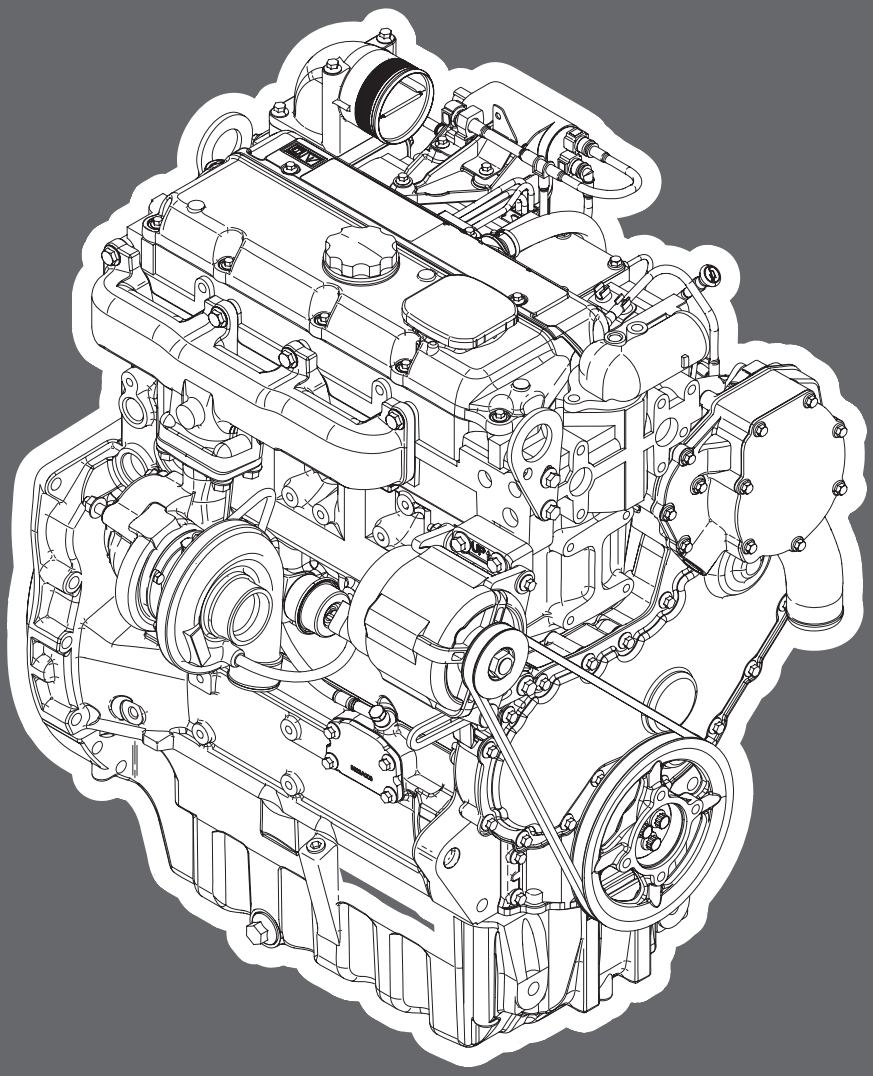
647016EN (16/06/2008)

ENGINE

1104D EURO 3 - 80CV / 100CV

Repair manual



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ISSUE

16 / 06 / 2008 - 1st ISSUE
Engine 1104D E3 - 80CV/ 100CV

Specifications

1104D (Mech) Industrial Engine

NK (Engine)
NL (Engine)
NK (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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Engine Design

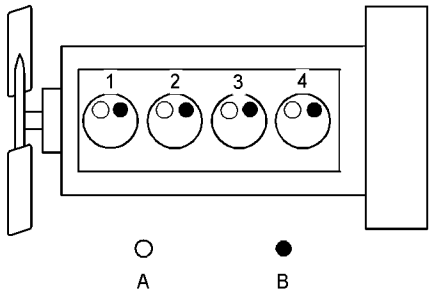

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Illustration 1

Cylinder and valve location

(A) Inlet valve
(B) Exhaust valve

Bore ..... 105 mm (4.133 inch)

