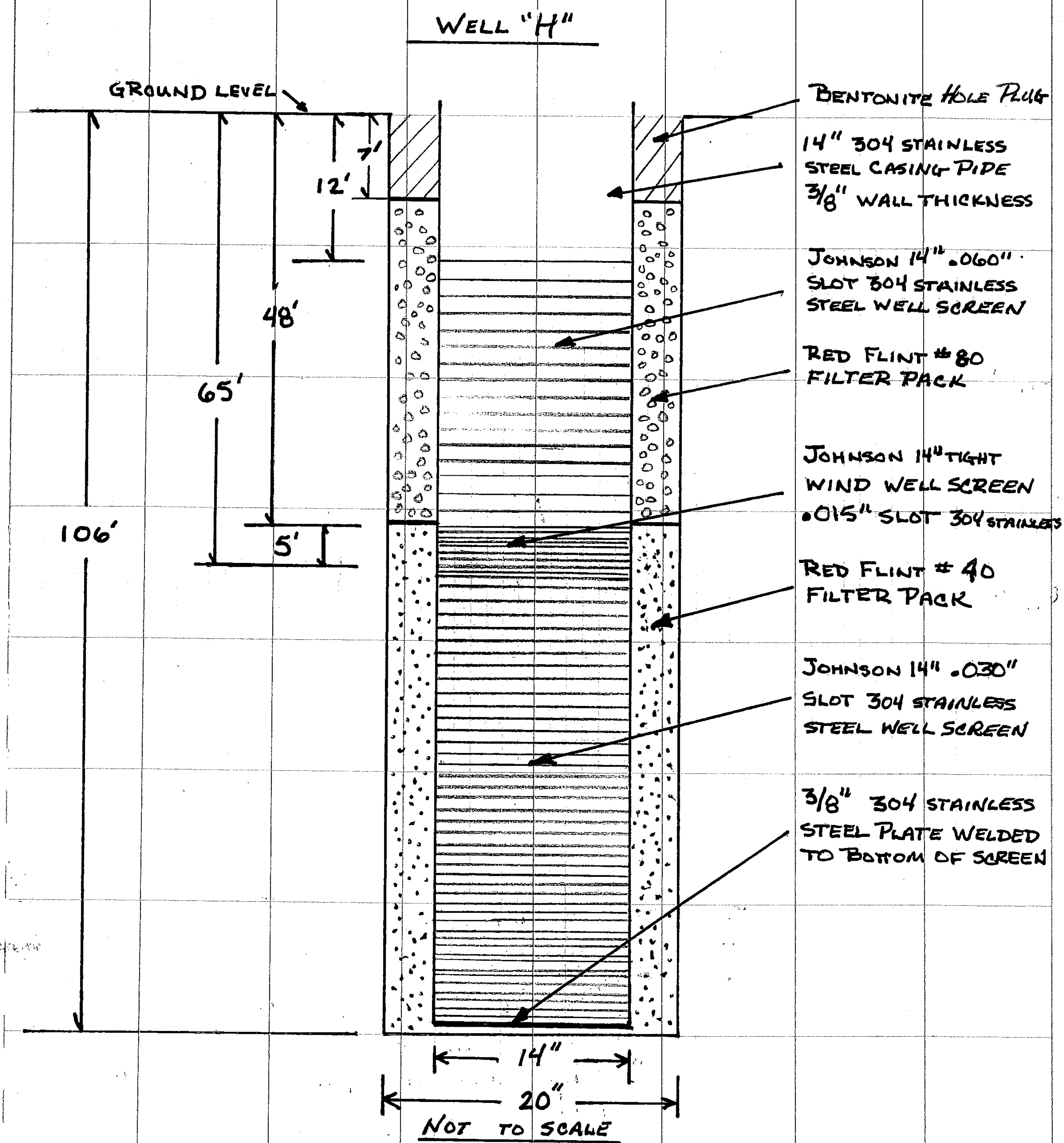
NOTE: Development with pump raised 50 ft. off of well bottom.

Page 3

Water Well Solutions

Project: Fox Island Division Habitat Rehabilitation and Enhancement

Job # W912EK-10-B-0025 Date: 11/2/2010 10/20/12 AS BUILT



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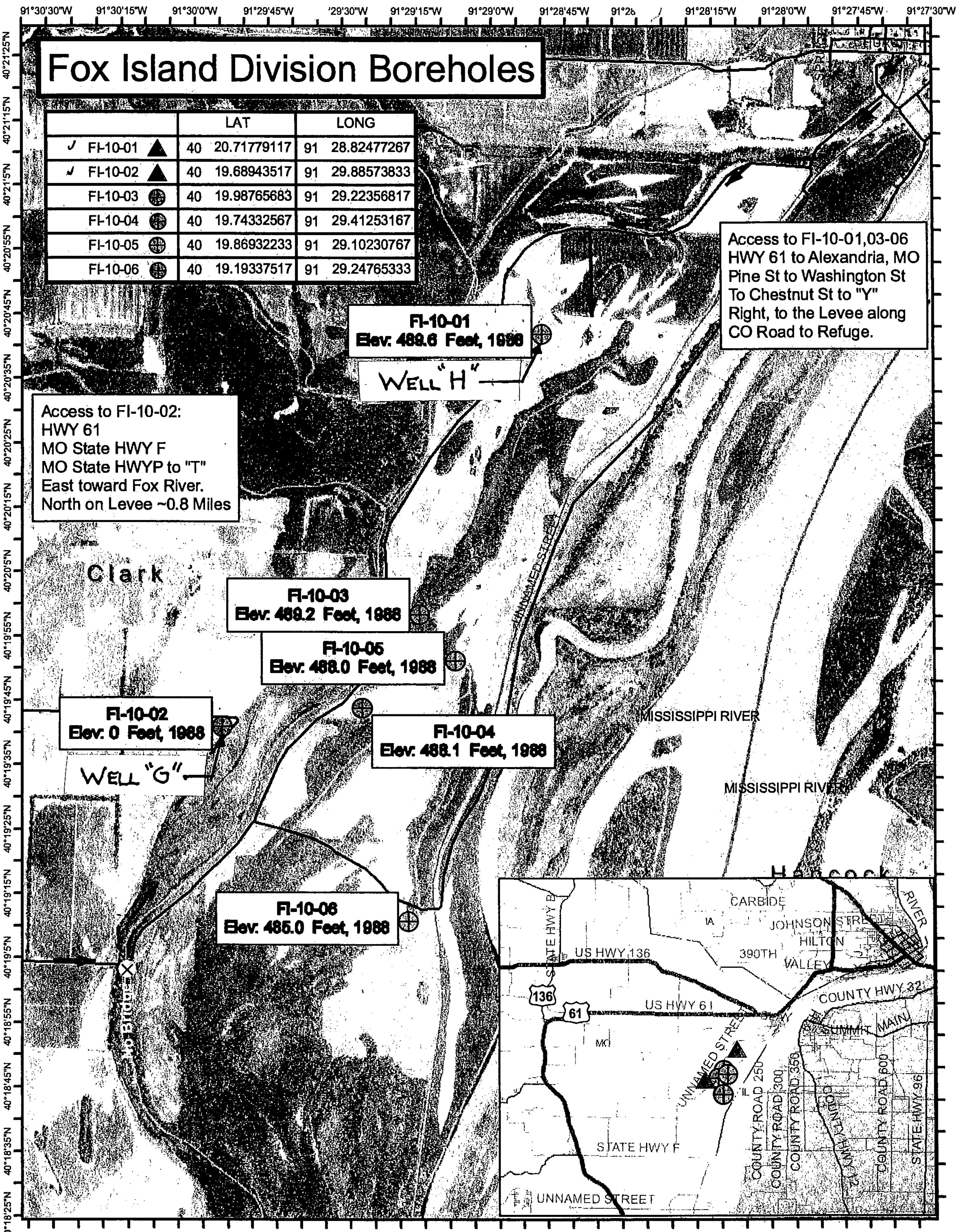


	LAT		LONG	
✓ FI-10-01 ▲	40	20.71779117	91	28.82477267
✓ FI-10-02 ▲	40	19.68943517	91	29.88573833
FI-10-03 ⊕	40	19.98765683	91	29.22356817
FI-10-04 ⊕	40	19.74332567	91	29.41253167
FI-10-05 ⊕	40	19.86932233	91	29.10230767
FI-10-06 ⊕	40	19.19337517	91	29.24765333

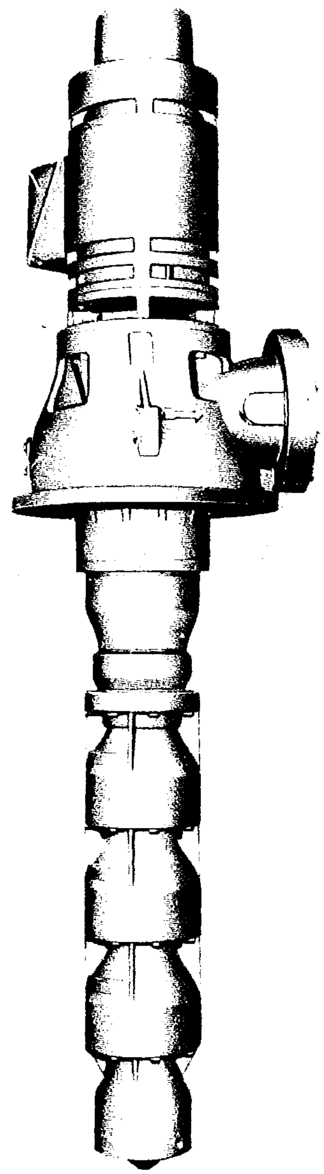
Section 6

GOULDS PUMPS

Installation, Operation and Maintenance Instructions

Model DWT

Deep Well Turbine Pumps



Goulds Pumps

ITT Industries

G-413

TABLE OF CONTENTS

SECTION 1
INTRODUCTION

1-1. INTRODUCTION

1-2. The design, material, and workmanship incorporated in the construction of Goulds Pumps makes them capable of giving long, trouble-free service. The life and satisfactory service of any mechanical unit, however, is enhanced and extended by correct application, proper installation, periodic inspection and careful maintenance. This instruction manual was prepared to assist operators in understanding the construction and the correct methods of installing, operating and maintaining these pumps.

Study thoroughly Sections 1 - 13 and carefully follow the instructions for installation and operating. Sections 14 - 16 are answers to trouble and maintenance questions. Keep this instruction manual handy for reference. Further information can be obtained by contacting the Vertical Turbine Division, Goulds Pumps, Inc., City of Industry, California or your local branch office.

> WARNING: Goulds Pumps, Inc. will not be liable for any damages or delay caused by failure to comply with the provisions of this instruction manual.

1-3. RECEIVING AND CHECKING

1-4. The pump shall be carefully supported prior to unloading from the carrier. Handle all components carefully. Inspection for damage of the shipping crate shall be made prior to unpacking the pump. After unpacking, visually inspect the pump, and check the following:

A. Contents of the pump assembly against shipping list.

B. All components against damage.

C. The shaft is not bent.

1-5. Any shortages or damages should be immediately called to the attention of the local freight agent of the carrier by which the shipment arrived and proper notation made on the bill. This shall prevent any controversy when claim is made and facilitate prompt and satisfactory adjustment.

1-6. MATERIALS AND EQUIPMENT REQUIRED

1-7. The material and equipment necessary for installation of the pump, will vary with the size of the pump and the type of installation.
The following list of standard tools and supplies are offered only as a guide.

A. BULK MATERIAL

- Anti-Galling Lubricant such as ("MOLYKOTE" DOW CORNING).
- Thread Compound
- Lubrication Oil
- Turbine Oil (SEE SECTION 17)
- Grease (SEE SECTION 17)
- Solvent, petroleum-base (kerosene, distillate or unleaded gasoline)
- Grouting material, non-shrinking

B. RIGGING EQUIPMENT

- Mobile power hoist; or a traveling crane; or a derrick
- Dragline and blocks
- Deep throat clamp
- Elevator clamps
- Clevises — for use with eyebolts
- Capstan drive (Cat head and cat line) for making threaded joints (optional)
- Timbers — size, length and quantity as required to support long pump parts on the floor
- I-Beams or timbers to support pump over well
- Tail rope — size and length as required

C. HAND TOOLS

- Pipe wrenches
- Chain tongs
- Chain wrench (clamp type)
- Clean rags
- Feeler gages
- Set of mechanic's tools including: files, wire brush, pliers, wirecutters, pocket knife and pipe wrenches

OPTIONAL TOOLS TO FACILITATE PUMP ASSEMBLY AND DISASSEMBLY:

All pumps:

1. Ammeter to assist in final impeller adjustment (SEE SECTION 13).

All pumps with impeller taper collets:

1. Collet hammer to assist in bowl assembly and disassembly (SEE SECTION 16).

Oil lubrication (enclosed line shaft).

1. Tube tension adapter. (SEE SECTION 9).
2. Dynamometer Scale.

SECTION 2
STORAGE

2-1. STORAGE

2-2. Goulds Pumps carefully preserves and protects its products for shipment. However, the effective life of the preservatives applied at the factory can vary from 3 to 18 months depending on the severity of the environment in which the equipment is stored. This section provides procedures for preparation prior to storage and maintenance during storage of Goulds' pumps. These procedures are necessary to protect the precision parts of the pumps. Specific procedures for storing motors, gearheads, and engines, should be obtained from the equipment manufacturer. This section is intended to be of general assistance to users of Goulds' pumps. It shall not modify, amend and/or otherwise alter the scope of Goulds Pumps warranty in any way whatsoever.

2-3. STORAGE PREPARATION

2-4. Goulds vertical pumps require proper preparation for storage, and regular maintenance during storage. The pump shall be considered in storage when it has been delivered to the job site and is waiting installation. If a pump has been installed but is not in regular operation, such as seasonal shutdown, see Section 14.

2-5. RECOMMENDED STORAGE PROCEDURES

A. Controlled storage facilities should be maintained at an even temperature 10°F or more above the dew point with relative humidity less than 50% and little or no dust. (If these requirements cannot be met the pump is to be considered in uncontrolled storage).

B. For uncontrolled storage periods of 6 months or less, the pump is to be inspected periodically to insure that all preservatives are intact.

C. All pipe threads and flanged pipe covers are to be sealed with tape.

D. The pump must not be stored closer than 6 inches to the ground.

2-6. PREPARATIONS FOR UNCONTROLLED LONG TERM STORAGE

2-7. Storage periods over 6 months require the preceding uncontrolled storage procedure plus the following:

A. Inspect the lube oil and seal flush piping, and either fill the piping with rust preventative oil, or recoat the piping periodically to prevent corrosion.

B. Place 10 pounds of moisture absorbing dessicant or 5 pounds of vapor phase inhibitor crystals near the center of the pump. If the pump is assembled, place an additional one pound in the discharge nozzle securely fastened to the discharge flange.

C. Install a moisture indicator near the perimeter of the pump. Cover the pump with 6 mil minimum thickness black polyethylene or equal and seal it with tape. Provide a small ventilation hole approximately ½ inch diameter.

D. Provide a roof or a shed shelter to protect from direct exposure to the elements.

SECTION 3
PREPARING THE SITE

3-1. PREPARING THE FOUNDATION

3-2. The foundation must be rigid, level and of adequate strength to support the complete weight of the pump plus the weight of the liquid passing through it. Weight data is given on the Certified Pump Outline Drawing, if provided, or may be calculated from data given in Section 17. For fluid weight see Table 17-5 (SECTION 17). Concrete foundations shall have bolts with a pipe sleeve 2½ times the bolt diameter embedded in the concrete, sized and located in accordance with the dimensions given on the Pump Certified Outline Drawing or established by actual measurement of discharge head or subbase mounting holes. The pipe sleeve allows movement for final positioning of the foundation bolts. A dam for grouting shall be constructed. (SEE FIGURE 3-1). Occasionally there is a gradual settling of the ground around a well. If settling is anticipated pour a foundation on opposite sides of the well, outside the area of potential settling, and bridge across the well with suitable I-Beams to carry the weight of the pump. When mounted directly on a structural steel frame, the pump shall be located directly over or as near as possible to the main

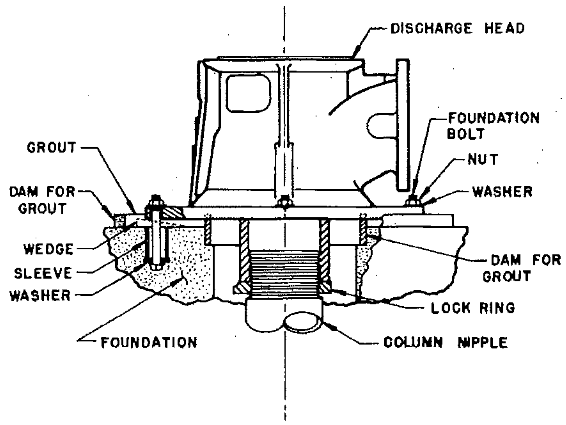


Figure 3-1 Preparing the Foundation

building members, beams or walls. Base plates shall be bolted to the supports to avoid distortion, prevent vibration, and retain proper alignment.

3-3. DEEP WELL TURBINE PUMP

Install the pump only after the well has been proven and production characteristics established, by means of a test pump. The lowest extremity of the pump must be above the perforations of the well casing, to avoid air entrainment, and excessive friction which may cause extensive pump damage.

3-4. WATER LEVEL

3-5. To establish the water level in a well proceed as follows:

A. Install a pipe or copper tube of known length, 10 to 20 feet below the lowest possible pumping level. Make all joints air tight utilizing thread compound.

B. Pump air into the line until the indicated air pressure stabilizes. This indicates that all the water has been expelled from the pipe. The gage reading indicates the pressure necessary to support a column of water of a height equal to the depth that the pipe is submerged.

WATER LEVEL = AIR LINE LENGTH (FT.)
(Ft. Below Ground)

$$\text{MINUS} \quad \frac{\text{GAGE READING IN PSI} \times 2.31}{\text{SPECIFIC GRAVITY OF LIQUID}}$$

3-6. The first stage (closest to suction bowl) must be completely submerged at the minimum standing water level. With a tail pipe the minimum pumping water level may fall below the first stage, but this distance must be subtracted from the NPSH available. The NPSH available must always exceed NPSH required by the pump. The suction bowl or tail pipe must be sufficiently submerged to prevent vortexing.

SECTION 4
INSTALLING THE BOWL

4-1. BOWL INSTALLATION

4-2. Pumps that are 20 feet or less in length are usually shipped completely assembled with exception of the driver, vent piping, mechanical seal or packing, and headshaft, if a vertical hollow shaft driver is supplied.

WARNING

DO NOT WORK UNDER A HEAVY, SUSPENDED OBJECT UNLESS THERE IS A POSITIVE SUPPORT UNDER IT, WHICH WILL PROTECT PERSONNEL SHOULD A HOIST OR SLING FAIL.

4-3. Prior to installing the bowl, remove all accumulated dust, oil or other foreign matter from external surfaces of the pump components and proceed as follows:

A. Position a suitable lifting device over the well or sump opening. Place two timbers or I beams across the well or sump opening strong enough to safely support the weight of the entire pump.

NOTE

IF THE PUMP IS COMPLETELY ASSEMBLED, PROCEED TO SECTION 7.

B. If pump exceeds 200 feet measure available bowl lateral (shaft end play) by pushing shaft towards suction bowl, mark shaft, pull shaft out and mark again and record, this will later aid in adjusting impellers.

C. If provided, install tail pipe (697). Place an elevator clamp just below the tail pipe threads. Attach a sling to the clamp and to hoist hook. Hoist over the well or sump and attach strainer (698) if provided. Lower tail pipe until clamp rests firmly on the supporting timbers. (SEE FIGURES 5-1 AND 6-1).

D. Attach and secure an elevator clamp just below and firmly butted against the top intermediate bowl flange (670). Attach a sling to the clamp and pass the loop end of the sling over the hoist hook. Guide the pump suction to prevent bumping or dragging and hoist the assembly over the well or sump opening.

E. If pressure flush lines to the tail bearing are provided, attach the flush lines to suction bowl and along the length of the bowl assembly. Lubricate joints with thread compound.

F. If a tail pipe is provided, apply thread compound to the tail pipe threads and carefully thread tail pipe into bowl assembly, until joints butt.

G. If a suction strainer (698) is provided, assemble to suction bowl.

H. Lower the bowl assembly into well or sump until elevator clamp rests firmly on the supporting timbers.

J. Place a cover over bowl assembly to prevent entrance of dirt or other foreign matter. Check to see that pump shaft coupling (649) is clean.

K. If keyed shaft coupling is used, remove upper split ring and key.

CAUTION

DO NOT DROP ANY FOREIGN OBJECT INTO THE BOWL ASSEMBLY. SUCH AN OBJECT CAN CAUSE SERIOUS DAMAGE TO THE PUMP AND ANY DOWNSTREAM COMPONENTS. ANY FOREIGN OBJECT DROPPED INTO THE BOWL ASSEMBLY MUST BE RETRIEVED PRIOR TO CONTINUING ASSEMBLY.

SECTION 5
INSTALLING PRODUCT LUBRICATION COLUMN (OPEN LINESHAFT)

5-1. INSTALLING PRODUCT LUBRICATION COLUMN (SEE FIGURE 5-1).

5-2. Installation of product lubrication column, proceed as follows:

A. Check that bottom line shaft is not bent and insert into bottom column section.

B. Place an elevator clamp near top of column just below, and butted firmly against, column pipe coupling (645). For flanged columns, place the elevator clamp just below the flange.

NOTE

FOR FLANGED PIPE, TOP OF COLUMN HAS A FLANGE WITH UNTAPPED HOLES.

CAUTION

ELEVATOR CLAMP PADS MUST BE BUTTED FIRMLY AGAINST THE FLANGE, NOT AGAINST FLANGE TO COLUMN WELD, AND POSITIONED IN SUCH A MANNER AS TO ALLOW MAXIMUM INSERTION OF FLANGE BOLTS. BEFORE PROCEEDING, CHECK BY INSERTING FLANGE BOLTS THROUGH FLANGE. A MINIMUM OF ONE-HALF OF THE FLANGE BOLT HOLES MUST NOT BE OBSTRUCTED.

C. Attach a sling to elevator clamp and to hoist hook. Tie bottom of shaft (646) to column (644), by tying a tail rope to deep throated clamp attached to the bottom of column, then tie a clove hitch or double half hitch around the shaft in the threaded area. Figure 5-2 also shows the alternate method (dotted lines).