Stroke ..... 127 mm (5.000 inch)

Displacement ..... 4.4 L (269 in^3)

Cylinder arrangement ..... In-line

Type of combustion ..... Direct injection

Compression ratio

Naturally aspirated engines 19.3:1
Turbocharged engines 18.2:1

Number of cylinders 4

Valves per cylinder 2

Valve lash

Inlet valve ..... 0.20 mm (0.008 inch)
Exhaust valve ..... 0.45 mm (0.018 inch)

Firing order 1, 3, 4, 2

When the crankshaft is viewed from the front of the engine, the crankshaft rotates in the following direction: ..... Clockwise

When the camshaft is viewed from the front of the engine, the camshaft rotates in the following direction: ..... Clockwise

The front of the engine is opposite the flywheel end. The left side and the right side of the engine are viewed from the flywheel end. The No. 1 cylinder is the front cylinder.

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Fuel Injection Lines

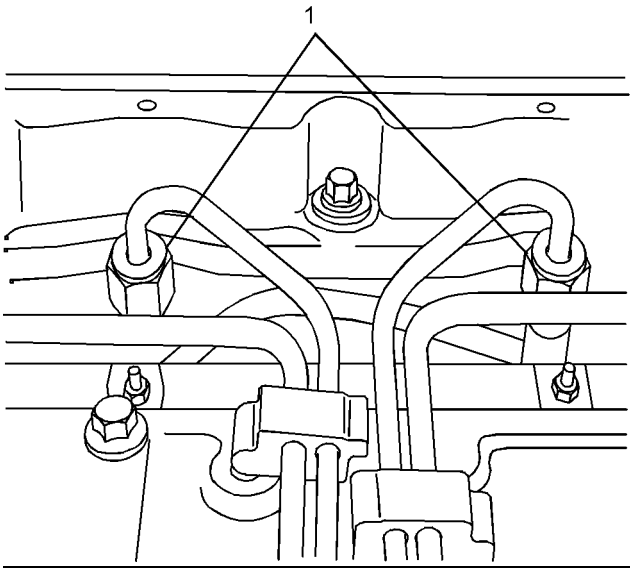

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Illustration 2

Typical example

(1) Tighten the union nuts for the fuel injector nozzles to the following torque. ..... 30 N·m (22 lb ft)

Tighten the union nuts for the fuel injection pump (not shown) to the following torque. ..... 30 N·m (22 lb ft)

i02663071

Fuel Injection Pump

Note: Before the fuel injection pump is removed from the engine the fuel injection pump shaft must be locked. Position the engine to TC compression stroke of number one cylinder before tightening the locking screw. The locking screw will prevent the shaft from rotating. If the fuel injection pump was removed prior to correctly timing the engine and locking the shaft, the fuel injection pump will need to be timed by trained personnel.

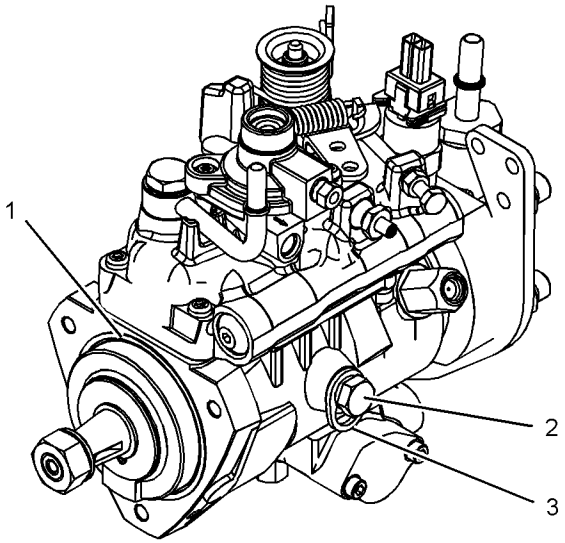

Illustration 3 g01352237
Typical example

Note: The solenoid on the fuel injection pump is a serviceable item. The fuel injection pump is a nonserviceable item.