D. For all keyed shafts, threaded shafts, and for safety, use chain wrenches (clamp type) attached to shaft just above the shaft tail rope hitch. For keyed shafts, the tail rope hitch shall be above the keyway.

E. Utilize the remaining tail rope to keep tension on the knots during hoisting. Lower end of column section shall be guided by drag line which is pulled by the hoist. A traveling block for the drag line shall be attached to a deep throated clamp, which is secured to bottom of the column.

NOTE

FOR FLANGED COLUMN, TRAVELING BLOCK SHALL BE ATTACHED TO AN EYE BOLT, THREADED THROUGH A FLANGE BOLT HOLE.

F. Hoist column section over pump, keeping tension on tail rope. With column in a vertical position, remove drag line and traveling block, lower column until bottom line shaft is properly aligned with impeller shaft coupling.

CAUTION

USE "MOLYKOTE" DOW-CORNING OR EQUAL FOR ALL GALLING MATERIALS SUCH AS 316 STAINLESS STEEL.

G. For keyed shaft, install retaining ring, and insert key onto line shaft. Lower into shaft coupling approximately one inch. Insert split ring, lower lineshaft until split ring bottoms in the groove.

H. With line shaft in proper position on coupling, remove tail rope, and start threading line shaft into coupling. Clean any dirt which may have entered the threads underneath the tail rope, and apply a few drops of oil to shaft threads if non-galling material. Thread manually until resistance is felt. Finish the joint utilizing a pair of pipe wrenches. Use care not to apply wrenches on bearing journal areas.

NOTE

SHAFT THREADS ARE LEFT HAND.

CAUTION

MAKE UP THREADED JOINTS MANUALLY TO VERIFY THAT THREADS ARE PROPERLY ENGAGED PRIOR TO APPLYING A WRENCH OR A POWER DRIVE. IF CROSS - THREADING OCCURS, BREAK THE JOINT AND REPAIR THREADS. IF THREADS ARE BEYOND REPAIR, REPLACE THE DAMAGED PART.

J. Pumps equipped with keyed coupling, secure retaining ring with capscrews.

K. Clean column threads and lubricate with thread compound.

L. Lower column section (644) until column aligns with discharge bowl threads. Manually, thread column into discharge bowl.

M. Complete joint by tightening column with chain tongs, or capstan drive, and rope until end of column butts firmly against discharge bowl (661).

N. Flanged columns-lower column section until column flange engages the flanged top bowl register. Insert as many capscrews through both flanges as possible, a minimum of one-half the total. Tighten capscrews gradually in diametrically opposite pairs.

CAUTION

DO NOT DROP ANY FOREIGN OBJECT INTO THE PUMP ASSEMBLY. SUCH AN OBJECT CAN CAUSE SERIOUS DAMAGE WHEN THE PUMP IS STARTED, AND ALSO TO DOWNSTREAM COMPONENTS. ANY FOREIGN OBJECT DROPPED INTO THE PUMP ASSEMBLY MUST BE RETRIEVED PRIOR TO CONTINUING ASSEMBLY.

P. Pump with flanged column — Lift pump assembly high enough to allow rotation of the elevator clamp one-quarter turn. Realign and lower assembly. Install and tighten remaining capscrews. Repeat rotation and tightening procedure until all the capscrews are uniformly tight.

Q. If required, attach the next section of pressure flush line and secure to column.

R. Lift the assembly and remove the elevator clamp secured to bowl assembly. Slowly lower assembly into well or sump until column elevator clamps gently come to rest on timbers, and remove sling.

S. Place bearing retainer (652) over shaft (646) and locate it in the column flange register or column coupling recess, whichever the case may be.

NOTE

POUR A SMALL AMOUNT OF OIL BETWEEN BEARING AND SHAFT OR SHAFT SLEEVE. (METAL BEARINGS ONLY).

T. REMOVABLE SHAFT SLEEVE — Slip sleeve on shaft and through bearing retainer, align sleeve hole and shaft hole, and press in roll pin.

CAUTION

DO NOT STRIKE PIN WITH A HAMMER. THIS WILL KNOCK THE SHAFT OUT OF ALIGNMENT.

NOTE

PLACE A COVER OVER COLUMN OPENING TO PREVENT ENTRANCE OF FOREIGN MATTER.

NOTE

AFTER THE FIRST COLUMN SECTION, THE SHAFT SHOULD BE SUPPORTED WITHIN THE LINESHAFT BEARING (653). THE SHAFT SHOULD EASILY BE PULLED TO THE CENTER OF THE BEARING. IF RESISTANCE IS FELT, WHEN MOVING THE SHAFT A BENT LINESHAFT MAY BE INDICATED. PULL PUMP AND CHECK LINESHAFT FOR STRAIGHTNESS.

U. Clean shaft (646) threads and lubricate with oil if non-galling material. Thread shaft coupling (649) on shaft until one-half of coupling threads are engaged.

V. KEYED COUPLING — Install lower half of keyrod coupling on shaft. Remove upper retaining ring, upper split rings, and key.

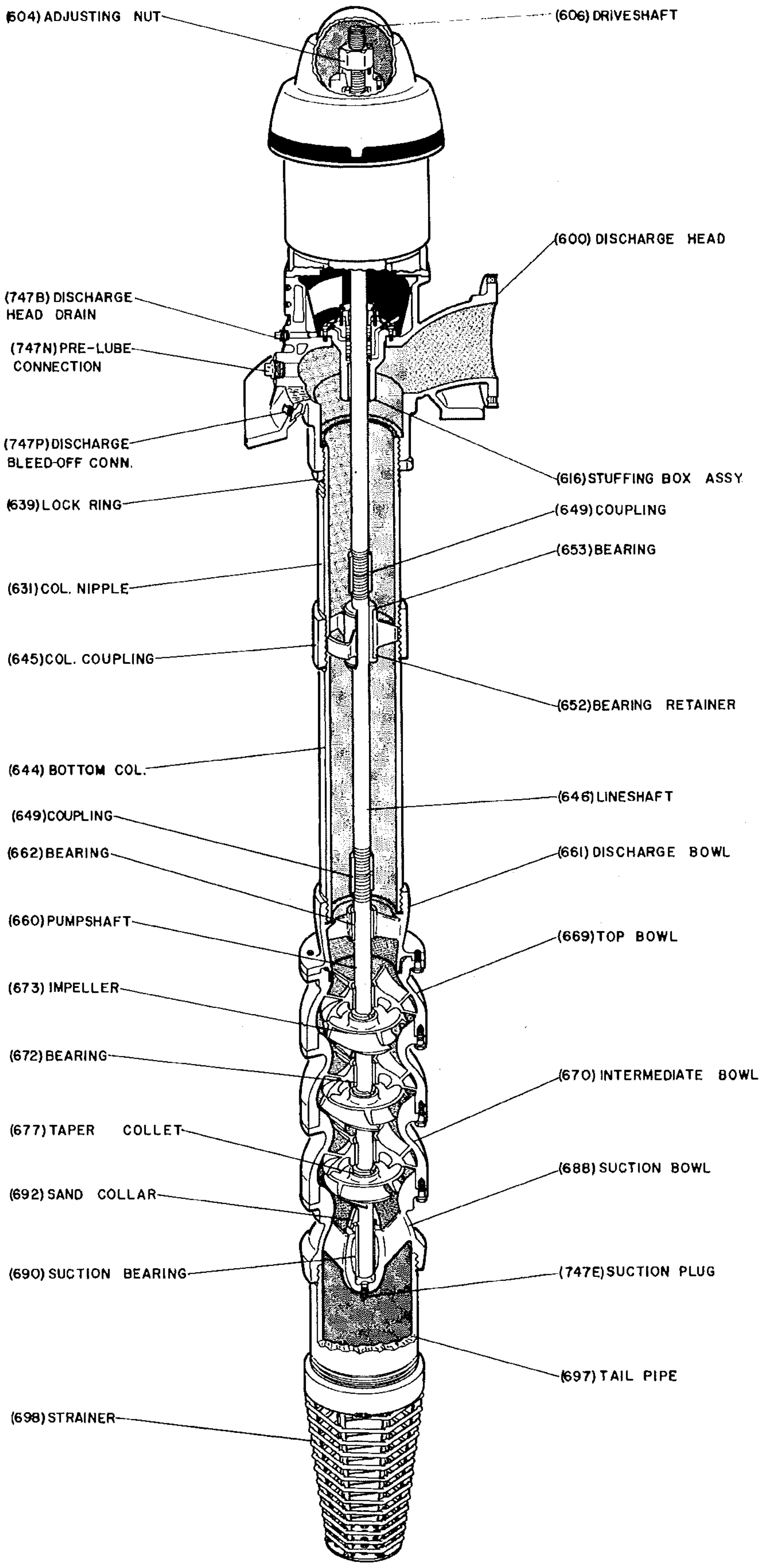


Figure 5-1 Product Lubrication Pump

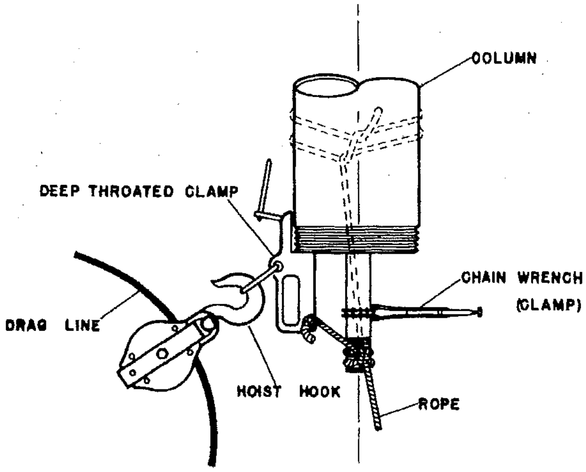


Figure 5-2 Product Lubrication Column Hoisting

W. Repeat the preceding procedures until all column sections required for the proper setting have been installed excluding the column adjusting nipple (631), if required.

NOTE

FOR FLANGED COLUMN, DO NOT OVER-TIGHTEN FLANGE BOLTS IN ORDER TO MAKE FLANGE FACES MEET. FLANGE FACES ARE DESIGNED TO BE SEPARATED BY BEARING RETAINER.

X. If required, install the column nipple with longest threaded end upward. Thread lock ring (639) on column.

CAUTION

DO NOT USE A CLAMP ON THE COLUMN ADJUSTING NIPPLE TO SUPPORT THE PUMP ASSEMBLY.

SECTION 6
INSTALLING OIL LUBRICATION COLUMN (ENCLOSED LINESHAFT)

6-1. INSTALLING OIL LUBRICATION COLUMN (SEE FIGURE 6-1).

6-2. Installation of oil lubrication column, proceed as follows:

A. Insert tube (654) and shaft (646) sections into column section.

B. Place an elevator clamp near top of column just below and butted firmly against column pipe coupling (645). For flanged columns, place the elevator clamp just below the flange.

CAUTION

ELEVATOR CLAMP PADS MUST BE BUTTED FIRMLY AGAINST THE FLANGE, NOT AGAINST FLANGE TO COLUMN WELD, AND POSITIONED IN SUCH A MANNER AS TO ALLOW INSERTION OF FLANGE BOLTS. BEFORE PROCEEDING, CHECK BY INSERTING FLANGE BOLTS THROUGH FLANGE. A MINIMUM OF ONE-HALF OF FLANGE BOLT HOLES MUST NOT BE OBSTRUCTED FOR INSERTION OF FLANGE BOLTS.

C. Attach a sling to elevator clamp and to hoist hook. Attach bottom of shaft (646) to column (644), by tying a tail rope to deep throated clamp attached to bottom of column. (SEE FIGURE 6-2). Tie a clove hitch or double half hitch around the enclosing tube and then around the shaft in threaded area. Figure 6-2, also shows the alternate method (dotted lines).

D. For all keyed shafts, and for safety, on threaded shafts, use chain wrenches (clamp type) on the shaft just above the shaft tail rope hitch. (SEE FIGURE 6-2). For keyed shafts the tail rope hitch shall be above the keyway.

E. Utilize the remaining tail rope to keep tension on the knots during hoisting. Lower end of column section shall be guided by a drag line which is pulled by the hoist. A traveling block for the drag line shall be attached to a deep-throated clamp, which is secured to bottom of the column. Take care that clamp does not damage the column threads.

F. Hoist column section over pump, keeping tension on tail rope. With column in a vertical position, remove drag line and traveling block, lower column until bottom line shaft is properly aligned with pump shaft coupling.

CAUTION

USE "MOLYKOTE" DOW-CORNING OR EQUAL FOR ALL GALLING MATERIALS SUCH AS 316 STAINLESS STEEL.

G. For keyed shaft, install retaining ring and insert key onto line shaft, lower into shaft coupling approximately one inch. Insert split ring, lower lineshaft until split ring bottoms in the groove.

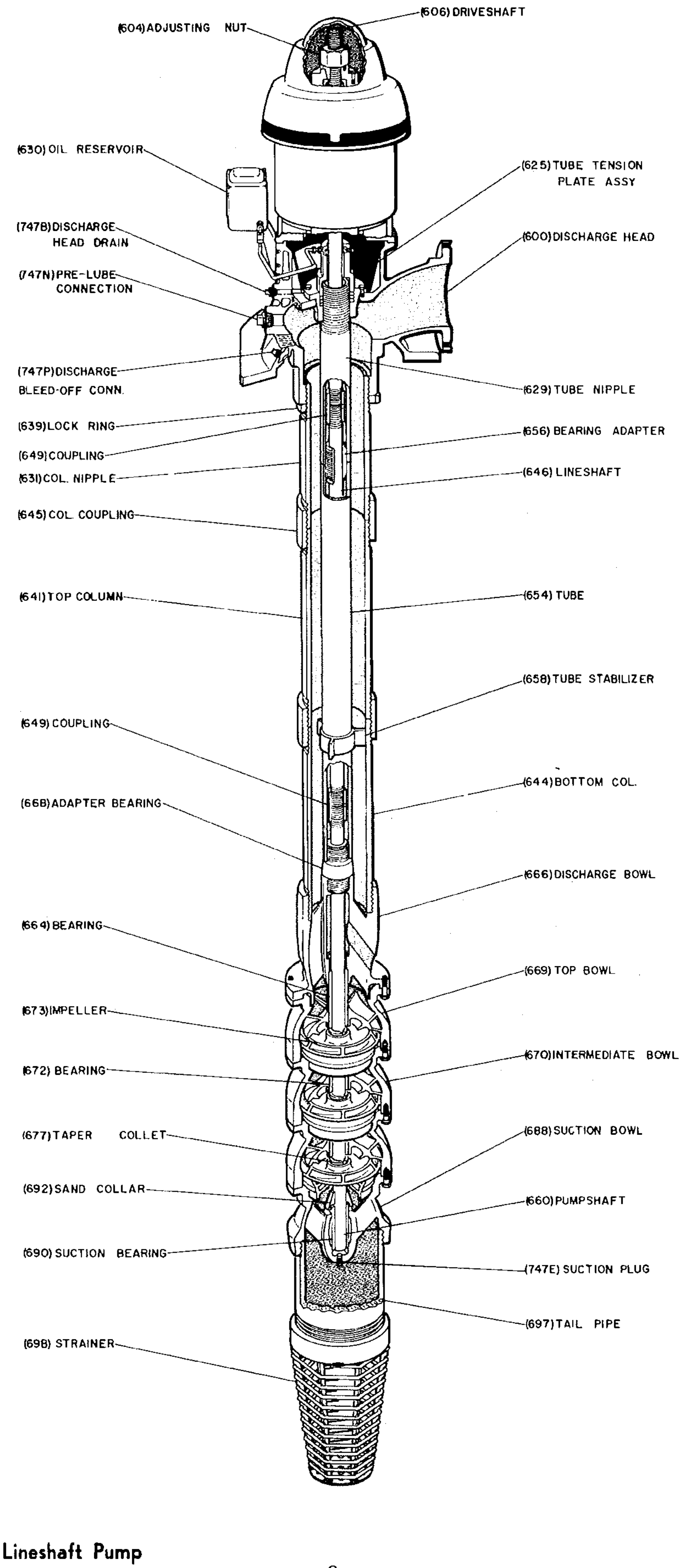


Figure 6-1 Enclosed Lineshaft Pump

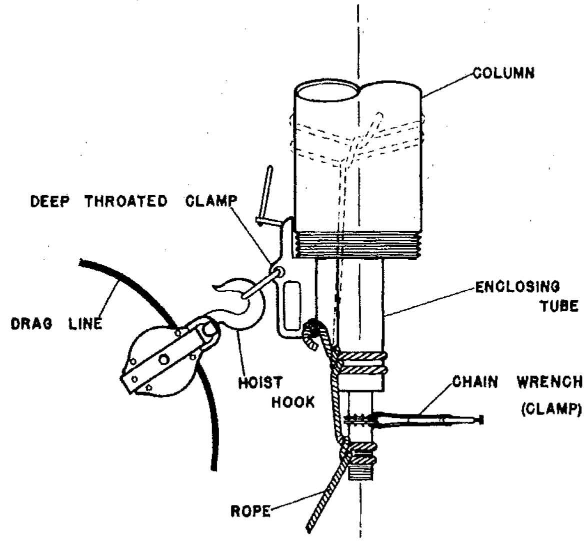


Figure 6-2 Oil lubrication Column Hoisting

H. With line shaft in proper position on coupling, remove tail rope and start threading line shaft into coupling. Clean any dirt which may have entered the threads underneath the tail rope and apply a few drops of oil to shaft threads (If non-galling material).

NOTE

SHAFT THREADS ARE LEFT HAND.

CAUTION

MAKE UP THREADED JOINTS MANUALLY TO VERIFY THAT THREADS ARE PROPERLY ENGAGED PRIOR TO APPLYING A WRENCH OR A POWER DRIVE. IF CROSS - THREADING OCCURS, BREAK THE JOINT AND REPAIR THREADS. IF THREADS ARE BEYOND REPAIR, REPLACE THE DAMAGED PART.

Thread shaft into coupling, manually until resistance is felt. Complete the joint utilizing a pair of pipe wrenches, butting the bottom of the shaft against the top of the shaft. Use care not to apply wrenches on bearing journal areas. Remove all burrs and chips with a clean cloth.

J. Pumps equipped with keyed coupling, secure retaining ring with capscrews.

K. Carefully lower column section until lower end of the tube section rests on adapter bushing (668). Remove tail rope, clean outside of adapter bushing and lubricate with thread compound. Thread tube section onto adapter bushing manually, until resistance is felt. Complete tube joint by utilizing a pair of pipe wrenches or chain tongs, butting the end of the tube against the upper end of the tube adapter bushing.

L. Clean column threads and lubricate with thread compound.

M. Lower column until column aligns with discharge bowl. Manually thread column into discharge bowl. Complete joint by tightening column, utilizing chain tongs or capstan drive and rope until end of column butts firmly against discharge bowl.

CAUTION

MAKE UP THREADED JOINTS MANUALLY TO VERIFY THAT THREADS ARE PROPERLY ENGAGED PRIOR TO APPLYING A WRENCH OR A POWER DRIVE. IF CROSS - THREADING OCCURS, BREAK THE JOINT AND REPAIR THREADS, IF THREADS ARE BEYOND REPAIR REPLACE THE DAMAGED PART.

N. Flanged columns — lower section until column flange engages the flanged discharge bowl register. Insert as many capscrews through both flanges as possible a minimum of one-half the total. Tighten capscrews gradually in diametrically opposite pairs. Lift pump assembly, rotate elevator clamp one-quarter turn, realign and lower assembly. Install, and tighten the remaining capscrews. Repeat rotation and tightening procedure until all capscrews are uniformly tight.

CAUTION

DO NOT DROP ANY FOREIGN OBJECT INTO THE PUMP ASSEMBLY.

P. If provided, attach the next section of pressure flush line and secure to the column.

Q. Lift pump assembly and remove elevator clamp secured to bowl assembly. Slowly lower assembly into well or sump until elevator clamp gently comes to rest on timbers and remove the sling.

R. Keyed coupling — Install lower half of keyed coupling on shaft. Remove upper retaining plate, upper split ring and key.

S. Repeat the preceding procedures. At equally spaced intervals throughout the column assembly, install tube stabilizer (658) over the enclosing tube (654), using soapy water as lubricant. Continue until all column sections for the proper setting have been installed, excluding the column adjusting nipple (631), if provided. If pump is equipped with column adjusting nipple, install it with longest threaded end upward. Thread lock ring (639) on column.

CAUTION

DO NOT USE A CLAMP ON THE COLUMN ADJUSTING NIPPLE TO SUPPORT PUMP ASSEMBLY.

SECTION 7
INSTALLING THE DISCHARGE HEAD

7-1. INSTALLING A COMPLETELY ASSEMBLED PUMP

7-2. For pumps shipped from the factory assembled with driver, suction bearing pressure flush line, suction strainer, and/or tail pipe, remove these components prior to installing the pump assembly.

A. Attach a sling to the discharge head and hoist the pump assembly over the well. Carefully guide the pump to avoid dragging or bumping the suction end.

B. If applicable, reassemble suction bearing lube line, tail pipe and/or suction strainer. Refer to SECTION 4.

C. Continue assembly procedure with paragraph 7-4 step H.

7-3. INSTALLING THE DISCHARGE HEAD

7-4. If a subbase is provided, remove any burrs and clean thoroughly. Install the discharge head on the subbase and secure it with capscrews provided.

A. If the stuffing box (SEE FIGURE 8-1) or oil tube tension nut (SEE FIGURE 9-1), is assembled to the head, remove these components at this time.

B. Thread two eyebolts in the head driver mounting holes diametrically opposite. Attach a sling to eyebolts and hoist discharge head over the pump.

CAUTION

DO NOT LIFT HEAD BY LIFTING LUGS IF PUMP IS NOT ATTACHED. THE HEAD IS HEAVIER ON THE DISCHARGE SIDE AND WILL TIP.

C. Clean the threads at upper end of column assembly and lubricate with thread compound.

CAUTION

DO NOT BUMP OR SCRAPE THE SHAFT PROTRUDING ABOVE THE COLUMN. THIS COULD RESULT IN BENDING OR DAMAGING THE SHAFT.

D. Slowly lower the discharge head, aligning the vertical hole in the center with the shaft protruding above the column. Continue to lower the discharge head (600), until the large threaded hole in the bottom of discharge head rests squarely on top of column. Rotate discharge head, threading onto column, butting the top of column tightly against the discharge head. (SEE FIGURE 6-1).