(1) O-ring

(2) Locking screw

(3) Washer

Locking the shaft

Loosen locking screw (2) and move the washer (3) to the locked position. Tighten the bolt to the following torque. ..... 17 N·m (12 lb ft)

Unlocking the shaft

Loosen locking screw (2) and install the washer (3) to the unlocked position. Tighten the bolt to the following torque. ..... 12 N·m (9 lb ft)

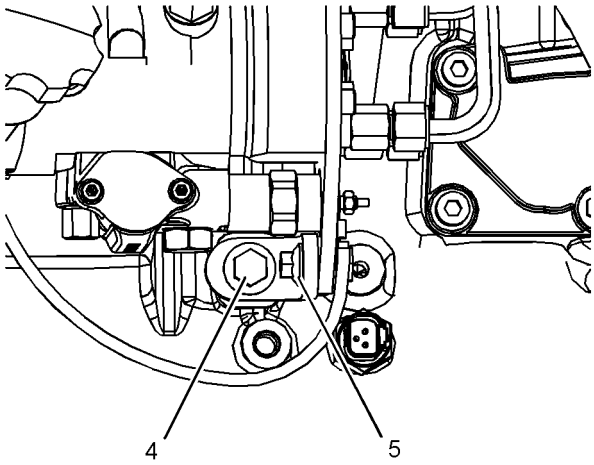

Illustration 4 g01352239
Typical example of a support bracket

(4) Tighten the mounting bolt to the following torque. ..... 44 N·m (32 lb ft)

(5) Tighten the mounting bolt and the nut to the following torque. ..... 22 N·m (16 lb ft)

Note: The support bracket must be installed after the coolant pump is installed. In order to stop the distortion of the timing case, finger tighten the bolt (4) and then tighten the nut and bolt (5). Tighten the bolt (4).

Tighten the bolts that hold the fuel pump to the front housing to the following torque. ..... 25 N·m (18 lb ft)

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Fuel Injectors

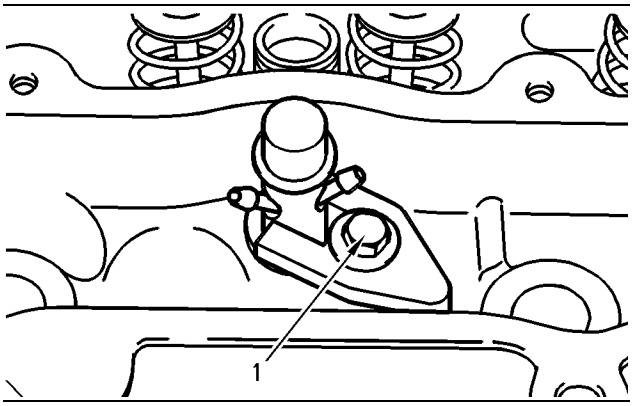

Illustration 5 g00908211

Fuel injector clamp

(1) Tighten the bolt in the clamp for the fuel injector to the following torque. ..... 35 N·m (26 lb ft)

The fuel injector should be tested at the pressure in table 1.