E. If pump has a column nipple (631) with product lube, screw the discharge head onto the column nipple until the head shaft (608) extends above the top of pump base, about one inch plus adjusting nut thickness, and the distance through the motor or gearhead drive, often referred to as the C.D. Dimension. For oil lube (enclosed line shaft), the tube nipple (631) should be approximately ¾" above the surface where the tube tension plate (625) mates with the head (600).

F. If a pressure flush line is being installed, terminate above the discharge head base.

G. Hoist the discharge head by lifting lugs, and remove elevator clamp attached to column.

H. Remove the supporting timbers or I beams and clean the top of foundation area. Orient the discharge head in the required position. Lower the pump, until the base of the discharge head engages the foundation bolts. If a concrete foundation is used place leveling wedges near the foundation bolts. In case of a structural foundation or pump which will not be grouted to the foundation use shims for leveling the pump.

J. Continue to lower the pump until base of discharge head or subbase rests firmly on the wedges or shims.

K. Check the levelness of the discharge head in all directions, utilizing a spirit level across the driver mounting surface of the discharge head. The discharge head must be level with all wedges or shims butting tightly against the base of discharge head and against the foundation. Install nuts on foundation bolts, tighten them gradually and uniformly. Check to see that pump has remained level in all directions after final tightening.

SECTION 8
STUFFING BOX INSTALLATION (PRODUCT LUBRICATION)

8-1. STUFFING BOX INSTALLATION

A. If provided install headshaft sleeve and press pin into shaft.

NOTE

DO NOT STRIKE PIN WITH A HAMMER, THIS WILL BEND SHAFT OR KNOCK IT OUT OF ALIGNMENT.

8-2. FOR STYLE "A"

A. Position gasket (779A) on discharge head. Slide stuffing box (616) down over the headshaft (608) into position on the gasket. Secure with capscrews (758B).

B. Insert lantern rings (621), and packing rings (620A) as shown in figure 8-1. Install packing rings 180° apart, for each successive packing ring installed.

C. Install split gland (618), and insert studs (739A) through split gland and into stuffing box. Install nuts (735A) finger tight. Install grease line or pipe plug (747G) in grease port, and bypass line (624) in bypass port.

NOTE

GREASE PORT IS DESIGNATED AS PORT "A" AND BYPASS AS PORT "B" STAMPED ON STUFFING BOX.

CAUTION

DO NOT OVER-TIGHTEN STUFFING BOX. IT CAN WEAR OUT PACKING PREMATURELY AND SERIOUSLY DAMAGE THE SHAFT.

8-3. FOR STYLE "B"

A. Same as for style "A".

B. Insert packing washer (789C) and packing (620A) as shown in figure 8-1.

C. Install split gland (618) and insert studs (739A) through split gland and into stuffing box. Install nuts (735B) finger tight. Install bypass line in bypass port (624).

NOTE

GREASE LINE MAY BE INSTALLED AS AN OPTION TO BYPASS LINE IF DISCHARGE PRESSURE IS LESS THAN 100 PSI.

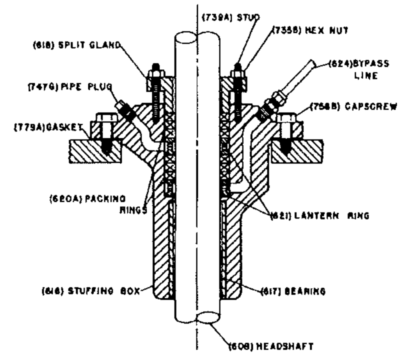
8-4. FOR STYLE "C"

A. Same as for style "A".

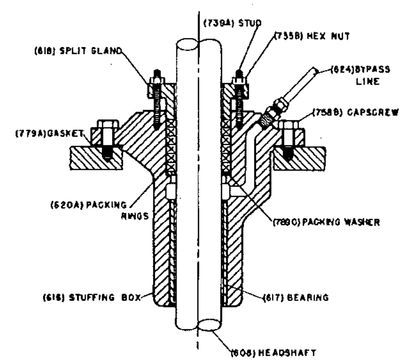
B. Install packing rings (620A).

C. Install split gland (618) and insert studs (739A) through split gland and into stuffing box. Install nuts (735A) finger tight.

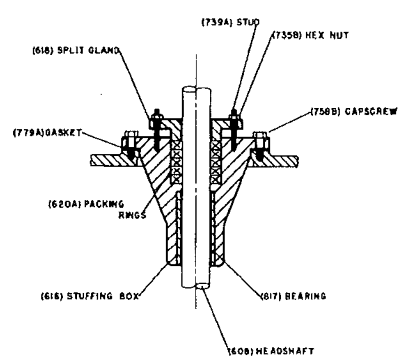
8-5. Instructions for installing the mechanical seal are provided by the manufacturer of the seal. These instructions must be carefully followed to prevent leakage or premature wear of the seal or the pump shaft.



Style A



Style B



Style C

Figure 8-1 Stuffing Box

SECTION 9
INSTALLING TUBE TENSION PLATE ASSEMBLY AND LUBRICATION SYSTEM (OIL LUBRICATION)

9-1. INSTALLING THE TUBE TENSION NUT

A. Lubricate tube threads and underside of tension plate flange with thread compound. Thread the tension plate (625) onto the enclosing tube nipple (629) manually until its shoulder rests on the discharge head. (SEE FIGURE 9-1).

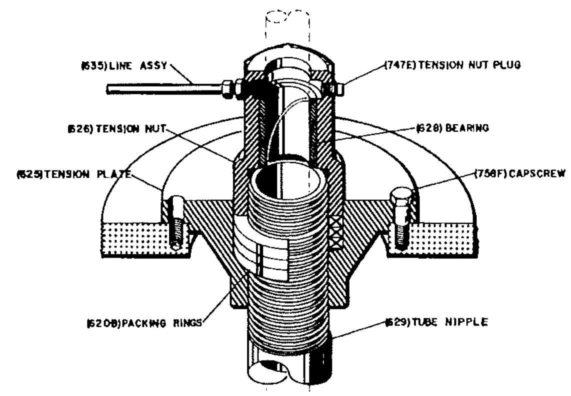


Figure 9-1 Tension Plate Assy (Drip Feed Lubrication)

9-2. TENSIONING THE ENCLOSING TUBE

A. The enclosing tube sags from its own weight as it is installed, and must be pulled tight (tensioned) to make it straight. This section describes two methods of tensioning the tube. The direct pull method is more precise and is preferred. The second method — the wrenching method — is given as an alternate.

NOTE

THE CORRECT TENSION IS EQUAL TO THE WEIGHT OF THE ENCLOSING TUBE PLUS 10%.

B. Weights per foot for each tube size are given in Table 9-1. Multiply by total length of the tube to determine the total weight.

9-3. DIRECT PULL METHOD

A. The upper end of the tube may be pulled by the hoist to obtain the pre-determined tension value. This requires the use of a dynamometer scale and an adapter fitting to grip the tube. (TUBE TENSION ADAPTER AVAILABLE THROUGH FACTORY). With the tension plate installed manually but not tightened, thread the special fitting onto the top of the tube to full engagement. Attach the dynamometer scale to the fitting, and connect the upper end of the scale to the hoist hook. Operate the hoist hook to apply the required tension. This shall pull the tension plate off the discharge head. Manually thread the tension plate to reset it. Release tension, remove dynamometer scale and special fitting.

TABLE 9-1
WEIGHT-PER-FOOT OF ENCLOSING TUBE

TUBE SIZE (INCH)	WEIGHT PER FOOT (LB.)
1¼	2.99
1½	3.63
2	5.02
2½	7.66
3	10.25
3½	12.50
4	14.98
5	20.78
6	28.57

9-4. WRENCHING METHOD

A. If a dynamometer scale is not available, the tube can be tensioned by wrenching the tube nut. Torque the tension plate to take all slack out of the tube, and induce a reasonable amount of tension by turning tension plate counterclockwise.

NOTE

DO NOT TURN CLOCKWISE TO ALIGN HOLES IN TENSION PLATE AND DISCHARGE HEAD.

9-5. DIRECT PULL AND WRENCHING METHOD

A. Install capscrews (758F) in the tension plate. Pour one pint of oil down the oil tube.

B. Install packing in the tension plate and thread the tension nut (626), tightening it firmly against the packing.

C. If a packed type tension nut (623) is used, install packing (620C), packing gland (618) and secure with stud (739E) and nut (735B). Screw nut finger tight. Install line assembly (635) and connect to flush liquid supply. (SEE FIGURE 9-2).

CAUTION

BE SURE THAT THE TOP OF THE ENCLOSING TUBE DOES NOT INTERFERE WITH THE TENSION NUT.

D. If top of the tube interferes with the tension nut determine the distance, if tube is too long or too short. Remove tension plate, raise pump assembly, unthread lock ring (639), and adjust nipple (631) (SEE FIGURE 6-1) the required distance to eliminate interference. Reinstall and re-level pump. Refer to SECTION 7 paragraphs J and K.

9-6. LUBRICATION SYSTEM

A. Connect solenoid valve (IF PROVIDED), oil lines, and fill the oil reservoir with oil. Refer to SECTION 18.

B. Check the lubricator feed and see that the oil reservoir is flowing freely. (In the case of a solenoid valve, temporary power connections are required). Set the proper drops per minute on the regulator. Table 9-2 shows recommended regulator setting.

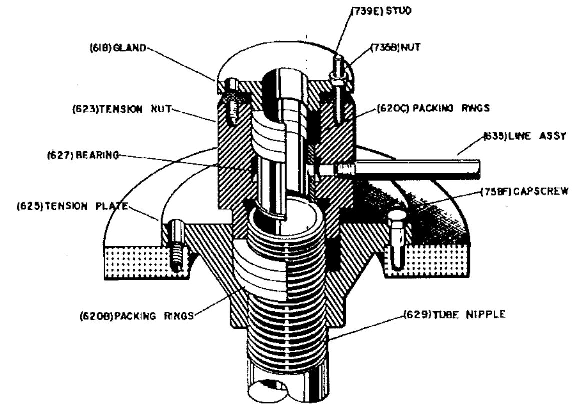


Figure 9-2 Tension Plate Assy (Flush Lubrication)

TABLE 9-2 REGULATOR SETTING

DROPS PER MINUTE PER 100 FEET OF SETTING	SHAFT SIZE (INCH)
8	¾ to 1
16	1 3/16 to 1 15/16
20	2 3/16 and larger

SECTION 10
INSTALLING THE DRIVER (VHS)

10-1. INSTALLATION OF HOLLOW SHAFT DRIVER

WARNING

DO NOT WORK UNDER A HEAVY SUSPENDED OBJECT UNLESS THERE IS A POSITIVE SUPPORT UNDER IT WHICH WILL PROTECT PERSONNEL SHOULD A HOIST OR SLING FAIL.

10-2. DRIVER SUPPORT. If a driver support is furnished proceed as follows:

A. Hoist driver support and inspect mounting surfaces and register and clean these surfaces thoroughly.

B. Install driver support on discharge head and secure with capscrews.

CAUTION

USE "MOLYKOTE" DOW-CORNING OR EQUAL FOR ALL GALLING MATERIALS SUCH AS 316 STAINLESS STEEL.

10-3. COMBINATION DRIVESHAFT. In the case of a pump having a combination driveshaft (shaft extends above the motor mounting flange) proceed as follows:

A. Remove driver cover and drive coupling. (SEE FIGURE 10-1).

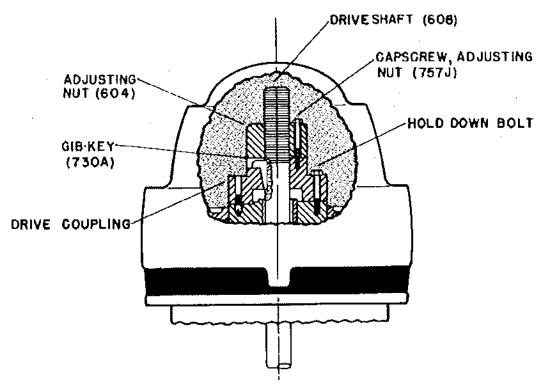


Figure 10-1 Hollow Shaft Adjusting Nut

B. Attach a sling to the lifting lugs on driver. Hoist driver, inspect the mounting surfaces and register, and clean these surfaces thoroughly. If any burrs are found, remove burrs with a smooth mill file.

C. Lower driver slowly, aligning the driver hollow shaft with the combination driveshaft, and onto the discharge head or driver support being extremely careful that combination driveshaft does not bind in the driver hollow shaft. Orient the driver conduit box in the required position and align the mounting holes with the mating tapped holes in the discharge head or driver support.

D. Secure driver to discharge head or driver support with capscrews provided.

E. Check that the pump shaft is concentric with the hollow shaft of driver by sliding the driver coupling over the combination headshaft. If the driver coupling freely engages the drive pins at the top of the driver, the pump headshaft is properly concentric. Eccentricity at this point may be to a bent shaft or to foreign particles between butting ends of shaft sections. The cause must be found and corrected before proceeding. Remove driver coupling.

10-4. SEPARATE HEADSHAFT AND DRIVESHAFT. In the case of a pump having a separate headshaft and driveshaft (headshaft terminates below the driver mounting flange) proceed as follows:

A. Slowly lower the driver onto driver mounting flange, orient the driver conduit box in the required position and align the mounting holes with the mating tapped holes in the discharge head.

B. Apply a thin film of oil to headshaft threads (if non-galling material), install coupling to headshaft utilizing a strap wrench below the coupling.

CAUTION

DO NOT DAMAGE HEADSHAFT OR COMBINATION HEADSHAFT. ANY BURRS RAISED ON SHAFTING SHALL MAKE IT DIFFICULT TO REMOVE SEAL, SLEEVE, OR STUFFING BOX.

C. Slide the driveshaft (606) downward through the hollow shaft of the driver to meet the headshaft coupling. Apply a thin film of oil to the shaft threads (if non-galling material) and screw into coupling. Make sure the shaft is not damaged in any way.

10-5. ALL PUMPS. The following information applies to all pumps.

A. On drivers having non-reverse ratchet, manually turn the driver shaft clockwise until the non-reverse ratchet fully engages.

B. Lubricate the driver bearings in accordance with the instructions given on the lubrication plate attached to the driver case.

WARNING

THE MOTOR MUST NOT BE TESTED FOR DIRECTION OF ROTATION WHEN COUPLED TO THE PUMP. IF PUMP SHOULD ROTATE IN THE WRONG DIRECTION, SERIOUS DAMAGE TO THE PUMP AND DRIVER AND SERIOUS INJURY TO NEARBY PERSONNEL COULD RESULT.

C. Make temporary electrical connections according to tagged leads or diagram attached to the driver. The driver must rotate counterclockwise when viewed from above. See arrow on pump name plate. If driver does not rotate counterclockwise, change driver rotation by interchanging any two leads, for three phase only. For single phase, see driver manufacturer's instructions.

D. Slip on driver coupling (SEE FIGURE 10-1). Apply a thin film of oil on gib key (730A) and install key. Key shall be a slide fit allowing adjustment of the drive shaft by means of the adjusting nut. Secure drive coupling, see that the drive coupling is properly seated. Install adjusting nut (604), but do not adjust impellers at this time.

10-6. PRELIMINARY ADJUSTMENTS OF IMPELLERS. Mechanical seals if used must be disengaged before impeller adjustment.

10-7. Pumps with setting over 200 feet, continue with paragraph 10-8.

A. With impellers touching bowl faces, turn adjusting nut (604) counterclockwise until face of the nut makes contact with motor coupling.

B. Align hole "A" in adjusting nut and hole "C" in motor coupling. (SEE FIGURE 10-2).

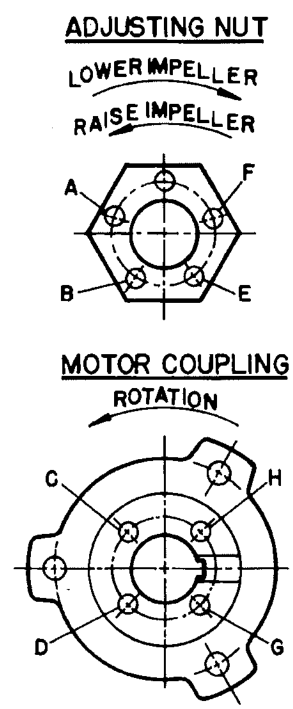


Figure 10-2 Impeller Adjustment

C. Insert capscrew in hole "B". Turn adjusting nut counterclockwise until holes "B" and "D" line up. This gives minimum adjustment 1/20 of one turn — (SEE TABLE 10-1 for vertical movement).

D. By turning adjusting nut still more and aligning holes "E" and "G" impellers are raised 2/20 turn. When holes "F" and "H" align, impellers are raised 3/20 turn and so on. SEE TABLE 10-1.

E. For open impellers, turn adjusting nut 3/20 turn for pumps up to 10 feet of column. Add 2/20 turn for each additional 10 feet of column.

F. For enclosed impellers, use two turns for the first 100 feet and one turn for each additional 50 feet of setting.

10-8. For pump settings over 200 feet adjustment procedures are as follows:

A. Turn adjusting nut counterclockwise until impellers reach the top of bowl (resistance is felt when impellers rub against the top of bowl). Lower impellers 30% of distance acquired in Section 4 paragraph 4-3 step B. SEE TABLE 10-1.

10-9. GROUTING THE BASE. If the pump is on a concrete foundation, it is recommended that the discharge head base be grouted to the foundation. If desired, this may be delayed until the pump installation has been tested. (SEE FIGURE 3-1). Pour the grout into the foundation and force it between the discharge head and the dammed-in area. Allow ample time for the grout to cure before starting the pump.

NOTE

USE ONLY NON-SHRINKING GROUTING MATERIAL.

TABLE 10-1
IMPELLER VERTICAL MOVEMENT

SHAFT SIZE	THREAD	VERTICAL MOVEMENT IN 1/20 TH TURN
3/4 INCH	3/4-16 LH	.003
1	1-12 LH	.004
1 3/16	1-12 LH	.004
1 1/2	1-10 LH	.005
1 11/16	1-10 LH	.005
1 15/16	1-10 LH	.005
2 3/16	1-10 LH	.005
2 7/16	1-10 LH	.005
2 11/16	1-8 LH	.006

SECTION 11
INSTALLING THE DRIVER (VSS)

11-1. INSTALLATION OF SOLID SHAFT DRIVER

11-2. The coupling shown between the driver shaft and pump shaft may be a non-spacer figure 11-1 type or a spacer type figure 11-2. The latter is used on pumps having a mechanical shaft seal, to permit replacing the seal without lifting the driver.

WARNING

DO NOT WORK UNDER A HEAVY SUSPENDED OBJECT UNLESS THERE IS A POSITIVE SUPPORT UNDER IT, WHICH WILL PROTECT PERSONNEL SHOULD A HOIST OR SLING FAIL.

11-3. In the case of a pump having a solid shaft driver proceed as follows:

A. Apply a thin film of oil on headshaft key (730C) and insert key into headshaft keyseat.

B. Gently lower pump hub (614) over headshaft.

C. Install adjusting plate (613) on headshaft.

D. If a driver support is furnished, inspect registers and install on the discharge head, securing it with capscrews.

E. Attach a sling to the lifting lugs of driver. Hoist driver, inspect the mounting surface, the register, and shaft extension, and clean these surfaces thoroughly. If any burrs are found, remove burrs with a smooth mill file, cleaning thoroughly afterward.

F. Apply a thin film of oil to driver key (730B) and insert it into the driver shaft keyseat. Place the driver hub (610) over the driver shaft and key, sliding it up the shaft until the groove near the end of shaft is exposed. Install split ring (722) in the groove, and slide the driver hub down over the split ring to capture it.

G. Orient the driver conduit box in the required position, and align the mounting holes with the mating tapped holes in the driver support. Lower the driver until the registers engage and driver rests firmly on the driver support. Secure driver with capscrews provided.

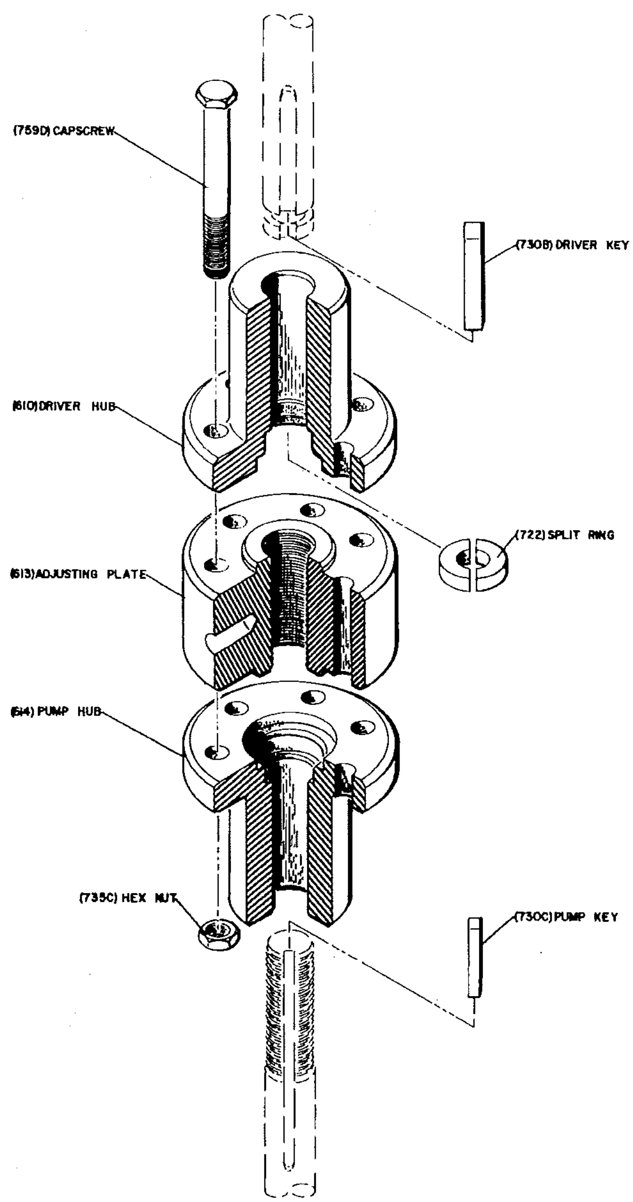


Figure 11-1 Flanged Adjustable Coupling

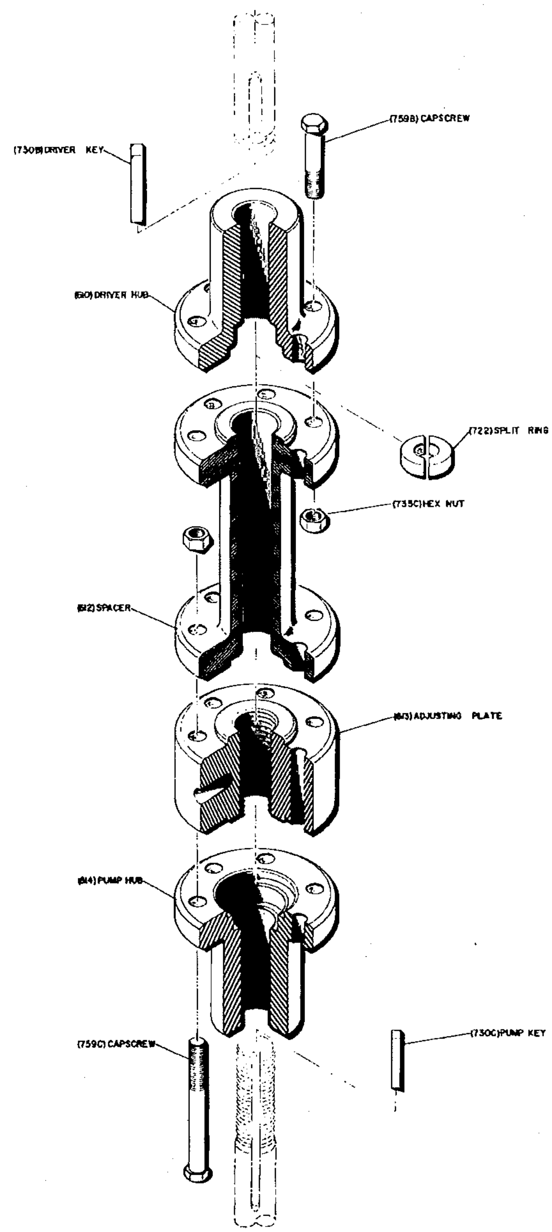


Figure 11-2 Flanged Adjustable Coupling with Spacer

H. Lubricate driver bearings in accordance with instructions given on the lubrication plate attached to the driver case.

WARNING

THE MOTOR MUST NOT BE TESTED FOR DIRECTION OF ROTATION WHEN COUPLED TO THE PUMP. IF PUMP SHOULD ROTATE IN THE WRONG DIRECTION, SERIOUS DAMAGE TO THE PUMP AND DRIVER AND SERIOUS INJURY TO NEARBY PERSONNEL COULD RESULT.

J. Make temporary electrical connections according to tagged leads or diagram attached to the driver. Driver must rotate counterclockwise when viewed from above. See arrow on pump name plate. If driver does not rotate counterclockwise, change driver rotation by interchanging any two leads, for three phase only. For single phase see driver manufacturer's instructions.

K. On drivers having a non-reverse ratchet, manually turn the driver shaft clockwise until the non-reverse ratchet fully engages.

11-4. PRELIMINARY ADJUSTMENTS OF IMPELLERS. Pumps with settings less than 200 feet proceed as follows:

A. For enclosed impellers raise adjusting plate (613) toward driver hub (610) or spacer hub (612). Obtain 3/16 inch clearance between adjusting plate, and driver hub or spacer hub 1/4 inch if setting exceeds 100 feet but less than 200 feet.

B. Align adjusting plate holes with pump hub (614) holes, insert capscrews (759D), and draw pump hub to mate with driver hub or spacer hub. Tighten capscrews gradually and uniformly.

C. For open impellers procedure is the same as for enclosed impellers with following exception:

D. Obtain .015 inch clearance between adjusting plate and motor hub or spacer hub, for the first 10 feet of column. Add 0.010 for each additional 10 feet of column.

11-5. For pump settings over 200 feet procedure is the same as in paragraph 11-4 with following exception:

A. Use adjusting plate and capscrews for raising or lowering impellers instead of the adjusting nut of a hollow shaft driver.

11-6. GROUTING THE BASE. If the pump is on a concrete foundation, it is recommended that the discharge head base be grouted to the foundation. If desired, this may be delayed until the pump installation has been tested. (SEE FIGURE 3-1). Pour the grout into the foundation and force it between the discharge head and the dammed-in area. Level off the grout flush with the top of the dam. Allow ample time for the grout to cure before starting the pump.

NOTE

USE ONLY NON-SHRINKING GROUTING MATERIAL.

SECTION 12
INSTALLING THE GEARHEAD

12-1. GEARHEAD DRIVE INSTALLATION

12-2. Installation procedures for gearhead drives are similar to those for electric drivers except as follows:

A. Slowly lower the gearhead and orient with the input shaft. Align mounting holes with the mating tapped holes in the discharge head. Lower the gearhead until the registers engage and the gearhead rests firmly on the discharge head. Install capscrews in the mounting holes and tighten them gradually and uniformly.

B. Some gearheads are equipped with an oil cooling system which is supplied with cooling fluid from the pump or from external source. Make cooling connections with tubing or rubber hose.

CAUTION

DO NOT USE RIGID PIPE FOR THIS PURPOSE. RIGID PIPE IS SUSCEPTIBLE TO LEAKING AT THE JOINTS, DUE TO VIBRATION.

If pump fluid is to be used, connect a length of tubing and a flow-regulating valve between the inlet on the gearhead and a pipe tap hole in the discharge head. Attach another tube or a rubber hose to the outlet on the gearhead. This may be used to conduct the fluid back to the sump or to any convenient drain.

C. Assemble the flexible shaft flanges on gearhead drive and engine. The prime mover (engine or steam turbine) must be mounted on a firm foundation in alignment with the gearhead. The flexible shafts shall be within two degrees parallel. Keep the lugs on flange yokes in same position as shipped from the factory. If slip joint is moved, be sure lugs are realigned. If a flexible coupling is used, the pump and prime mover should be installed on the same foundation. Consult the prime mover and coupling or drive shaft manufacturer's instructions for detailed information.

WARNING

MOVING PARTS OF THE PRIME MOVER, COUPLING DEVICE, AND GEARHEAD MUST BE COVERED WITH A SUITABLE RIGID GUARD IN COMPLIANCE WITH LOCAL REGULATIONS TO PREVENT INJURY TO PERSONNEL.

12-3. GROUTING THE BASE. If the pump is on a concrete foundation, it is recommended that the discharge head base be grouted to the foundation. If desired, this may be delayed until the pump installation has been tested. (See Figure 3-1). Pour the grout into the foundation and force it between the discharge head and the dammed-in area. Level off the grout flush with the top of the dam. Allow ample time for the grout to cure before starting the pump.

NOTE

USE ONLY NON-SHRINKING GROUTING MATERIAL.

SECTION 13
STARTUP AND FINAL IMPELLER ADJUSTMENT

13-1. PRE-START PROCEDURE. Before starting the pump check the following:

A. ALL PUMPS
1. Wiring of driver (IF APPLICABLE).
2. Driver must rotate counterclockwise when viewed from above.
3. Pressure flush system (IF APPLICABLE).
4. Lubrication to suction bowl (IF APPLICABLE).
5. Lubrication of driver.

B. OPEN LINE SHAFT PUMPS
1. Pumps exceeding 50 feet of setting prelubrication is necessary. (SEE SECTION 14, paragraph B).
2. All bearings are lubricated.
3. Grease to stuffing box (IF APPLICABLE).
4. Stuffing box bleed line connected (IF APPLICABLE).
5. All piping and gages.

C. ENCLOSED LINE SHAFT PUMPS
1. Oil lubrication piping connected (IF APPLICABLE).
2. Drip rate.

D. For most pumps, valve must be open. Some pumps can be started against a closed valve but only when designated for this application. Start the flow of lubricating fluid prior to starting the pump. Open line shaft pumps are self-lubricating and except for pumps longer than 50 feet require no external lubrication for the lineshaft bearings. Pumps longer than 50 feet require prelubrication before starting.

13-2. PUMP STARTUP

13-3. Multiply the setting by 0.1 to find the approximate number of seconds for fluid to reach discharge. Start the pump. IF PUMP DOES NOT DISCHARGE FLUID WITHIN 2 TIMES THE ESTIMATED TIME — SHUT OFF THE PUMP. Determine the cause and correct the problem before restarting. (SEE SECTION 15). Also, if DRIVER OVERHEATS OR THERE IS EXCESSIVE VIBRATION STOP THE PUMP, and correct the problem before restarting. (SEE SECTION 15).

13-4. On oil lube pumps in which the enclosing tube was tensioned by wrenching the tension tube nut, check for excessive leakage. If excessive leakage occurs, tube nut must be tightened.

13-5. With product lube pump in operation, there shall be some leakage at the stuffing box packing. The correct leakage is a rate which keeps the shaft and stuffing box cool (approximately 4 ounces per minute). Refer to SECTION 14 for packing adjustment.

13-6. FINAL ADJUSTMENT OF IMPELLERS

13-7. Final adjustment of impellers using an ammeter, proceed as follows:

A. ENCLOSED IMPELLERS

1. Connect ammeter to driver leads, start pump and record ammeter reading. Reading should be taken at maximum anticipated operating discharge head.

2. Stop pump and lower adjusting nut one-quarter turn. Start pump and record ammeter reading. Continue procedure until reading increases indicating that impeller is dragging on the bowl. Stop the pump and raise the adjusting nut one turn, impeller should clear the bowl. Start the pump and check ammeter. Ammeter should return to previous low reading. Impeller adjustment is complete.

B. OPEN IMPELLERS

1. Connect ammeter to driver leads, start pump and record ammeter reading. Reading should be taken at maximum anticipated operating discharge head.

2. Stop pump and lower adjusting nut one-quarter turn. Start pump and record reading. Ammeter reading should increase slightly. Continue procedure until reading increases sharply indicating that the impeller is dragging on the bowl. Stop the pump and raise the adjusting nut one-half turn. Impeller adjustment is complete.

13-8. Final impeller adjustment without ammeter: Lower adjusting nut until impeller bottoms on bowl. Repeat preliminary adjusting procedure outlined in SECTION 10 OR SECTION 11. This procedure is necessary as lateral often changes after first startup.

SECTION 14
MAINTENANCE

TABLE 14-1 PREVENTIVE MAINTENANCE PROCEDURES

PROCEDURE	TIME INTERVAL (HOURS)
Clean dirt, oil and grease from the driver and discharge head.	As required.
Driver ventilation passages shall be cleaned to prevent over-heating.	As required.
Check oil level in reservoir. It should never be less than one-quarter full. Refill, check drip rate. See Table 9-2 for correct drip rate.	24
Pumps utilizing a high pressure flush system, the pressure shall be 10 psi higher than maximum, pump discharge pressure plus 2% of the maximum discharge pressure.	Periodically
Pumps equipped with a lubrication line to conduct grease, oil, or other fluid to tail bearing, replenish supply through lubrication fitting, usually located at the base of the discharge head.	100
Check the level in sight gage, for oil-drip lubrication.	Periodically
Open line shaft pumps, check stuffing box for correct leakage. see SECTION 14-4. If packing is supplied with grease add through filter on side of packing container.	100

14-1. PREVENTIVE MAINTENANCE

14-2. Preventive maintenance includes periodic inspection, adjustments, lubrication and tightening procedures presented in Table 14-1. Systematic inspection of the pump shall be made at regular intervals. The frequency required depends upon the operating conditions of the pump and its environment.

14-3. PACKING ADJUSTMENT AND REPLACEMENT

14-4. Pumps equipped with adjustable packing at top of shaft, shall be adjusted whenever the leakage rate exceeds 8 ounces per minute. Adjust the stuffing box as follows:

A. With the pump in operation, tighten the split gland nuts one-quarter turn for each adjustment. Allow packing to equalize against the increased pressure and leakage to gradually decrease to a steady rate, before making another adjustment.

CAUTION

DO NOT OVER-TIGHTEN THE STUFFING BOX. EXCESSIVE PRESSURE CAN WEAR OUT PACKING PREMATURELY AND SERIOUSLY DAMAGE THE SHAFT.

B. With the pump shut down and when packing has been compressed to the point that the split gland is about to contact the upper face of stuffing box, remove split gland, add one extra packing ring, and re-adjust. If this fails to reduce leakage to 4 ounces per minute remove all packing rings and replace with new rings.

C. If the replacement packing is in the form of a continuous coil or rope, it must be cut into rings before installing. Tightly wrap one end of the packing material around the top shaft like one coil of a coil spring, and mark the coil with a sharp knife. Rings must have a gap of 1/16 to 1/8 inch and the ends must be parallel. For repacking sequence refer to Section 8.

14-5. SEASONAL SHUTDOWN PROCEDURES

WARNING

MANUALLY ROTATE SHAFT SEVERAL TIMES PRIOR TO RESTARTING PUMP, WHICH HAS BEEN SHUT DOWN.

A. For oil lubricated pumps that are shut down for an extended period of time, it is suggested that the pump be operated for at least 15 minutes every two weeks with the oil feed wide open 2 hours before and during startup in order to maintain a film of oil on the shafting and shaft bearings. This practice is also desirable to restore a film of oil on driver bearings.

B. Bearings on water lubricated pumps are lubricated by the liquid being pumped. On water lubricated pumps over 50 feet of setting, prelubrication is necessary. Extensive damage may result from failure to prelubricate the bearings. A pipe for prelubrication is installed on back of the discharge head and water injected into the pipe for at least 3 minutes to assure ample lubrication for pump settings up to 300 feet. For each additional 100 feet of setting, the prelubrication shall be increased one minute. If no other water supply is available a prelubrication tank is suggested. The prelubrication tank must always be kept full. If the pump is to be shut down for an extended period of time, operate it, for at least 15 minutes with adequate prelubrication every two weeks.

C. Before resuming normal operations oil should be changed on drivers, gearheads and lubricating oil system. After 15 minutes of operation adjust lateral. Refer to SECTION 13.

SECTION 15
TROUBLESHOOTING

TABLE 15-1 TROUBLESHOOTING

TROUBLE	PROBABLE CAUSE	REMEDY
No liquid delivered.	1. Discharge valve closed.	Check that discharge valve is in full open position.
	2. Wrong rotation.	Check for CCW rotation when viewed from above. Check engagement of motor coupling.
	3. Speed too low.	Check if driver is directly across the line and receiving full voltage.
	4. Driver with reduced voltage, or reduced current, starting does not come up to speed.	Consult factory.
	5. Improper lateral adjustment.	Reset lateral, see Section 13.
	6. Lack of prime or breaks suction.	Check standing and pumping water level, see Section 3.
	7. Standing water level is below 1ST stage or pumping water level is below suction.	Increase pump setting, by adding column.
	8. Tail pipe is used and suction lift is too high.	Check NPSH required by pumps against NPSH available. Increase pump setting by increasing column length, if insufficient NPSH available.
No liquid delivered.	9. Static lift too high.	Check distance from pumping water level to discharge, against design head of pump. If greater than pump rating, decrease static head above grade, or consult factory for adding bowl stage or increase impeller diameter.
	10. Suction below well perforations.	Raise pump until suction is approximately 10 feet above well perforations, recheck pumping water level.
	11. Viscosity, specific gravity or desolved gasses too high.	Consult factory after fluid analysis.
	12. Air leak in tail pipe only if pumping water level is below suction bowl.	Add column or pull pump, and reinstall tail pipe using thread sealer.
	13. Strainer, bowl, impeller plugged.	Pull pump and clean.
	14. Damaged bowl assembly; broken or disconnected shaft.	Pull pump and repair all damaged components.

(Continued next page)

TROUBLESHOOTING (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Not enough liquid delivered.	15. Same as steps 1 thru 6.	Same as Steps 1 thru 6.
	16. Field head requirement greater than design head.	Check system friction losses. Increase discharge piping. Lower head required. Consult factory for adding bowl stages or increase impeller diameter.
	17. Same as steps 8 thru 12.	Same as steps 8 thru 12.
Not enough pressure.	18. See not enough liquid delivered.	See — not enough liquid delivered.
Pump works for a while and quits.	19. See not enough liquid delivered.	See — not enough liquid delivered.
Excessive vibrations.	20. Bent shaft.	Replace or straighten shaft.
	21. Crooked well.	Survey the well and consult factory.

SECTION 16
PUMP DISASSEMBLY

16-1. PUMP DISASSEMBLY

16-2. Clear a large area adjacent to the pump as a storage space for pump parts as they are disassembled. If the pump has a long column made up of several sections, arrange parallel timbers on the ground to support the pump column and shaft sections horizontally.

WARNING

DO NOT ATTEMPT TO LIFT THE ENTIRE PUMP BY THE LIFTING LUGS OF THE DRIVER. THESE LUGS AND BOLTS CANNOT SUPPORT THE WEIGHT OF THE ENTIRE PUMP.

DO NOT ATTEMPT TO LIFT THE ENTIRE PUMP AND DRIVER BY SLINGING TO THE DISCHARGE HEAD. WITH THE DRIVER IN PLACE, THE CENTER OF GRAVITY MAY BE HIGHER THAN THE LIFTING POINTS. THE PUMP MAY TIP AS IT IS LIFTED, WHICH MAY RESULT IN SEVERE DAMAGE TO THE PUMP AND SURROUNDING STRUCTURE AND INJURY TO NEARBY PERSONNEL.

BEFORE OPENING THE CONDUIT BOX OF AN ELECTRICAL MOTOR, BE SURE THAT THE CURRENT TO THE MOTOR IS SHUT OFF. SEVERE INJURY TO PERSONNEL COULD RESULT IF CONTACT WITH LIVE MOTOR LEADS IS MADE.

16-3. In the following pump disassembly procedures references are made to assembly sections of this manual, these sections will aid in the disassembly of the pump.

A. Disconnect discharge and lubrication piping. Remove all external piping, and related hardware attached to the pump. Disengage mechanical seal if provided.

B. Uncouple driver from pump shaft. Refer to Section 10 hollow shaft driver, Section 11 solid shaft driver, and Section 12, gearhead driver.

C. Remove capscrews holding driver and hoist driver off discharge head or driver support and remove driver support, if provided.

D. Remove capscrews (758B) and slide stuffing box (616) off the driveshaft (606). Refer to Sections 8 and 9.

E. Take off bolts and nuts holding the discharge head to the subbase or to the foundation. Lift head, attach elevator clamp just below first column coupling and remove head. Refer to Section 7.

F. For removal of column sections, refer to Section 5 Product Lube Column, and Section 6 for Oil Lube Column.

G. For removal of bowl assembly, hoist the bowl assembly from the sump or well, using elevator clamps. Hoist in the same manner as for the column. Refer to Section 4. Proceed to disassemble the bowl assembly as follows.

16-4. BOWL DISASSEMBLY-PRODUCT LUBRICATION (SEE FIGURE 5-1).

A. Unscrew pump shaft coupling and remove capscrews from top bowl (669).

B. Slide discharge bowl (661) and top bowl off the pump shaft (660), impeller (673) is now exposed.

C. Pull shaft out as far as possible. Strike the impeller hub using a collet hammer or equivalent sliding on the shaft, to drive the hub off the taper collet (677).

D. After impeller has been freed, insert a screwdriver into the slot in the taper collet to spread it and remove it off the shaft. Slide impeller off the shaft. Use the same procedure until entire bowl assembly is completely disassembled.

E. Remove pump shaft from suction bowl (688).

NOTE

DO NOT REMOVE SAND COLLAR (692) UNLESS PUMP SHAFT IS REPLACED.

16-5. BOWL DISASSEMBLY-OIL LUBRICATION. (SEE FIGURE 6-1).

A. Unscrew pump shaft coupling and remove.

B. Remove adapter bearing (668).

C. Follow preceding steps, B, C, D, and E for complete disassembly of bowl assembly.

16-6. REASSEMBLY OF BOWLS ASSEMBLY. (SEE FIGURE 6-1).

A. If a pump shaft (660) is being replaced and a sand collar is provided, see Table 17-7 for positioning of sand collar (692). The sand collar is attached to the shaft by a shrink fit. Heat the collar until it can slip onto the shaft.

WARNING

WEAR PROTECTIVE GLOVES AND USE THE APPROPRIATE EYE PROTECTION TO PREVENT INJURY WHEN HANDLING HEATED PARTS.

B. Slide pump shaft into bearing (690) in suction bowl (688), until sand collar rests on the suction bowl bearing (690). If no collar is used, mark "X" dimension on shaft, see Table 17-7 and slide pump shaft into bearing (690) in suction bowl (688), until "X" dimension is flush with suction bowl hub.

C. Hold the shaft in place with a washer and capscrew. Insert capscrew through the threaded hole in suction bowl and thread into shaft. Slide the first impeller over the shaft until it seats on the bowl.

D. Insert a screwdriver into slot of taper collet (677), spread it and place over the shaft. Hold the impeller against the bowl, slide taper collet into hub.

E. Drive the taper collet in place with a collet hammer.

F. Slide intermediate bowl (670), over impellers and secure with capscrews.

G. Repeat the preceding procedures, checking that the bowl lateral is not being lost after each stage, until all stages are assembled.

NOTE

MARK BOWL FLANGES IN SEQUENCE OF DISASSEMBLY TO AID IN THE REASSEMBLY PROCEDURE.

CAUTION

IF THREADED COUPLING WILL NOT READILY UNSCREW, APPLY HEAT TO COUPLING (NOT TO SHAFT), FOR APPROXIMATELY 30 SECONDS, AT THE SAME TIME APPLYING TORQUE TO THE SHAFT.

SECTION 17
PUMP DATA

17-1. CALCULATING PUMP WEIGHT

17-2. The following tables contain approximate component weights, to be used in estimating the entire pump weight.