Leakage in 10 seconds ..... 0 drops

Table 1

Service setting for the Fuel Injector
Injection Pressure
29.4 + 0.8 MPa (4264 + 116 psi)

i02661897

Fuel Transfer Pump

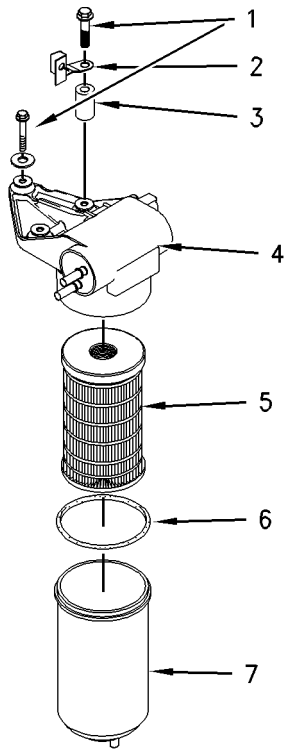

Illustration 6 g00986823

(1) Retaining bolts

(2) Clip

(3) Spacer

(4) Fuel transfer pump

Type ..... 12 or 24 volt electric motor

(5) Fuel filter element

(6) O ring

(7) Fuel filter bowl

Note: Tighten the fuel filter bowl by hand. Rotate the bowl 1/8 of a turn more by hand.

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Lifter Group

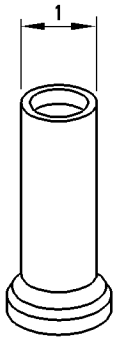

Illustration 7 g00629433

(1) Diameter of the lifter body .. 18.987 to 19.012 mm (0.7475 to 0.7485 inch)

Clearance of the lifter in the cylinder block bore ..... 0.038 to 0.095 mm (0.0015 to 0.0037 inch)

i02655105

Rocker Shaft

Table 2

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	27610227	Spacing Tool	4

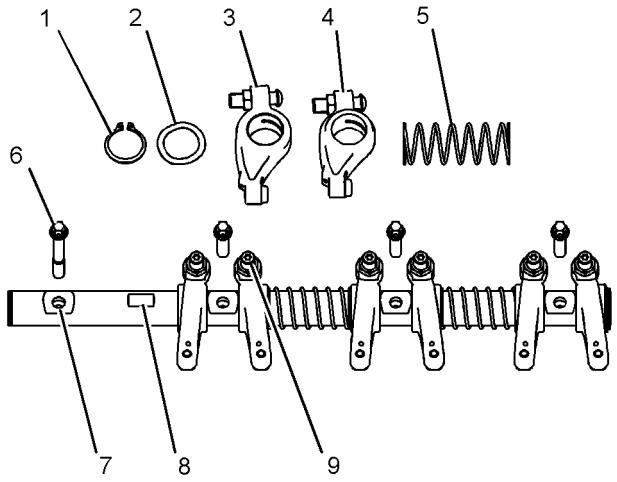

Illustration 8 g01345401

The rocker shaft

Note: In order to install the rocker shaft assembly, Tooling (A) is required.

(1) Snap ring

(2) Washer

(3) Rocker arm

(4) Rocker arm bore

Diameter of the rocker arm bore ..... 25.013 to 25.051 mm (0.9848 to 0.9863 inch)

Rocker arm

Clearance between the rocker arm and the rocker shaft ..... 0.026 to 0.089 mm (0.0010 to 0.0035 inch)
Maximum permissible clearance between the rocker arm and the rocker shaft ..... 0.17 mm (0.007 inch)

(5) Spring

Note: Install the longest screw at the front of the rocker shaft assembly.

(6) Tighten the screws evenly. Begin in the center and work toward the outside. Tighten the screws to the following torque. ..... 35 N·m (26 lb ft)

(7) Rocker shaft

Diameter of the rocker shaft ..... 24.962 to 24.987 mm (0.9828 to 0.9837 inch)

(8) In order to install the rocker shaft assembly, ensure that the machined square is to the top of the rocker shaft.