TABLE 17-1 BOWLS

SIZE	APPROX. WEIGHT PER STAGE
4 INCH	10 LB.
6	25
7	35
8	50
9	75
10	90
11	115
12	140
14	200
16	350
18	450

TABLE 17-2 COLUMN, SUCTION AND DISCHARGE PIPE

SIZE	WEIGHT/FOOT
2½ INCH	6 LB.
3	8
4	11
5	15
6	19
8	25
10	32
12	44
14	55

TABLE 17-3 DISCHARGE HEAD

SIZE	APPROX. WEIGHT
2½ INCH	40 LB.
4	160
6	300
8	430
10	540
12	900
14	1400

TABLE 17-4
ELECTRIC DRIVER (WPI)

HORSE POWER	APPROX. WEIGHT
3 H.P.	100 LB.
5	100
7½	200
10	200
15	250
20	350
25	350
30	400
40	500
50	550
60	650
75	700
100	1500
125	1500
150	1500
200	1700

TABLE 17-5 WEIGHT OF WATER IN PUMP COLUMN

NOM. PIPE SIZE	WT. OF WATER PER FT. OF PIPE
3 IN.	3.0 LB.
4	5.0
5	8.0
6	12.0
8	20.0
10	32.0
12	48.0
14	57.0
16	76.0
18	97.0
20	120.0
24	177.0

NOTE

For liquids other than water multiply the above by the specific gravity of the liquid.

TABLE 17-6 SHAFT

SHAFT SIZE	APPROX. WEIGHT PER FOOT
1 INCH	2.6
1 3/16	3.8
1 1/2	6.0
1 11/16	7.6
1 15/16	10.0
2 3/16	12.8
2 7/16	15.8
2 11/16	19.3
2 15/16	23.0
3 3/16	27.1

TABLE 17-7 SAND COLLAR LOCATION DIMENSION — BOWL SHAFT

PUMP SIZE	"X" DIMENSION
4D	2.75
6A	3.25
6J	2.75
6D	3.62
7A	3.25
8A	3.25
8S	3.63
8J	4.00
8D	4.37
9A	3.50
10A	4.50
10J	5.25
10D	6.38
10L	6.12
11A	5.44
12J	5.88
12D	6.87
14J	7.00
14H	7.50
14D	8.25
16D-BELL	7.25
16D-BOWL	8.75
18H	7.50

17-3. The following example is given to calculate approximately the entire pump weight.

1. BOWL WEIGHT = ESTIMATE WT. PER STAGE X NO. OF STAGES
2. COLUMN WEIGHT = SETTING X (COLUMN WT. + SHAFT[1])
3. HEAD WEIGHT
4. DRIVER WEIGHT
   PUMP WEIGHT = TOTAL OF 1 + 2 + 3 + 4
   LIFTING WEIGHT (PUMP MINUS DRIVER) = TOTAL OF 1 + 2 + 3

[1]) NOTE: For pumps with enclosing tubes; tube and shaft weight may be estimated by multiplying shaft weight by 3.

SECTION 18
RECOMMENDED LUBRICANTS

MANUFACTURER	GREASES FOR LINE SHAFTS, SUCTION BOWL BEARINGS AND SHAFT PACKINGS	TURBINE OILS FOR LINE SHAFT, SUCTION BOWL BEARINGS AND SIMILIAR APPLICATIONS		TURBINE OILS FOR GEAR DRIVES VERTICAL PUMPS	
	TEMPERATURE —32°F TO 120°F	TEMPERATURES BELOW 32°F	TEMPERATURE ABOVE 32°F	TEMPERATURE BELOW 32°F	TEMPERATURE ABOVE 32°F
American Oil Co.	Amoco Lithium Grease All-Weather	Rykon Industrial Oil No. 11	Rykon Industrial Oil No. 31	Rykon Industrial Oil No. 21	Rykon Industrial Oil No. 51
Atlantic Richfield Co.	Arco Multipurpose Grease	Duro S-150 LP	Duro S-150 or Duro S-150 LP	Duro AWS-315	Duro 600
Cato Oil & Grease	Mystik JT-6	2107 Water Well Turbine Oil or 1872 Antiwear Hyd./Ind. Oil A.5	2107 Water Well Turbine Oil or 1872 Antiwear Hyd./Oil A.5	1875 Antiwear Hyd./Ind Oil C or 1837 R & O Gearhead C	Mystik JT-7 SAE 80/90 Antiwear Ind. Oil F, or 1855 R & O Gearhead F
Cities Service Oil Co.	Citgo H-2	Citgo Pacemaker 15	Citgo Packemaker 15	Citgo Pace-maker 20	Citgo Pace-maker 60
Gulf Oil Co.	Gulfcrown Grease No. 2 or Gulf Supreme Grease No. 2	Paramount 39	Harmony 44	Paramount 45	Harmony 69
Humble Oil & Refining Co.	Lidok No. 2	Nuto 43 or Esstic 42	Teresstic 43 or Nuto 43	Nuto 43 or Esstic 42	Terresstic 65 or Nuto 63
Mobil Oil Corp.	Mobilux No. 2	DTE 23	DTE BB	DTE 23	DTE Extra Heavy or DTE AA
The Pennzoil Co.	Pennzoil 705 HDW	Pennbell No. 1	Pennbell No. 2	Pennbell No. 2	Pennbell No. 5
Shell Oil Co.	Alvania EP Grease 2 or Alvania EP Grease 1 (for prolonged ambient below 0°F.)	Tellus Oil 23	Tellus Oil 27	Tellus Oil 29	Tellus Oil 41
Texaco, Inc.	Novatex Grease No. 2	Regal Oil A (R & O)	Regal Oil A (R & O)	Regal Oil C (R & O)	Regal Oil F (R & O)
Fiske Bros. Refining Co.	Lubriplate 130AA (0° to 120°F)	Lubriplate 3V	Lubriplate 3V	Lubriplate APG 90	Lubriplate APG 90

SECTION 19

PARTS LIST

ITEM NO.	DESCRIPTION
600	HEAD—DISCHARGE
602	SUPPORT—DRIVER
604	NUT—ADJUSTING
606	DRIVESHAFT
608	HEADSHAFT
610	HUB-DRIVER COUPLING
612	SPACER—COUPLING
613	PLATE—ADJUSTING
614	HUB—PUMP COUPLING
616	BOX—STUFFING
617	BEARING—STUFFING BOX
618	GLAND—SPLIT PACKING
620A	PACKING—STUFFING BOX
620B	PACKING—TENSION PLATE
621	RING—LANTERN
623	NUT—TUBE TENSION
624	LINE—BYPASS
625	PLATE—TUBE TENSION
626	NUT—TUBE TENSION
627	BEARING—TUBE TENSION
628	BEARING—TUBE TENSION
629	NIPPLE—ENCLOSING TUBE
630*	RESERVOIR—OIL
631	NIPPLE—THREADED COLUMN
632*	BRACKET—OIL RESERVOIR
633*	VALVE—SIGHT FEED
634*	VALVE—SOLENOID
635*	LINE ASSEMBLY—LUBRICATION
639	RING—LOCK THREADED
641	COLUMN—TOP
642*	COLUMN—INTERMEDIATE
644	COLUMN—BOTTOM
645	COUPLING—THREADED COLUMN
646	LINESHAFT

ITEM NO.	DESCRIPTION
649	COUPLING—THREADED LINESHAFT
650*	RETAINER—KEYED LINESHAFT
652	RETAINER—OPEN LINESHAFT
653	BEARING—OPEN LINESHAFT
654	TUBE—SHAFT ENCLOSING
656	BEARING—ADAPTER
658	STABILIZER—TUBE
660	PUMPSHAFT—TURBINE
661	BOWL—DISCHARGE—OPEN LINE
662	BEARING—DISCHARGE BOWL
664	BEARING—THROTTLE
666	BOWL—DISCHARGE—ENCLOSED LINE
668	BEARING—ADAPTER
669	BOWL—TOP
665*	RING—SEAL
670	BOWL—INTERMEDIATE
672	BEARING—INTERMEDIATE BOWL
673	IMPELLER—TURBINE
677	COLLET—TAPER
688	BOWL—SUCTION
690	BEARING—SUCTION
692	COLLAR—SAND
697	PIPE—TAIL
698	STRAINER—SUCTION
735B	NUT—HEX GLAND STUD
739A	STUD—STUFFING BOX
747B	PIPE—PLUG DISCHARGE HEAD DRAIN
747E	PIPE PLUG—SUCTION
747N	PIPE PLUG—PRELUBE CONNECTION
747P	PIPE PLUG—DISCHARGE BLEED OFF CONNECTION
758B	CAPSCREW—STUFFING BOX
779A	GASKET—STUFFING BOX
789C	WASHER—PACKING

GOULDS PUMPS

Goulds Pumps

ITT Industries

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Section 7

OPERATION AND MAINTENANCE INSTRUCTIONS

RANDOLPH RIGHT ANGLE GEAR DRIVES

INSTALLATION

Gear drives for domestic shipment are shipped with lubricant installed. Air freight shipments are shipped with the initial fill of oil in a separate container.

Inspect and clean top of discharge base and bottom of gear drive to assure removal of burrs or foreign material that might cause misalignment.

Install gear drive on discharge base and install non-reverse clutch over head shaft. The non-reverse clutch should fit on the head shaft and engage the drive block **without springing** the head shaft. Lubricate head shaft threads and bottom of adjusting nut before raising the pump impellers.

Remove protective material from the input shaft extension and clean the shaft. Install coupling half or flange. Hammering the flange or coupling into place may damage bearings and change gear adjustment. This is not permissible. Interference fits are permissible if coupling can be heated for installation and fitted without hammering to install on the input shaft. Check the run out of the aligning surfaces on both coupling halves before installing the connecting members.

Align driver with gear drive to obtain parallel and angular alignment within coupling or drive shaft manufacturers specification. Misalignment should be as close to zero as possible for maximum life and smoothest operation. Use only the correct specified tools and procedures when aligning the gear drive and driver. Improper alignment will void the warranty on the RANDOLPH right angle gear drive.

Excessive noise and vibration in a new gear drive is almost always an indication of misalignment or poor installation. All drives are test run at the factory and checked for noise and vibration. Failure to correct the installation can result in damage to the pump and gear drive. Our warranty will not apply unless drive is properly installed. Proper installation includes alignment of the power unit, right angle drive, and pump. Adequate foundation must be provided for engine and pump to prevent shifting or settling of either member. Positive alignment must be maintained. Recheck alignment at regular intervals after starting the operation of the system and correct if settling or drifting has occurred.

With engine drive systems, it is not uncommon for one or more resonate speeds to exist between zero RPM and the operating speed of the system. Continued operation at a resonate speed will result in torsional vibrations which can be damaging to all components in the system. Unusual rumbling or clattering noise from the gear drive at a sharply defined speed is the most common indication of torsional vibrations. As the speed is increased or decreased, the noise will disappear. This noise is not indicative of a defect but results when the vibratory torque exceeds the drive torque causing the gear teeth in the gear drive to separate and clash together very rapidly. Transition through a resonate speed range to operating speed is not normally damaging, but operation of the system close to a resonate speed should be avoided. To avoid operation at a resonate speed it may be necessary to change the elastic characteristics of the rotating components in the system, or change the speed of the engine with respect to the pump. This can be accomplished by changing the gear ratio of the gear drive.

LUBRICATION

Use only rust and oxidation inhibited (R&O) gear oils in accordance with American Gear Manufacturers Association (AGMA) standard 250.04 dated Sept. 1981.

For general operating conditions, AGMA lubricant number and corresponding viscosity range are shown on the permanent identification plate attached to the main case of the gear drive. Contact the factory for lubricant recommendations for operation under extremely hot or cold ambient conditions. Gear drives operating in extremely cold weather must be provided with an oil which will flow through the oil lines at start up. Oil flow must be immediate otherwise the bearings and gears will not be properly lubricated. A lube oil heater may be required for consistent cold weather starting.

For ambient conditions between 50 and 125 degrees Fahrenheit use the following:

LUBRICANTS

ISO Viscosity Grade	**220**
SAE Grade	50
AGMA Lubricant #	**5**
Viscosity range	
SSU @ 100 F.	**918-1122**
CST @ 40 C.	198-242
Celsius	10 to 52
Ambient Temp. F.	**50-125**

AMOCO	PERMAGEAR/AMOGEAR EP220
CASTROL	**ALPHA EP 220**
CHEVRON	NL GEAR COMPOUND 220
AMOCO	IND OIL 220
CHEVRON-USA	AW MACH. 220
CITGO	PACEMAKER 220
CONOCO	GEAR OIL 220
DIAMOND SHAMROCK	**INDIGO 220**
EXXON-USA	TERRESSTIC 220
FINA	PONTONIC N 220
MOBILE OIL	MOBILE GEAR 630
PENNZOIL	PENNZGEAR 220
PHILLIPS	MAGNUS 220
SHELL-USA	OMALA 220
SUN OIL	SUNVIS 999
TEXACO	MEROPA 220

List of brand names is for purpose of identifying types and is not to be construed as exclusive.

OIL CHANGE INTERVAL

Change oil at least every 1000 to 1500 hours of operation. If gear drive is operated intermittently less than 1000 hours per year in a season of two or three months, change oil at the end of that period of operation to eliminate water formed in the gear case due to condensation. More frequent oil changes are necessary for units operating at temperatures above 190 F. or 82 C. Oil temperatures of 200 F. or 93 C. are not dangerous, but will require changes of oil every 500 to 750 hours. To drain oil, remove plug in base flange below the inspection plate. To refill, replace drain plug and tighten securely. Fill through plug located in the inspection plate. If drive is equipped with sight gage, fill to level indicated. If drive is not equipped with sight gage, fill to oil level hole and replace plug.

COOLING

Our fan cooled drives are designed to eliminate the need of cooling water in most cases. Drive sizes M40 through M80 and G40 through G200 are not equipped with cooling coils except on special order. The operating temperature of these models should not exceed 190 F. Propeller Pump Gear Drives Model M80P thru M30A require no water cooling.

Drives sizes M100 thru M200 and G250 through F1000 are equipped with auxiliary cooling coils. **The water cooling coils must be hooked up** to reduce excessive heat generation. **Failure to properly use the water cooling system will void the warranty.** The amount of fresh water required at 70 F. will be 3 gal. per minute for G250 to 7 gal. per minute for F1000. Water pressure through the cooling coils should be limited to 90 psi or less. Oil temperature will rise with increase of speed above 1760 RPM or in rooms with limited air circulation causing high room temperatures.

NON-REVERSE CLUTCH - PIN TYPE

The four pins enclosed are for the non-reverse clutch. They are to be installed in the drilled holes of the clutch if non-reverse protection is desired. They may be omitted if non-reverse protection is not needed. Pins must be clean and free from oil so they will fall freely.

The non-reverse protection is not guaranteed. Settings of over 400 ft. (122 meters) deep will require special procedures, and in some cases the pin and ratchet type non-reverse will not work. Consult supplier for proper procedure for shutting down the well. The gear drive can be damaged by shock engagement caused by the pump starting to back spin before the pins engage. Check the gear drive carefully after shock engagement of the non-reverse for any damage to the gear drive.

NON-REVERSE CLUTCH - SPRAG TYPE

The sprag non-reverse is a positive type available on most models. The sprag clutch allows no more than 1 degree backspin of the pump. When the sprag non-reverse is in service, the engine should be idled back, and the Power Take Off clutch should be disengaged at a slow speed allowing the non-reverse to stop the pump.

CAUTION: Failure to install a P.T.O. (clutch) between the engine and gear drive, and failure to disengage same on pump shut down can cause damage to the Sprag Non-Reverse as well as the pin type non-reverse. Repeated engine roll back into the gear drive will cause damage to the non-reverse pins, the ratchet plate, and shear the clutch drive bolts. NON-REVERSE PROTECTION IS NOT GUARANTEED.

WARNING

All rotating shafts and couplings must be adequately guarded before operating the gear drive. The top cover supplied with the gear drive must be installed over the non reverse coupling and the top of the head shaft before operating the gear drive.

An adequate guard (supplied by others) must be installed around the drive line or coupling between the gear drive and the engine before operating the gear drive.

All gear drives are furnished with lifting devices which are adequate for safely lifting the gear drive.

1. **Disconnect the drive line or coupling from the horizontal shaft of the gear drive.**
2. **Remove the pump head shaft nut.**
3. **Remove the non reverse clutch from the head shaft.**
4. **Disconnect the gear drive from the pump discharge base.**
5. **Lift the gear drive using the lifting device provided with the gear drive.**

Caution: Lifting devices provided are not designed to lift the gear drive and pump together.

LONG TERM STORAGE - PRIOR TO INSTALLATION

If possible the drives should be stored inside out of the weather. All exposed machined surfaces, such as the input shaft, clutch coupling and bottom of drives should be coated with a rust-preventative, such as Tectyl No. 502-C.
In order to protect the internal parts such as gears, shafting and bearings the unit must be run at 300 to 500 RPM for approximately 10 minutes every 30 days. If the unit is exposed to the weather for an extended time it must be covered to exclude dirt, dust, moisture, and foreign materials. At a minimum, a heavy water proof bag should be slipped over the unit.

If the gear unit cannot be rotated under power, rotation of the input shaft by hand is suggested. Rotate the input shaft eight to twelve complete revolutions by hand every 30 days, and cover the unit with a vapor barrier.

The above are recommendations and do not imply any responsibility on the part of RANDOLPH MFG. CO.

WARRANTY

THE RANDOLPH RIGHT ANGLE GEAR DRIVE IS GUARANTEED AGAINST DEFECTS IN WORKMANSHIP AND MATERIAL FOR A PERIOD OF 24 MONTHS AFTER INSTALLATION WHEN OPERATED UNDER NORMAL SERVICE AT RATED CAPACITY. WITHIN THE ABOVE STATED PERIOD THE MANUFACTURER WILL REPLACE DEFECTIVE PARTS , RETURNED TRANSPORTATION PREPAID. THE GUARANTEE WILL NOT APPLY TO REPAIRS MADE OUTSIDE THE FACTORY WITHOUT THE CONSENT OF THE MANUFACTURER, OR TO DRIVES WHICH HAVE BEEN SUBJECT TO ABUSE, ACCIDENT, NEGLECT, IMPROPER INSTALLATION, OR TORSIONAL DAMAGE. WE MAKE NO WARRANTY OF ANY KIND WHATEVER, EXPRESSED OR IMPLIED, IN REGARD TO BEARINGS, TRADE ACCESSORIES, MACHINERY, OR OTHER ARTICLES OF MERCHANDISE NOT MANUFACTURED BY US. NO RESPONSIBILITY WILL BE ASSUMED FOR OVERLOADING THE RATED CAPACITY OF THE THRUST BEARING. (THE THRUST CAPACITY OF THE DRIVES SHOULD BE VERIFIED BY THE PUMP MANUFACTURER WITH WHOSE EQUIPMENT THE DRIVE IS USED.) THIS WARRANTY IS EXPRESSLY MADE IN LIEU OF ANY WARRANTIES OTHERWISE IMPLIED BY LAW.

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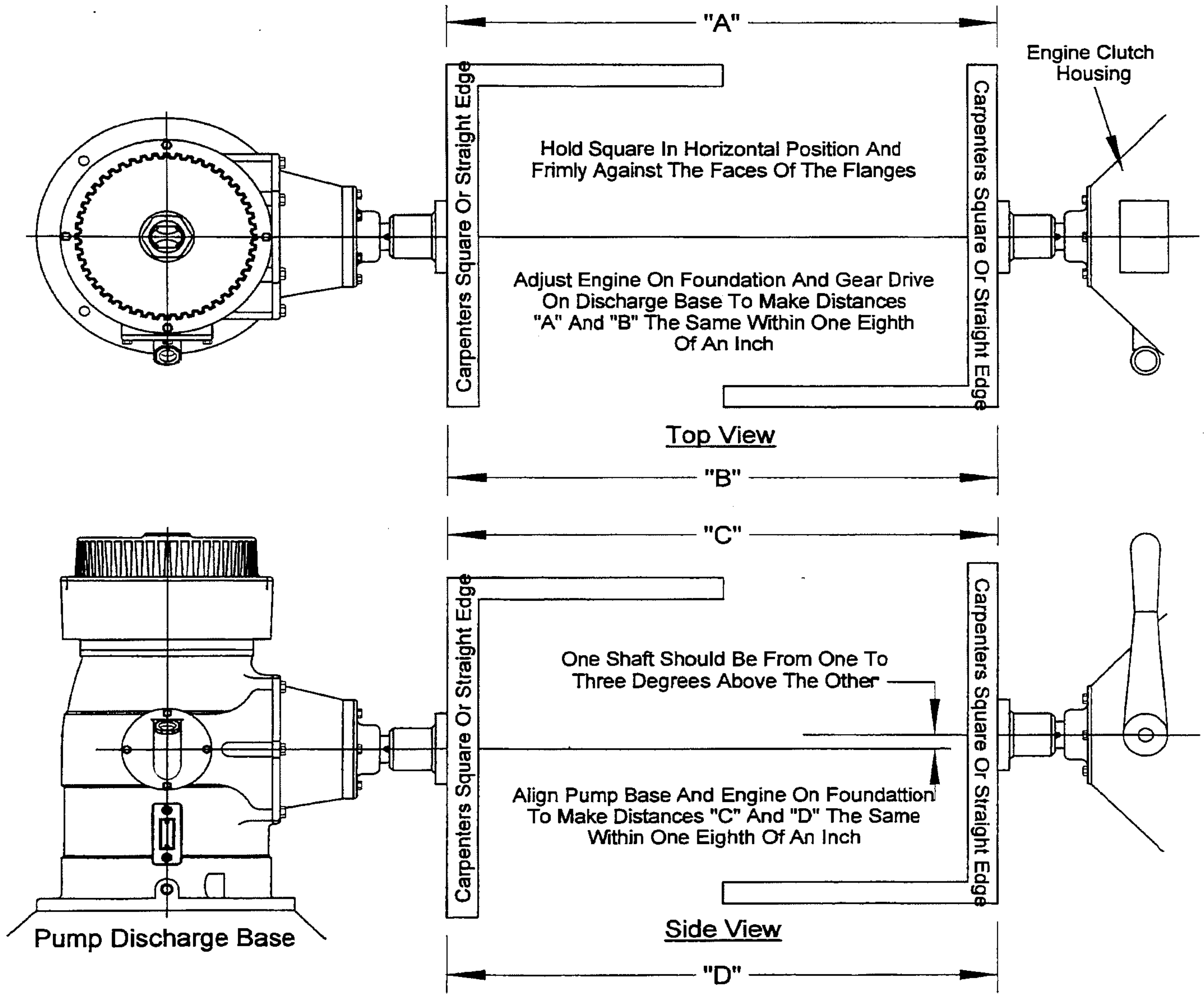
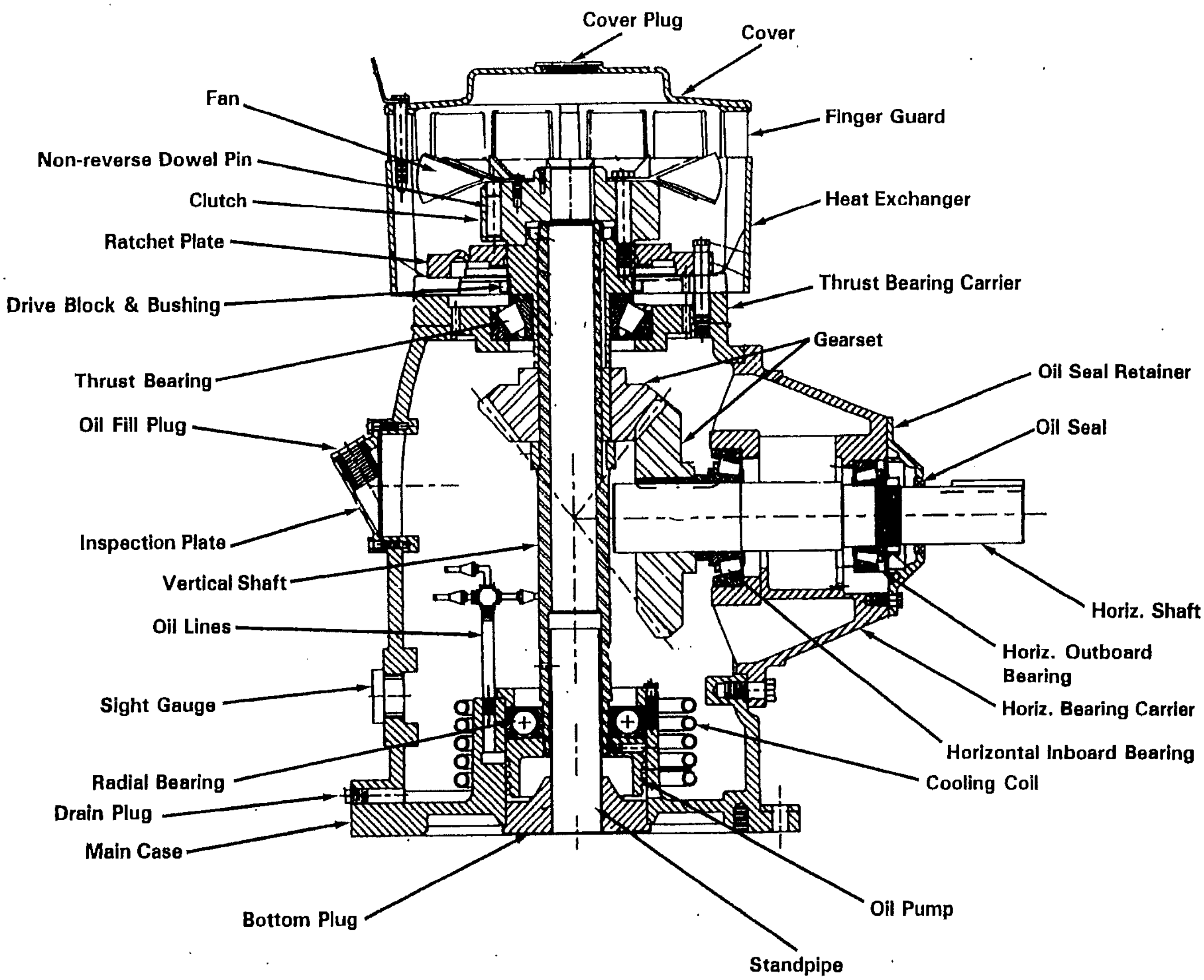
1110 NORTH AVE. T.
LUBBOCK, TEXAS 79415
PHONE 806-765-5583 -- FAX 806-765-7735