(9) Locknut

Torque for the locknut ..... 27 N·m (20 lb ft)

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Valve Mechanism Cover

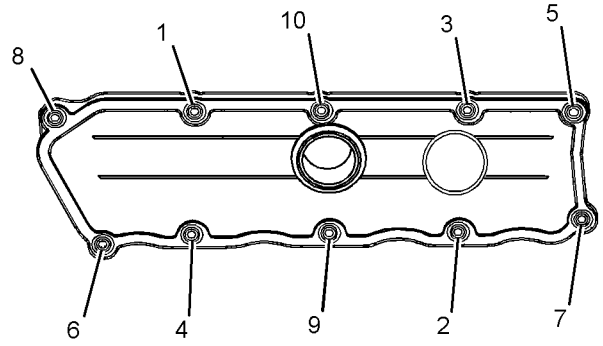


Illustration 9 g01277221

Tighten the bolts for the valve mechanism cover in the sequence that is shown to the following torque. ..... 9 N·m (7 lb ft)

i02662486

Cylinder Head Valves

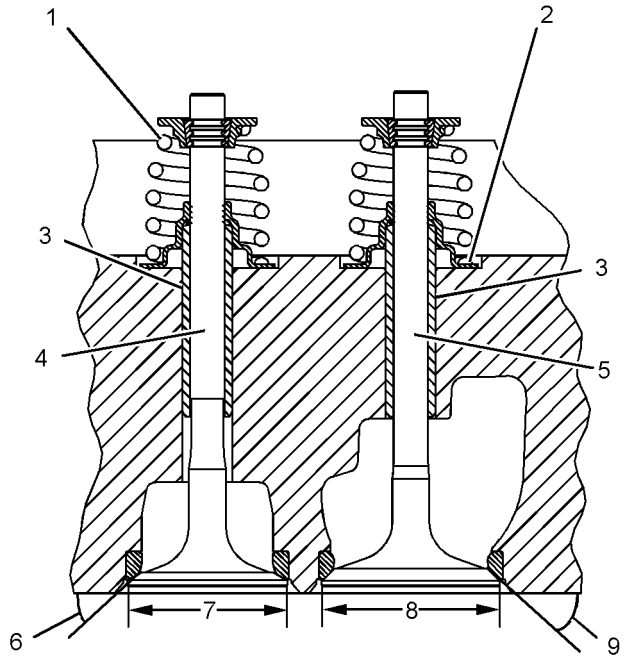


Illustration 10 g01345407

Cross section of cylinder head

(1) Valve spring

Naturally aspirated engines

The installed length of the valve springs ..... 35.17 mm (1.3846 inch)

The load for the installed valve springs ..... 335 N (75 lb)

Turbocharged engines

The installed length of the inlet valve springs (high ratings) ..... 35.17 mm (1.3846 inch)
The load for the installed inlet valve springs ..... 335 N (75 lb)
The installed length of the inlet valve springs (low ratings) ..... 36.17 mm (1.4240 inch)
The load for the installed inlet valve springs ..... 312 N (70 lb)
The installed length of the exhaust valve springs (all ratings) ..... 36.17 mm (1.4240 inch)
The load for the installed exhaust valve spring ..... 312 N (70 lb)

Turbocharged aftercooled engines

The installed length of the valve springs ..... 36.17 mm (1.4240 inch)
The load for the installed valve springs ..... 312 N (70 lb)

(2) Valve spring recess

(3) The finished valve guides

Inside diameter of valve guide ..... 9.000 to 9.022 mm (0.3543 to 0.3552 inch)

Outside diameter of the valve guide ..... 13.034 to 13.047 mm (0.5131 to 0.5137 inch)

Interference fit of valve guide in cylinder head ..... 0.007 to 0.047 mm (0.0003 to 0.0019 inch)

Length of Valve guide ..... 51.00 to 51.50 mm (2.018 to 2.027 inch)

Projection of the valve guide above the valve spring recess (2) ..... 12.35 to 12.65 mm (0.486 to 0.498 inch)

Note: When new valve guides are installed, new valves and new valve seat inserts must be installed. The valve guides and the valve seat inserts are supplied as partially finished parts. The unfinished valve guides and unfinished valve seat inserts are installed in the cylinder head. The guides and inserts are then cut and reamed in one operation with special tooling. This procedure ensures the concentricity of the valve seat to the valve guide in order to create a seal that is tight. Refer to Disassembly and Assembly for removal and installation procedures.