Always consult Drive Shaft Manufacturers literature for alignment instructions specific to your drive shaft.



Drive Shaft Alignment


Cover Plug
Cover
Fan
Finger Guard
Non-reverse Dowel Pin
Clutch
Heat Exchanger
Ratchet Plate
Thrust Bearing Carrier
Drive Block & Bushing
Gearset
Thrust Bearing
Oil Seal Retainer
Oil Fill Plug
Oil Seal
Inspection Plate
Vertical Shaft
Horiz. Shaft
Oil Lines
Horiz. Outboard Bearing
Sight Gauge
Horiz. Bearing Carrier
Horizontal Inboard Bearing
Radial Bearing
Cooling Coil
Drain Plug
Main Case
Bottom Plug
Oil Pump
Standpipe

Engineering Bulletin - Torsional Damage

Over the past 10 years, the use of diesel engines to drive right angle drives, and pumping systems has increased. Competition among engine manufacturers has led to a drastic reduction in engine weight, increased compression ratios, and turbo charging. The end result is that the transfer of power from the engine to the driven equipment is not as fluid as it was. Along with the new engine innovations has come the premature failure of the components in the pump system caused by operating at or near a torsional resonant speed (+/- 10%). Typical modes of failure are broken crank shafts, drive line shafts twisting in two, broken input shafts, and broken gear teeth. Vibratory torque much higher than the rated torque of driven components is not uncommon.

We must emphasize Paragraph 7 of our OPERATION AND MAINTENANCE INSTRUCTIONS, which reads as follows:

"With engine drive systems, it is not uncommon for one or more resonant speeds to exist between zero rpm and the operating speed of the system. Continued operation at a resonant speed will result in torsional vibrations which can be damaging to all components in the system. Unusual rumbling or clattering noise from the gear drive at a sharply defined speed is the most common indication of torsional vibrations. As the speed is increased or decreased, the noise will disappear. This noise is not indicative of a defect but results when the vibratory torque exceeds the drive torque causing the gear teeth in the gear drive to separate and clash together very rapidly. Transition through a resonant speed range to operating speed is not normally damaging, but operation of the system close to a resonant speed should be avoided. To avoid operation at a resonant speed it may be necessary to change the elastic characteristics of the rotating components in the system, or change the speed of the engine with respect to the pump. This can be accomplished by changing the gear ratio of the gear drive."

Torsional analysis by computer simulation is the most reliable alternative to actual testing. Analysis by computer simulation during system design and application is preferable. Three sources of analysis are coupling manufacturers, engine manufacturers, and independent service firms like Midland Services, Inc. When specified in advance of purchase, the engine manufacturer will perform the torsional analysis as a service to sell the engine. We recommend that a torsional analysis be done on the system before it is installed; this is a common practice in industry, government and municipal applications. *The following are furnished by Midland Services:*

1. *Lloyds Register required accurate calculation of vibratory stresses in all propulsion and auxiliary shafting, with strict limits imposed.*
2. *U.S. Navy Mil Std-167 also imposes strict limits of calculated vibratory stress in all shafting.*
3. *U.S. Corps of Engineers requires Diesel Pump Sets to be analyzed for harmful frequencies within the Pump operating speed range. Criticals within +/- 25% of such speeds are unacceptable.*
4. *For gear drives, Lloyds will not accept vibratory torques across gears exceeding 33% of full load torque, while Mil Std-167 will not accept vibratory torques across gears exceeding 25% of full load torque.*

The torsional problems are generated by the engine. Even after the torsional analysis is performed, the gear drive manufacturer and the pump manufacturer do not change or modify their products in any way to address the torsional vibrations generated by the engine.

There is serious danger of damage to the pump system, the pump system operators, and the engine if the torsional vibrations are not addressed. Steps must be taken to avoid risks and damage to the system.

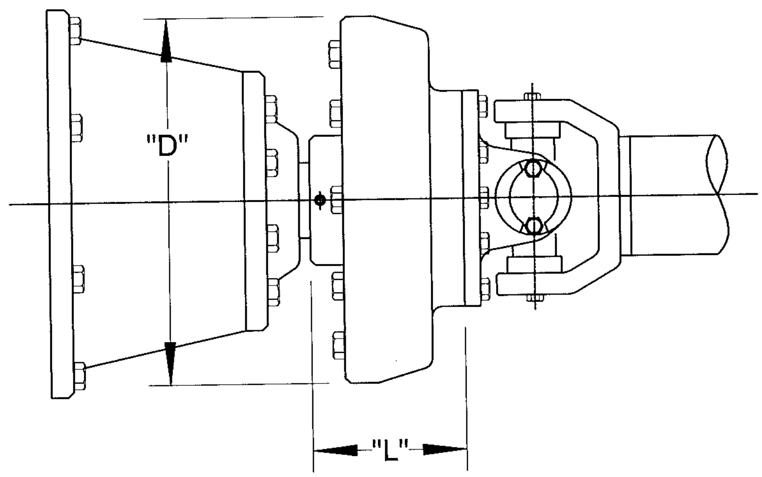
RANDOLPH GEAR, INC., is a supplier of only one component in the pumping system. We have no control over system design, or engine selection. It is the responsibility of those who select the equipment for the pumping project to assure that damage to any component does not occur due to Torsional Vibration.

RANDOLPH GEAR does not warranty products which have been subjected to torsional damage.

RANDOLPH GEAR, INC. – LUBBOCK, TEXAS
PHONE 806-765-5583, FAX 806-765-7735

(MIDLAND SERVICES, INC. – Phone 812-526-2032, Fax 812-526-8243)

TORSIONAL RUBBER COUPLING



					APPLICATION	
MODEL #	BORE	"D" DIA.	"L" LENGTH	WEIGHT	GEAR DRIVE	ONLY DRIVE SHAFT
4391.4071	1.875"	8.86"	3.47"	22 lbs	G40, G60, G80 M40, M60, M80, M100	1480, 1550
4391.4109	2.250"	10.63"	4.49"	44 lbs	G100, G125 M16AH	1480, 1550, 1610, 1710
4391.4069	2.438"	10.63"	4.49"	44 lbs	G150, G200	1480, 1550, 1610, 1710
4391.4070	2.938"	12.60"	5.31"	66 lbs	G250, G300 G350, G400	1610, 1710, 1810

This torsional coupling is designed to be installed with systems using U-joint type drive lines and standard gear drives. The bonded-rubber element is manufactured by Ringfeder and is self supporting. The coupling has been selected with the best compromise of torsional characteristics for engines operating between 1200 and 2400 rpm. In most cases the standard element will work. If all operating parameters are known, a torsional vibration analysis can be performed at an extra cost. If needed, rubber elements with different torsional characteristics can be supplied. Different selections may be determined by operation or analysis. (Ringfeder Corp. - 201-666-3320)

In most cases, the coupling can be installed with minimal modifications to the drive line shaft length and guarding system.

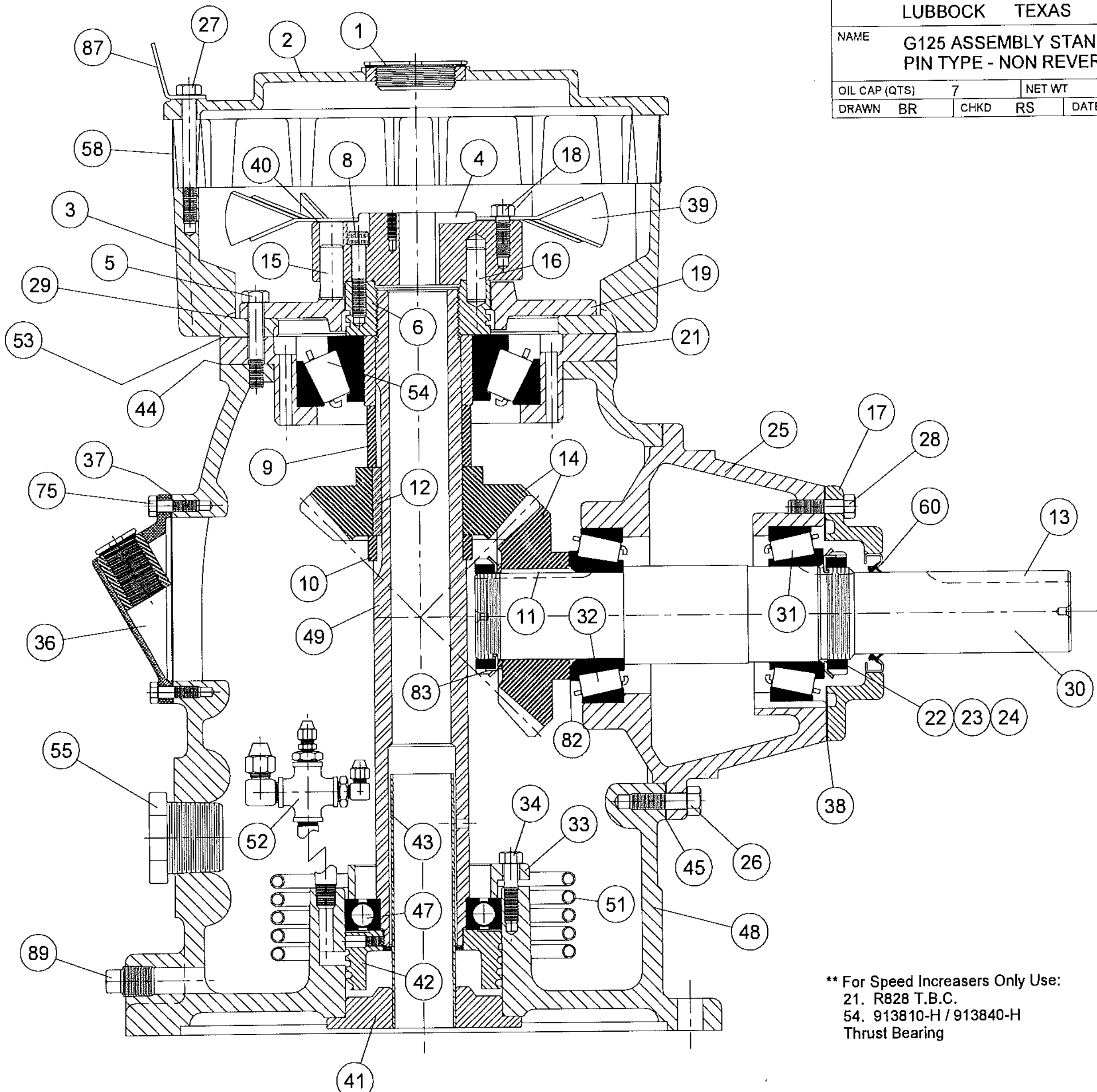
WARNING: ROTATING SHAFTS AND COUPLINGS ARE DANGEROUS AND CAN CAUSE SERIOUS INJURY. AN ADEQUATE GUARD MUST BE INSTALLED AROUND THE COUPLING AND DRIVE SHAFT BEFORE OPERATION OF THE GEAR DRIVE. THE GUARD IS NOT SUPPLIED BY RANDOLPH GEAR, INC.

RANDOLPH GEAR, INC.-LUBBOCK, TEXAS 1-888-726-4327, 806-765-5583, FAX 806-765-7735

(Contact Factory for Pricing) May 1, 2008

RANDOLPH MANUFACTURING CO.
LUBBOCK TEXAS

NAME	G125 ASSEMBLY STANDARD PIN TYPE - NON REVERSE				
OIL CAP (QTS)	7	NET WT	335	LB	
DRAWN	BR	CHKD	RS	DATE	5/8/91



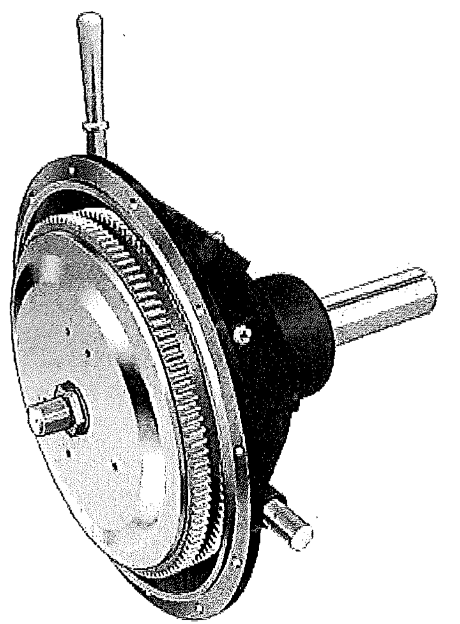
** For Speed Increasers Only Use:
21. R828 T.B.C.
54. 913810-H / 913840-H
Thrust Bearing

1. Cover Plug W/Gasket S250
2. Cover R91B
3. Heat Exchanger R91D
4. Clutch R89A (Specify Bore)
5. Hex Bolts & Lockwashers 7/16 X 2-1/4 (6 Req'd) CSH0709
6. Drive Nut R62
8. Socket Head 3/8 X 2 (2 Req'd) CSS0609
9. Over Gear Spacer (Vert) S-5-(Specify Ratio) (When Req'd)
10. Under Gear Spacer (Vert) S-5-(Specify Ratio) (When Req'd)
11. Gear Key 3/8 X 1/4 X (Specify Ratio) KY0604
12. Pinion Key 3/8 X 1/4 X (Specify Ratio) KY0604
13. Horizontal Shaft Key 5/8 X 5/8 X 2-3/4 - KY101022
14. Gear & Pinion Set (Specify Ratio)
15. Non-Reverse Dowell Pins 5/8 X 1-1/2 (4 Req'd) DP1012
16. Dowell Pins 1/2 X 1-1/2 (2 Req'd) DP0812
17. Oil Seal Retainer R95F
18. Hex Bolts & Lockwashers 3/8 X 3/4 (4 Req'd) CSH0603
19. Non-Reverse Ratchet Plate R93A
21. ** Thrust Bearing Carrier R92A
22. Lock Nut N13
23. Lockwasher W13
24. Flatwasher K13
25. Horizontal Bearing Carrier R94A
26. Hex Bolts & Lockwashers 7/16 X 1-1/2 (6 Req'd) CSH0706
27. Hex Bolts & Lockwashers 3/8 X 3-1/2 (4 Req'd) CSH0614
28. Hex Bolts & Lockwashers 3/8 X 1-1/4 (6 Req'd) CSH0605
29. Gasket G133
30. Horizontal Shaft H126AIAGEP (Use H126F For Ratio 2:1)
31. Horizontal Outboard Bearing 212011-HM / 212049-HM
32. Horizontal Inboard Bearing 212011-HM / 212044-HM
33. Hold Down Ring R63
34. Drilled Hex Head Bolts 3/8 X 1-1/4 (2 Req'd) CS00605
36. Inspection Plate R56A & Plug W/Gasket S200
37. Gasket G56
38. Gasket G95A
39. Fan R78
40. Gasket G109-4
41. Center Plug R87
42. Oil Pump R88 Set Screw 5/16 X 5/16 - Set0505
43. Stand Pipe R98
44. Shims G52-(007,015,030) (As Req'd)
45. Shims G54-(007,015,030) (As Req'd)
47. Radial Bearing 6212 Or 394A / 397
48. Main Case R50
49. Vertical Shaft V70
51. Cooling Coil Assembly CC-0050 (Optional)
52. Oil Assembly DA-0050
53. Gasket G52-015
54. ** Thrust Bearing 9380 / 9321
55. Oil Level Sight Gauge SG-A2890-07
58. Finger Guard R80
60. Oil Seal OS-472636
64. Bearing Bushing RB92HT Speed Decreasers & 1:1 Ratio Only
75. Hex Bolts & Lockwashers 5/16 X 1 (4 Req'd) CSH0504
82. Over Gear Spacer (Horiz) S-5-(Specify Ratio) (When Req'd)
83. Under Gear Spacer (Horiz) S-5-(Specify Ratio) (When Req'd)
87. Lifting Clip R45A (2 Req'd)
89. Pipe Plug (Oil Drain) 1/2 NPT - PFPL04
93. Lock Nut N12
94. Lockwasher W12
99. Gasket Kit GK-G020 (Contains Item #29,37,38,40,44,45,53, & 60)

WPT POWER CORPORATION

WTD PTO
MECHANICAL POWER TAKE OFF

INSTALLATION AND MAINTENANCE MANUAL



WPT Power Corporation
1600 Fisher Road - Wichita Falls, TX 76305
P.O. Box 8148 - Wichita Falls, TX 76307
Ph. 940-761-1971 Fax 940-761-1989
www.WPTpower.com

Table of Contents

Table of Contents

1.0 Introduction

1.1 The WPT Power Corporation PTO is the most rugged PTO available on the market today. Follow the procedures detailed in this Installation Maintenance Manual for years of service.

1.2 When ordering parts, use the part number from the Bill of Materials supplied with this unit. Also, please include the part number and the serial number from the unit itself. These will be found on the metal hand hole cover on the bell housing. Your WPT Distributor can provide a copy of the Bill of Materials if the one provided should become lost.

1.3 When performing installation and maintenance functions, refer to the drawings at the back of this manual, pages 17 thru 20. The references on the drawing in this manual DO NOT correspond to the references on the assembly drawing and Bill of Materials. Do not use the item numbers from the drawing in this manual for ordering parts.

2.0 Specifications

2.1 See Chart 3 for flywheel dimensions, page 15 and drawing page 16.

2.2 See Chart 3 for flywheel housing dimensions, page 15 and drawing page 16.

2.3 The maximum RPM is listed in Chart 2 for your PTO size, page 14.

3.0 Lubrication

3.1 The WPT mechanical PTO requires lubrication with NLGI #2 lithium based grease. Prior to installation, grease the main shaft bearings, sliding sleeve assembly, and operating shaft. Apply grease to each fitting until grease just appears at the respective seal surfaces. Although the PTO is normally lubricated at the factory, this step will insure that all moving parts are properly lubricated for initial use.

3.2 During normal operation, apply one grease gun shot of grease to the release mechanism (sliding sleeve assembly) fitting every 20 hours of operation.

3.3 Also lubricate the main bearings (located on the clutch shaft) and lever (operating) shaft every 100 hours of operation with one grease gun shot.

3.4 Amount and frequency of lubrication are only a recommendation. Actual requirements will vary, due to load and operating conditions. New units should be monitored for heat and wear for a period of time, to determine actual needs.

NOTE: Pilot bearing is "sealed for life" and does not require lubrication.

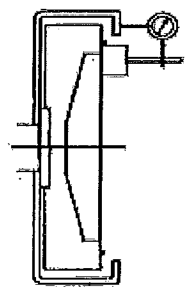
4.0 Inspection

4.1 **Preparation.** Upon receipt of your WPT product, inspect for and report any evidence of damage. To avoid damage or personal injury, insure that adequate lifting devices and hand tools are available. Compare the flywheel, flywheel housing, and pilot bearing bore to the bell housing, drive ring, and pilot bearing, respectively to insure that you have the correct size unit.

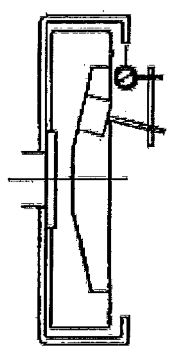
4.2 Check flywheel and flywheel housing alignment. It is strongly recommended that dial indicator checks be made prior to installation of the PTO, especially on new engines or when a previous PTO failure might indicate an alignment problem.

4.3 Flywheel to housing face runout check.

Mount the indicator base on the face of the flywheel and position the dial indicator tip perpendicular to the flywheel housing mounting face. Rotate the flywheel 360 degrees while holding pressure against the crankshaft thrust bearing. The total indicator reading should not exceed the values listed in the table shown below in Section 4.4.



4.4 Check flywheel housing bore runout. Mount the indicator base on the face of the flywheel and position the dial indicator tip so its movement is perpendicular to the pilot bore of the flywheel housing. Rotate the flywheel through 360 degrees.



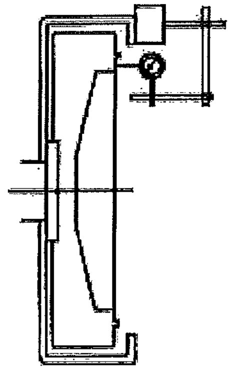
The total indicator reading should not exceed :

SAE "00" Housing: 0.019 inches (0.483 mm)
SAE ."0" Housing: 0.016 inches (0.406 mm)
SAE ."1" Housing: 0.012 inches (0.305 mm)
SAE ."2" Housing: 0.011 inches (0.279 mm)
SAE ."3" Housing: 0.010 inches (0.254 mm)
SAE ."4" Housing: 0.009 inches (0.229 mm)
SAE ."5" Housing: 0.008 inches (0.203 mm)
SAE ."6" Housing: 0.007 inches (0.178 mm)
(Reference: SAE J617 table 1A)

4.5 Check flywheel face runout.

Mount the indicator base on the flywheel housing and position the dial indicator tip so that its movement is perpendicular to the face of the flywheel. Position the indicator tip near the drive ring mounting bolt circle diameter. Rotate the flywheel 360 degrees while holding pressure against the crankshaft thrust bearing.

The total indicator reading should not exceed 0.0005 inches (0.013 mm) per inch of measured diameter.



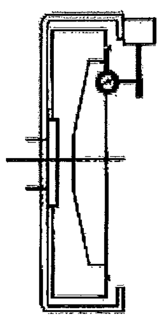
4.6 Check engine crankshaft endplay.

Measure and document the engine's crankshaft endplay before installing PTO. Using dial indicator as shown in 4.5 move the crankshaft back against the rear main bearing and then move the crankshaft to the front of the engine. Record the total movement as shown by the dial indicator.

4.7 Check flywheel pilot bore runout.

Mount the indicator base on the flywheel housing and position the dial indicator tip so its movement is perpendicular to the pilot bore diameter, to measure pilot bore runout. Rotate the flywheel through 360 degrees.

The total indicator reading should not exceed 0.005 inches (0.127 mm).



5.0 Installation

5.1 Use the drive ring provided with the PTO or remove the drive ring from the engine flywheel to use as an alignment gauge. Place the drive ring over the friction discs. Center the drive ring relative to the O.D. of the clutch body. Engage the clutch by operating the hand lever.

5.2 Remove the drive ring. Do not disengage clutch until installation is complete.

5.3 Install the drive ring on the engine flywheel making sure that the ring is seated in the locating bore. Use SAE Grade 5 bolts (or equivalent) with lock washers and torque to the specifications in Chart 1 on page 13 or to the engine manufacturers torque recommendation. Use the engine manufacturer's torque recommendation if different from that in Chart 1.

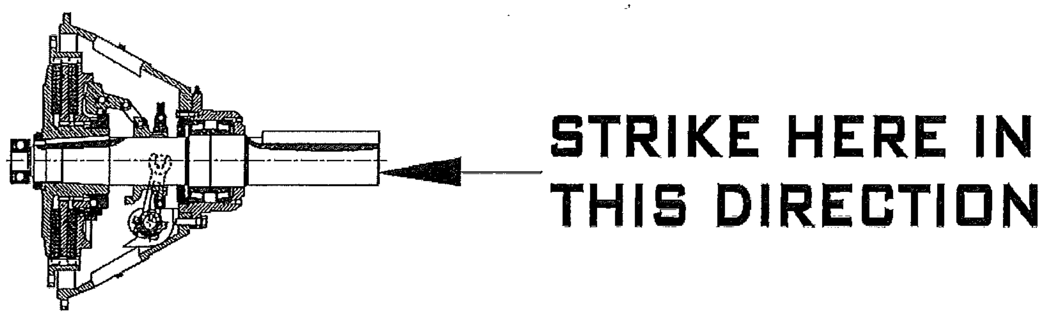
5.4 Install pilot bearing onto clutch end of PTO shaft, stopping before the bearing is flush with the shaft. Let the bearing overhang the shaft by 1/8". Only apply force on the inner race of the bearing.

5.5 Remove inspection cover nameplate from the PTO bellhousing and slowly draw the PTO toward the engine; this can be done by installing 3 or 4 equally spaced lengths of all-thread into the flywheel housing. Install nuts and tighten these while supporting the weight of the PTO with a hoist or cribbing.

5.6 As the PTO is drawn toward the engine, insure that the pilot bearing engages the crankshaft, and the friction discs engage the teeth on the drive ring without binding or interference.

5.7 When the PTO is fully in place, remove the studs if used and replace with SAE Grade 5 bolts (or equivalent) with lock washers and torque to the value in Chart 1 on page 13. Use the engine manufacturer's torque recommendation if different from that in Chart 1.

5.8 Strike the output end of clutch shaft with a soft face hammer to relieve bearing preloading caused by installation, see sketch below.



5.9 The operating handle (hand lever) may be installed on either side of the PTO engagement shaft, depending upon space requirements and convenience to the operator. Install lever with the cast hex facing away from the PTO.

⚠ **WARNING:** Operating handle must be mounted in the vertical position to eliminate excessive wear in the collar, see drawings on pages 18, 19 and 20.

5.10 To check relief from bearing preloading, engage the clutch, then move the hand lever back and forth to feel the bearing endplay. Shaft and clutch should move .003" to .010".

5.11 Re-check crankshaft endplay. If not the same as recorded in 4.6, STOP and determine the cause. Crankshaft and clutch shaft must have the proper amount of endplay or bearings may fail.

5.12 Support plate is required for SP311/214/314 side load applications and recommended for in-line applications. Support plate is required for all 18" applications.

⚠ **WARNING:**

The WPT mechanical PTO is capable of side load and inline power transmission applications. Special care should be exercised when installing the PTO in an inline application. Due to engine movement and other factors that may cause misalignment, WPT recommends that a flexible coupling or drive shaft be used to join the PTO and driven shaft. If a coupling is used, insure that it has sufficient horsepower capacity and that shafts are in line within the limits specified by the coupling manufacturer. If you are unsure about the procedure to align these shafts, consult the coupling manufacturer or WPT Power Transmission Corp.

6.0 Clutch Operation

6.1 Where high inertia loads must be started, engaging the clutch at idle speed may stall the engine. High inertia loads may be brought up to speed by engaging the clutch for short periods (1 second) at intervals long enough to prevent excessive heat build up in the friction discs. With extremely high loads, the engine may have to be operated at higher speeds while engaging the clutch.

6.2 Once the load is turning with the clutch fully engaged, the engine RPM may be increased.

⚠ WARNING:
UNDER NO CIRCUMSTANCES should the clutch be slipped for more than four seconds maximum without either fully engaging the clutch or completely disengaging the clutch to allow it to cool. Any excessive vibration in the PTO should be cause for investigation. All rotating parts of the WPT PTO are balanced at the factory.

7.0 PTO Adjustment

7.1 Clutch Adjustment

The WPT mechanical PTO uses an adjusting collar to adjust for clutch wear. If the engagement force reaches 2/3 of maximum specified torque, clutch slips, heats excessively, or operating lever fails to stay engaged, clutch adjustment is required.

7.1.1 Remove inspection cover nameplate.

7.1.2 Disengage locking pin for "SP" style clutches by pushing pin in with a screwdriver. For "C" style clutches pull locking pin out.

7.1.3 Turn adjusting ring clockwise to increase clutch engagement force.

7.1.4 Adjust clutch engagement force until the hand lever force required to engage the clutch is within the range specified on the inspection cover nameplate. Check engagement force with a torque wrench using the cast hex on the lever.

7.1.5 Release lock pin after completing adjustment.

7.1.6 Replace inspection cover nameplate.

NOTE: New friction discs require frequent adjustments during an initial break-in period. Please recheck clutch adjustment after the first 10 hours of operation.

Clutch Adjustment Frequency

7.1.7 As clutch wears, the hand lever force required to engage clutch will decrease.

7.1.8 The need to readjust the clutch is indicated when the handle force has decreased to 2/3 of the maximum force specified on the inspection cover plate **OR** anytime clutch slippage is detected.

7.1.9 Do not adjust clutch so tight that hand lever force exceeds the maximum as indicated on the inspection cover nameplate.

⚠ **WARNING:** Do not use any automated clutch engagement device which continues to apply pressure to the hand lever, after clutch is engaged. To prevent excessive wear to clutch sliding sleeve and other clutch parts, the hand lever should be allowed to rest in a vertical position with no external force applied to it once clutch is engaged.

7.2 Main Bearing Adjustments

7.2.1 PTO main bearings should be adjusted to provide .007" - .009" axial clearance in main shaft for 106 thru 211 PTO's and .009" - .012" axial clearance in main shaft for 311 thru 314 PTO's (18" PTO's do not have an adjustment).

7.2.2 Place PTO so the bellhousing flange supports its weight.

7.2.3 Mount dial indicator base on PTO housing.

7.2.4 Place dial indicator stem on end of shaft in a manner that will gauge shaft axial endplay.

7.2.5 Apply 200 lbs of "upward" force on shaft using a suitable hoist and lift device to fit the tapped hole in the end of the shaft.

7.2.6 Rotate shaft several revolutions.

7.2.7 Zero dial indicator reading.

7.2.8 Remove hoist from shaft and apply 200 lbs of "downward" force on shaft.

7.2.9 Rotate shaft several revolutions.

7.2.10 Read axial endplay from dial indicator.

7.2.11 Loosen bearing adjustment lock on inside of bell housing.

7.2.12 Rotate bearing locknut until proper shaft axial endplay is obtained.

NOTE: When loosening nut, strike output end of shaft with a soft face hammer to set bearing cup (outer race) against adjusting nut. See sketch on page 7 for direction.

7.2.13 Adjust bearing locknut until nearest notch lines up with tab on bearing adjustment lock.

7.2.14 Tighten bearing adjustment lock.

8.0 Disassembly

(Refer to PTO Illustration on pages 17, 18, 19 and 20 of this manual)
Use a hoist or other suitable lifting equipment to support the weight of the power take-off. Attach lifting devices at several places or use cribbing to support the PTO in a horizontal position during removal.

⚠ **CAUTION:**
The PTO is heavy. Use approved lifting eyes and procedures to prevent accident or injury.

8.1 Remove the PTO from the engine.

8.1.1 Remove hand lever and other connections to the PTO.

8.1.2 Remove drive shaft or drive belts from PTO output shaft.

8.1.3 Remove the mounting bolts attaching PTO to flywheel housing, removing those located near the top last. The PTO should separate from the flywheel housing. If the PTO doesn't separate, gently pry the flanges apart until the housing is removed from the engine flywheel housing pilot diameter.

⚠ **WARNING:** Use care when removing the PTO from the engine to avoid damage to grease fittings, friction disc teeth, and other components.

8.2 Remove the clutch from the PTO

8.2.1 Remove the pilot bearing from PTO shaft using a bearing puller.

8.2.2 Remove jam nut (on outside of bellhousing) in order to free grease fitting.

8.2.3 Bend hub lock washer tab away from hub locknut.

8.2.4 Remove hub locknut.

8.2.5 Remove hub lock washer.

8.2.6 Remove the clutch assembly using a gear puller and the tapped holes that are provided in the hub & backplate.

8.2.7 Remove the grease hose and fittings from the clutch assembly.

8.2.8 Remove cotter pins, straight pins, and any washers from the clutch assembly, allowing the sliding sleeve and collar to separate from the clutch.

8.2.9 Remove (2) nuts and bolts securing the brass collar halves to the sliding sleeve.

8.2.10 Push or pull clutch adjusting lock and remove adjusting collar from clutch.

8.3 Remove the shaft from the PTO housing

8.3.1 Remove the bearing adjustment lock (for 18" remove bearing retainer bolts).

8.3.2 Remove bearing adjustment nut from PTO housing (for 18" remove bearing retainer from housing).

8.3.3 Strike output end of shaft with soft faced hammer or use a suitable bearing press to loosen shaft and bearings from PTO housing. See sketch on page 7 for direction.

8.3.4 Remove inner cup and shaft with bearings from PTO housing.

8.3.5 Drive outer cup from PTO housing by placing a punch through (2) access holes provided in rear of the housing (does not apply to 18").

8.3.6 Using a suitable bearing press, remove bearings from shaft.

9.0 Assemble the PTO

9.1 Reverse steps 8.3.1 through 8.3.6 on page 10 and 11.

9.2 Adjust main bearings for proper PTO shaft axial endplay as indicated in steps 7.2.1 through 7.2.14 on page 9 (does not apply to 18").

9.3 Install clutch by reversing steps 8.2.1 through 8.2.10 on page 10.

9.4 Adjust clutch as indicated in steps 7.1.1 through 7.1.9 on pages 8 and 9.

10.0 Warranty

WPT POWER CORPORATION
STANDARD TERMS AND CONDITIONS OF SALE

1. PRICES, TERMS OF PAYMENT, TAXES. All quoted prices are prices in effect on the invoice date (unless quoted otherwise), or date of completion if shipment is deferred on purchaser's instructions, are F.O.B. point of shipment unless otherwise specified, and are subject to change without notice. Terms are net thirty (30) days to those with an established credit standing with WPT or who are satisfactorily rated in commercial reference books. WPT is not required to accept sales on open account and may choose to request C.O.D. payment. WPT also requires a substantial deposit for special or non-stock purchases. Minimum billing is $25.00. Interest at the maximum allowable rate will be charged on all delinquent accounts. No discount will be allowed for prompt payment. Prices set forth on the face hereof do not include duty, sales or use taxes. Any duty, sales or use taxes that WPT is obligated by law to collect will be added to the invoice price. Payment shall be made to WPT at its offices in Wichita Falls, Wichita County, Texas, USA and shall not be considered paid until WPT receives United States Legal Tender at the address listed on the face hereof.

2. QUOTATIONS. Quotations are given for prompt acceptance and are valid for 60 days unless otherwise agreed in writing. Quotations are generally held as price reference for a possible order and will not be binding unless otherwise agreed upon in writing. The submission of a quotation by WPT in response to purchaser's request, does not constitute an expression of acceptance of any term or condition which may have been set forth in purchaser's request. The terms and conditions of sale set forth herein are the only terms and conditions applicable to the sale of the products described on the face hereof, notwithstanding prior references.

3. INVOICE. Where WPT does not issue either a quotation or a sales confirmation and ships products pursuant to purchaser's purchase order, such sale shall be subject to WPT's Standard Terms and Conditions of Sale as set forth on WPT's invoice. Any additional or different terms or conditions of sale set forth in the purchase order or other communication from purchaser are objected to by WPT and shall not be effective nor binding unless assented to in writing by an officer of WPT.

4. WARRANTY. WPT guarantees all products will leave the factory in good condition. The products are warranted against defects in workmanship and material for a period of 365 (one year) after shipment. Adjustment under this warranty will be made only after completion of inspection of the part or product in our factory. Liability under the warranty shall extend only to the replacement or correction of any defective part or product as determined by WPT. All materials must be returned freight prepaid. This warranty shall not apply to any product that has been repaired or altered without the specific knowledge and consent of an authorized representative of the manufacturer; or operated or installed in a manner contrary to the manufacturer's instruction; or subjected to misuse or improper maintenance; or has been damaged by accident or negligence. This warranty is made in lieu of all other warranties, expressed or implied, including but not limited to warranties of merchantability or fitness for a particular purpose, and there are no other warranties that extend beyond this expressed warranty. WPT reserves the right to discontinue models or to change specification at any time without notice. No discontinuance or change will create any liability on the part of WPT in respect to its products in the hands of customers or products on order not incorporating such changes even though delivered after any such change. Rotating equipment is potentially dangerous and should be properly guarded. The user should check for all applicable safety codes and provide suitable guarding.

5. RETURNS AND CANCELLATIONS. No purchase order with respect to which WPT has issued or indicated a sales confirmation may be canceled or the manufacture of products thereunder suspended after the date of the sales confirmation without written consent of WPT. WPT's consent may, at its option, be predicated upon a cancellation charge. Upon such cancellation or suspension at the request of purchaser, purchaser agrees to reimburse WPT promptly for all expenditures for material used, labor and engineering services performed, or for which WPT has obligated itself, a proportionate share of direct manufacturing, engineering, selling, general and administrative expenses included in connection with such purchase order so far as it has been contemplated, and the proportionate amount of the normal profits which would have been earned under the purchase order. In addition, purchaser shall also reimburse WPT for any extraordinary costs and other expenses attributable to such suspension or cancellation.

In case products are rejected on inspection by purchaser, WPT must be notified in writing within fifteen (15) days from receipt of the product or WPT shall have no obligation to correct such defect. WPT shall then have the option of re-inspection at purchaser's plant or its own before allowing or disallowing purchaser's claim. Defects that do not impair service shall not be a cause for rejection, or recovery under any warranty.

NO PRODUCTS SHALL BE RETURNED TO WPT (WHETHER DUE TO CANCELLATION OF A PURCHASE ORDER OR FOR ANY OTHER REASON NOT THE FAULT OF WPT) WITHOUT PRIOR WRITTEN AUTHORIZATION FROM WPT. An inspection and restocking charge on all returned items will, at WPT's option, be required. Any request to return products shall include, in addition to other information reasonably requested by WPT, a full description of the products, the date of the purchase order and WPT's invoice number.

6. SHIPMENT. Unless otherwise specified herein, all shipments are F.O.B. or F.A.S. point of shipment indicated on the front hereof. WPT's responsibility for shipment terminates upon the delivery of products herein referred to, the title thereto and any risk of loss, shall be considered as being transferred to the purchaser upon delivery to the common carrier for transportation to the purchaser and title to the products shall not revert to WPT by operation of law for any purpose. No claims for shortages, damages or failure in delivery, whether by common carrier, parcel post or otherwise, may be made by the purchaser against WPT. In the absence of written shipping instructions from purchaser, WPT may ship the products freight collect to the purchaser upon delivery to the common carrier for transportation by any common carrier which it considers satisfactory or, if appropriate, in the opinion of WPT, by parcel post. WPT hereby retains a purchase money security interest in the products to secure the payment of the purchase price. Purchaser agrees that a reproduction hereof may be filed by WPT as a financing statement at any time.Except as provided on the face hereof or as hereinafter provided, prices include packing for products destined within continental limits of the United States, Canada, and Mexico. An additional charge may be made for crating and for export packing and crating.All scheduled delivery dates are estimated based on a normal work load and all deliveries are subject to change without liability to WPT.

7. MISCELLANEOUS. None of the Standard Terms and Conditions of Sale herein set forth may be added to, modified, superseded or otherwise altered except by a written instrument signed by an officer of WPT and delivered by WPT to purchaser. Each shipment received by purchaser from WPT shall be deemed to be upon the terms and conditions herein set forth, except as they may be added to, modified, superseded or otherwise modified as provided above, notwithstanding any terms and conditions that may be contained in any purchase order or other form of purchase, and notwithstanding purchaser's act of accepting or paying for the products or similar act of purchaser.

No agent, employee, or representative of WPT has any authority to bind WPT to any affirmation, representation or warranty concerning goods sold. Unless an affirmation, representation or warranty made by agent, employee or representative is specifically included within a written agreement and signed by an officer of WPT, it shall not be enforceable by purchaser.

Any typographical or clerical error herein is subject to correction.

This document and the sale of the products described herein shall be construed in accordance with the laws of the State of Texas.

WPT will not be liable for any losses or delays resulting from fire, flood, storm, strikes or other circumstances beyond its control which affect its operation or the operations of its suppliers.

11.0 Bolt Torque Values

TORQUE VALUES FOR SOCKET HEAD AND HEX HEAD CAPSCREWS

SOCKET HEAD CAP SCREWS

BOLT SIZE IN INCHES	As Received			Lubricated**		
	LB - FT	LB - IN	Nm	LB - FT	LB - IN	Nm
1/4	13	150	17	10	120	13
5/16	23	305	34	18	244	27
3/8	45	545	62	36	436	49
7/16	70	840	95	56	672	76
1/2	108	1300	147	86	1040	117
9/16	155	1860	210	124	1488	168
5/8	211	2530	286	168	2024	228
3/4	367	4400	497	293	3520	397
7/8	583	7000	791	466	5600	632
1	867	10400	1175	693	8320	940
1 1/8	1242	14900	1684	993	11920	1347
1 1/4	1750	21000	2374	1400	16800	1899
1 3/8	2317	27800	3142	1853	22240	2513
1 1/2	3042	36500	4125	2433	29200	3300
1 3/4	4950	59400	6714	3960	47520	5371
2	7492	89900	10161	5993	71920	8128

HEX HEAD CAP SCREWS - Grade 8

BOLT SIZE IN INCHES	As Received			Lubricated**		
	LB - FT	LB - IN	Nm	LB - FT	LB - IN	Nm
1/4	8	100	11	6	80	9
5/16	17	200	23	13	160	18
3/8	30	360	41	24	288	32
7/16	48	570	64	38	456	51
1/2	83	990	112	66	792	89
9/16	107	1285	145	85	1028	116
5/8	143	1714	194	114	1371	155
3/4	256	3070	347	204	2456	277
7/8	417	5000	565	333	4000	452
1	625	7500	848	500	6000	678

HEX HEAD CAP SCREWS - Grade 5

BOLT SIZE IN INCHES	As Received			Lubricated**		
	LB - FT	LB - IN	Nm	LB - FT	LB - IN	Nm
1/4	6	71	8	5	56	6
5/16	12	142	16	9	113	12
3/8	22	260	29	17	208	23
7/16	34	410	46	27	328	36
1/2	53	636	72	42	508	57
9/16	74	890	101	59	712	80
5/8	104	1250	141	83	1000	112
3/4	183	2200	249	146	1760	199
7/8	298	3570	403	238	2856	322
1	440	5280	597	352	4224	477
1 1/8	553	6640	750	442	5312	600
1 1/4	775	9300	1051	620	7440	840
1 3/8	1012	12140	1372	809	9712	1097
1 1/2	1350	16200	1831	1080	12960	1464

**** NOTE: For loctite use lubricated values**

Chart 1

12.0 Specifications and Duty Service Classification

SPECIFICATIONS

Model/ Size	Available SAE Housing Sizes	Maximum Input Torque lb-ft (Nm)	Duty Service Classification Maximum Clutch Ratings hp (Kw)[1]			Maximum Speed rpm[2]	Approx. Net Weight lbs (kgs)
		Class 1	Class 2	Class 3	Class 4		
C106	6,5,4	160 (217)	40 (30)	28 (21)	20 (15)	3500	53 (24.0)
C107	6,5,4	177 (240)	57 (43)	38 (28)	28 (21)	3200	56 (25.4)
C108	5,4,3	230 (312)	68 (51)	45 (34)	34 (25)	3100	73 (33.1)
C110	4,3,2	329 (446)	98 (73)	65 (49)	49 (37)	3400	117 (53.1)
SP111	3,2,1	452 (613)	128 (95)	85 (63)	64 (48)	3200	143 (64.9)
SP211	3,2,1	904 (1226)	255 (190)	170 (128)	128 (95)	3200	157 (71.2)
SP311	3,2	1620 (2200)	383 (286)	252 (188)	189 (141)	3200	223 (101.2)
SP114	1,0	800 (1085)	194 (145)	125 (93)	94 (70)	2400	263 (119.3)
SP214	1,0	1600 (2170)	388 (289)	252 (188)	190 (142)	2400	332 (150.6)
SP314	1,0	2400 (3255)	582 (434)	374 (279)	281 (210)	2400	413 (187.3)
SP318	0	6000 (8137)	936 (698)	627 (468)	463 (345)	1800	780 (353.8)

[1] Horsepower (Kw) ratings may be increased with optional clutch plates.
[2] Contact WPT Engineering for applications requiring higher speeds.

Duty Service Classifications[3]

Class 1
Primarily used as a disconnect clutch. Light loads with minimal slip.

Class 2
Primarily used as a disconnect clutch. Light to medium loads with a maximum 2 second slip before engagement.

Class 3
Used to start medium loads. Maximum 3 second slip before engagement.

Class 4
Used to start heavy loads. Maximum 4 second slip before engagement.

[3] If in doubt of proper duty service class to use, consult WPT Engineering for application assistance. Attention must also be paid to the maximum speed rating and side load capacities, in addition to clutch ratings. Clutch ratings are based on engagement at low idle speed and, once engaged, clutch must be engaged for at least one hour before disconnecting.

CHART 2

13.0 Flywheel and Housing Dimensions

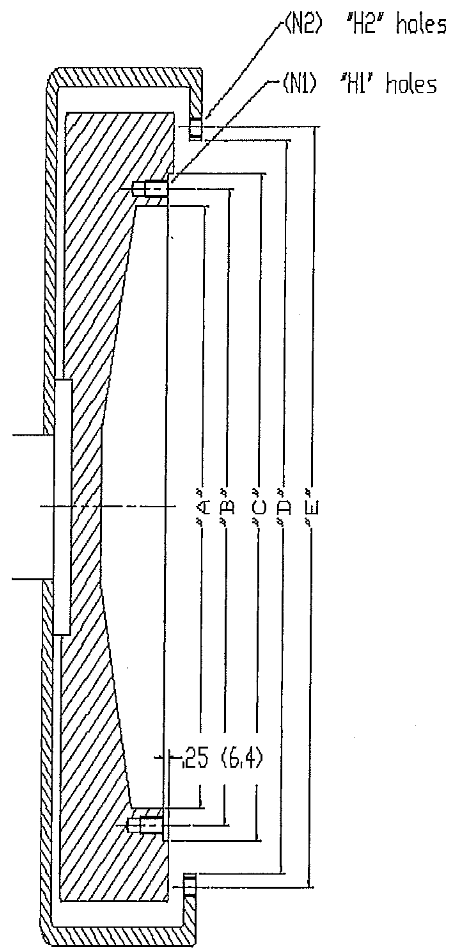
FLYWHEEL DIMENSIONS					
Clutch size	Flywheel Dimensions				
	"A"	"B"	"C"	N1	H1
6"	7.25 (184.2)	8.500 (215.90)	7.875 (200.02)	6	5/16 – 18 NC
7"	8.12 (206.2)	8.750 (222.25)	9.500 (241.30)	8	5/16 – 18 NC
8"	8.88 (225.6)	9.625 (244.48)	10.375 (263.52)	6	3/8 – 16 NC
10"	10.88 (276.4)	11.625 (295.28)	12.375 (314.32)	8	3/8 – 16 NC
11"	12.38 (314.5)	13.125 (333.38)	13.875 (352.42)	8	3/8 – 16 NC
14"	16.12 (409.4)	17.250 (438.15)	18.375 (466.72)	8	1/2 - 13 NC
18"	19.62 (498.3)	21.375 (542.93)	22.500 (571.50)	6	5/8 – 11 NC

FLYWHEEL HOUSING DIMENSIONS				
Housing size	Housing Dimensions			
	"D"	"E"	N2	H2
"6"	10.500 (266.70)	11.250 (285.75)	8	3/8 – 16 NC
"5"	12.375 (314.33)	13.125 (333.38)	8	3/8 – 16 NC
"4"	14.250 (361.95)	15.000 (381.00)	12	3/8 – 16 NC
"3"	16.125 (409.58)	16.875 (428.63)	12	3/8 – 16 NC
"2"	17.625 (447.68)	18.375 (466.73)	12	3/8 – 16 NC
"1"	20.125 (511.18)	20.875 (530.22)	12	7/16 - 14 NC
"1/2"	23.000 (584.20)	24.375 (619.12)	12	1/2 - 13 NC
"0"	25.500 (647.70)	26.750 (679.45)	16	1/2 - 13 NC
"00"	31.000 (787.40)	33.500 (850.90)	16	1/2 – 13 NC

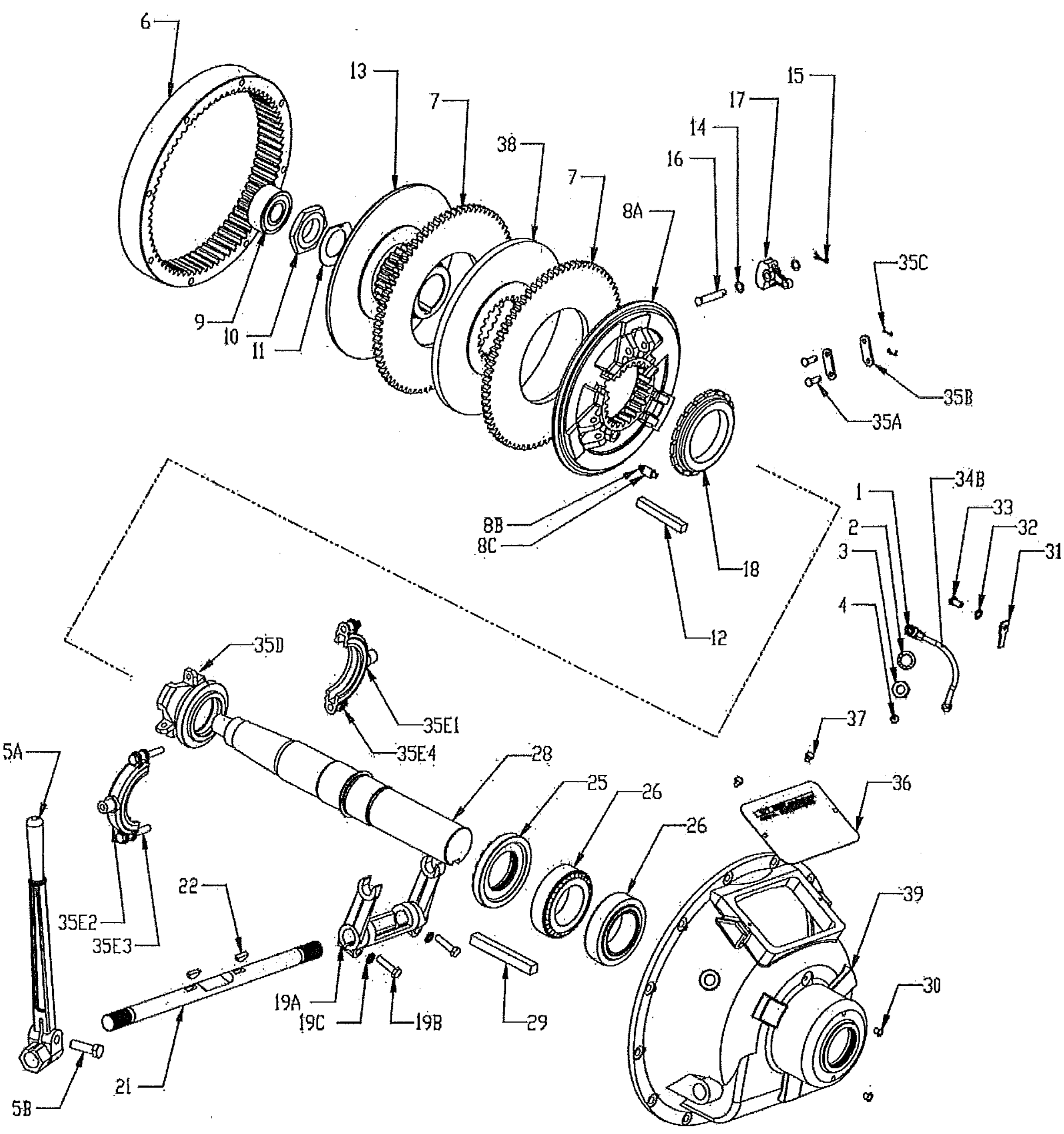
CHART 3

See page 15 for flywheel and housing drawing.

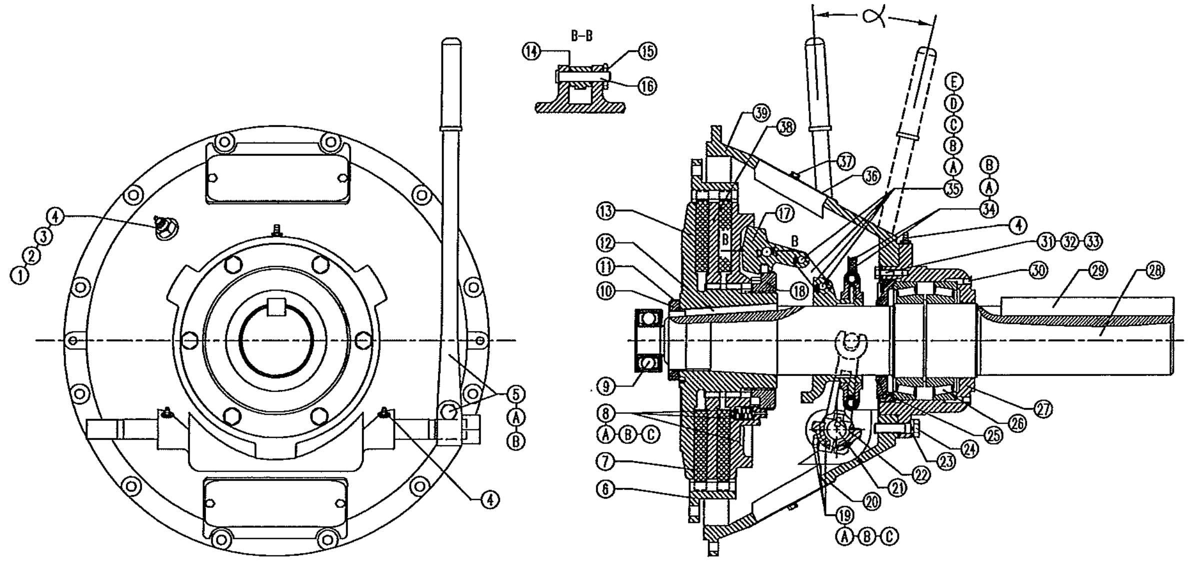
14.0 Flywheel and Housing Drawing



15.0 WTD-SP Style PTO Exploded View Drawing



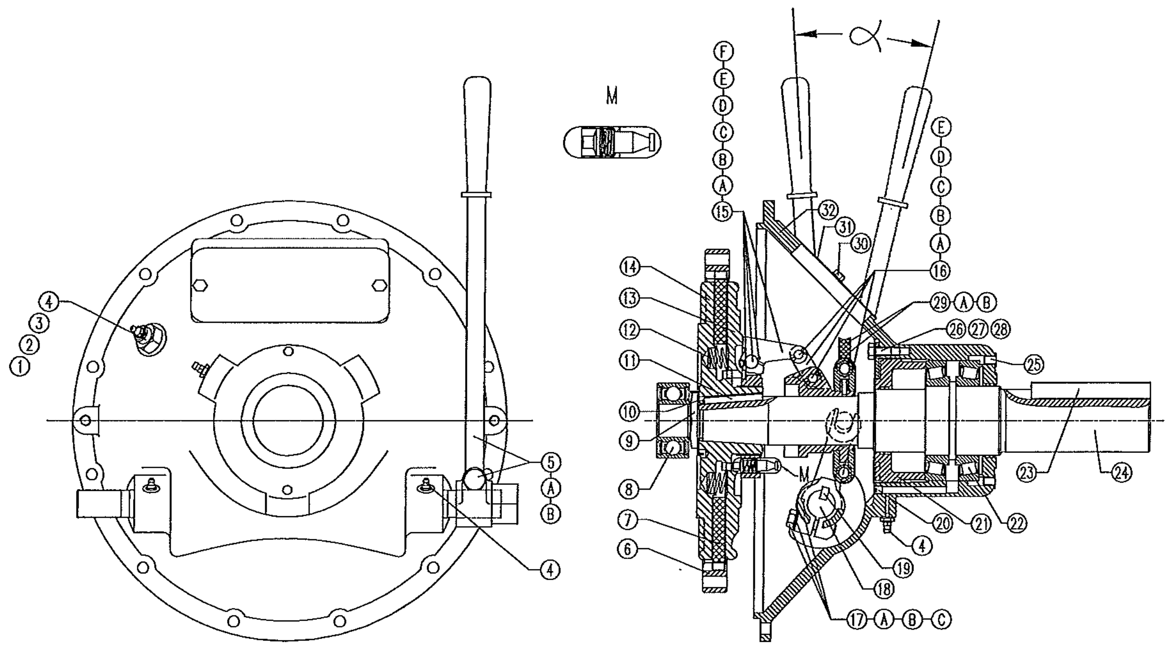
16.0 WTD-SP Style PTO Drawing and Parts List



Item	Description	Qty	Item	Description	Qty
1.	Bushing, grease	1	22.	Key, woodruff	2
2.	Washer, lock	1	23.	Washer, lock	6
3.	Nut	1	24.	HHCS	6
4.	Zerk, grease	4	25.	Retainer, bearing	1
5.	Assembly, lever, hand	1	26.	Bearing, roller, tapered	2
	A. Lever, hand	1	27.	Carrier, bearing	1
	B. HHCS	1	28.	Shaft, clutch	1
6.	Ring, drive	1	29.	Key, output shaft	1
7.	Disc, friction	2	30.	Plug, polyethylene	2
8.	Assembly, plate, floating	1	31.	Lock, bearing retainer	1
	A. Plate, floating	1	32.	Washer, lock	1
	B. Spring, adjusting	1	33.	HHCS	1
	C. Pin, adjusting	1	34.	Assembly, hose	1
9.	Bearing, pilot	1		A. Elbow	1
10.	Nut, hub	1		B. Hose, flexible	1
11.	Lock washer, hub	1	35.	Assembly, sliding sleeve	1
12.	Key, clutch	1		A. Pin, clevis	8
13.	Hub and backplate	1		B. Link, lever	8
14.	Washer, spring	8		C. Pin, cotter	8
15.	Pin, cotter	4		D. Sleeve, sliding	1
16.	Pin, clevis	4		E. Assembly, collar ***	1
17.	Lever	4	36.	Nameplate, instruction	1
18.	Ring, adjusting	1	37.	HHCS	4
19.	Assembly, yoke	1	38.	Plate, center	1
	A. Yoke	1	39.	Bellhousing	1
	B. HHCS	2			
	C. Washer, lock	2			
20.	Nameplate	1			
21.	Shaft, operating	1			

*** Optional "Ball Bearing Collar" available for 11", 14" and 18" Power Take Off.

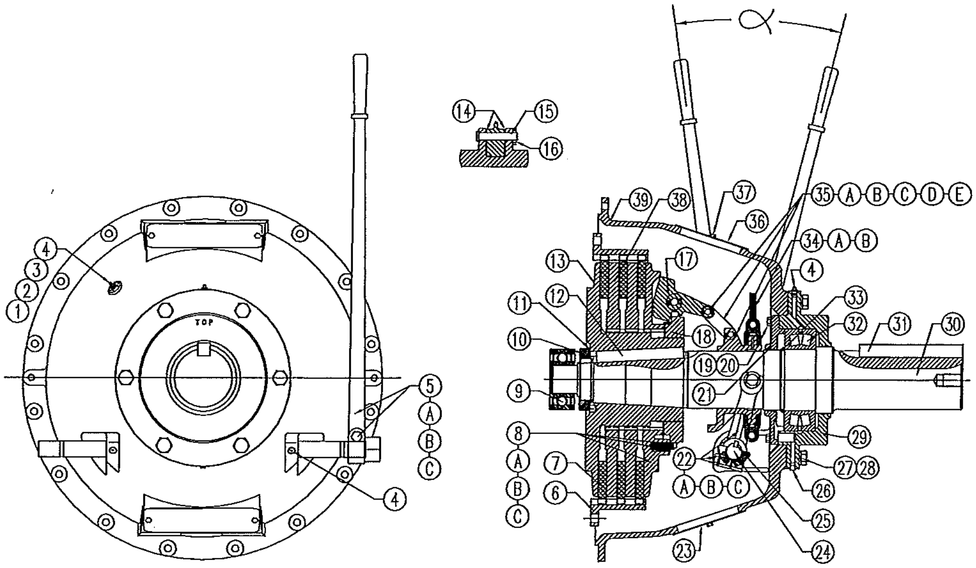
17.0 WTD-C Style PTO Drawing and Parts List



Item	Description	Qty	Item	Description	Qty
1.	Bushing, grease	1		D. Sleeve, sliding	1
2.	Washer, lock	1		E. Assembly, collar***	1
3.	Nut	1	17.	Assembly, yoke	1
4.	Zerk, grease	4		A. Yoke	1
5.	Assembly, lever, hand	1		B. HHCS	2
	A. Lever, hand	1		C. Washer, lock	2
	B. HHCS	1	18.	Shaft, operating	1
6.	Ring, drive	1	19.	Key, woodruff	2
7.	Disc, friction	1	20.	Screw, Set	1
8.	Bearing, pilot	1	21.	Retainer, bearing	1
9.	Nut, hub	1	22.	Bearing, roller, tapered	2
10.	Lock washer, hub	1	23.	Key, output shaft	1
11.	Key, clutch	1	24.	Shaft, clutch	1
12.	Spring, release	6	25.	Plug, polyethylene	2
13.	Plate, floating	1	26.	Lock, bearing retainer	1
14.	Hub and backplate	1	27.	Washer, lock	1
15.	Assembly, lever, adjusting	1	28.	HHCS	1
	A. Spring, adjusting	1	29.	Assembly, hose	1
	B. Pin, adjusting	1		A. Elbow	1
	C. Pin, cotter	4		B. Hose, flexible	1
	D. Pin, clevis	4	30.	HHCS	2
	E. Lever, finger	4	31.	Nameplate, instruction	1
	F. Ring, adjusting	1	32.	Bellhousing	1
16.	Assembly, sliding sleeve	1			
	A. Pin, clevis	8			
	B. Link, lever	8			
	C. Pin, cotter	8			

*** Optional "Ball Bearing Collar" available for 10" and 11" Power Take Off.

18.0 WTD-SP Style 18" PTO Drawing and Parts List



Item	Description	Qty	Item	Description	Qty
1.	Bushing, grease	1	23.	Nameplate, bottom	1
2.	Washer, lock	1	24.	Shaft, operating	1
3.	Nut	1	25.	Key, woodruff	2
4.	Zerk, grease	4	26.	Plug, pipe	1
5.	Assembly, lever, hand	1	27.	HHCS	6
	A. Lever, hand	1	28.	Washer, lock	6
	B. HHCS	1	29.	Carrier, bearing	1
	C. NUT	1	30.	Shaft, clutch	1
6.	Ring, drive	1	31.	Key, output shaft	1
7.	Disc, friction	3	32.	Bearing, roller, spherical	1
8.	Assembly, plate, floating	1	33.	Ring, snap	1
	A. Plate, floating	1	34.	Assembly, hose	1
	B. Spring, adjusting	1		A. Elbow	1
	C. Pin, adjusting	1		B. Hose, flexible	1
9.	Bearing, pilot	1	35.	Assembly, sliding sleeve	1
10.	Nut, hub	1		A. Pin, clevis	8
11.	Lock washer, hub	1		B. Link, lever	8
12.	Key, clutch	1		C. Pin, cotter	8
13.	Hub and backplate	1		D. Sleeve, sliding	1
14.	Washer, spring	8		E. Assembly, collar ***	1
15.	Pin, clevis	4	36.	Nameplate, instruction	1
16.	Pin, cotter	4	37.	HHCS	4
17.	Lever	4	38.	Plate, center	2
18.	Ring, adjusting	1	39.	Bellhousing	1
19.	HHCS	6			
20.	Washer, lock	6			
21.	Retainer, bearing	1			
22.	Assembly, yoke	1			
	A. Yoke	1			
	B. HHCS	2			
	C. Washer, lock	2			

*** Optional "Ball Bearing Collar" available for 11", 14" and 18" Power Take Off.