(4) Exhaust valve

Diameter of the exhaust valve stem ..... 8.938 to 8.960 mm (0.3519 to 0.3528 inch)

Clearance of valve in valve guide ..... 0.040 to 0.062 mm (0.0016 to 0.0024 inch)

Overall length of the exhaust valve ..... 128.184 to 128.634 mm (5.0466 to 5.0643 inch)

The face of the exhaust valve is recessed below the cylinder head by the following amount.

Naturally aspirated engines ..... 0.55 to 0.81 mm (0.0217 to 0.0319 inch)

Service limit ..... 1.06 mm (0.042 inch)

Turbocharged engines ..... 1.55 to 1.81 mm (0.0610 to 0.0713 inch)

Service limit ..... 2.06 mm (0.0811 inch)

Turbocharged aftercooled engines .. 1.55 to 1.81 mm (0.0610 to 0.0713 inch)

Service limit ..... 2.06 mm (0.0811 inch)

(5) Inlet valve

Diameter of the inlet valve stem ..... 8.953 to 8.975 mm (0.3525 to 0.3533 inch)
Clearance of valve in valve guide .. 0.025 to 0.069 mm (0.001 to 0.0027 inch)

Overall length of the inlet valve ..... 128.838 to 129.288 mm (5.0724 to 5.0901 inch)

The face of the inlet valve is recessed below the cylinder head by the following amount.

Naturally aspirated engines ..... 0.60 to 0.85 mm (0.0236 to 0.0335 inch)

Turbocharged engines (high rating) .. 0.60 to 0.85 mm (0.0236 to 0.0335 inch)

Service limit ..... 1.09 mm (0.043 inch)

Turbocharged engines (low rating) .. 1.60 to 1.85 mm (0.0630 to 0.0728 inch)

Turbocharged aftercooled engines .. 1.60 to 1.85 mm (0.0630 to 0.0728 inch)

Service limit ..... 2.09 mm (0.0823 inch)

(6) Exhaust valve face angle from the horizontal axis

Valve face angle ..... 30 degrees
Valve seat angle ..... 30 degrees

(7) Diameter of the exhaust valve head ..... 41.51 to 41.75 mm (1.634 to 1.643 inch)

(8) Diameter of the head of the inlet valve ..... 46.28 to 46.53 mm (1.8220 to 1.8319 inch)

(9) Angle of the inlet valve face from the vertical axis

Valve face angle ..... 45 degrees
Valve seat angle ..... 45 degrees

The valve lash is the following value when the engine is cold:

Inlet valves ..... 0.20 mm (0.008 inch)
Exhaust valves ..... 0.45 mm (0.018 inch)

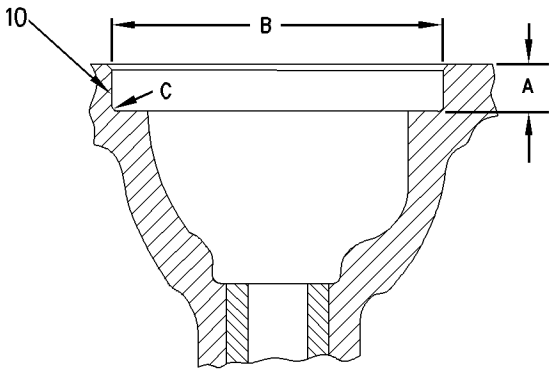


Illustration 11 g00809016

Recess for the valve seat insert

(10) Machine the recess in the head for valve seat inserts to the following dimensions.

Recess for Inlet Valve Seat for Naturally Aspirated Engines and high rated turbocharged engines

(A) ..... 9.84 to 10.04 mm (0.3874 to 0.3953 inch)
(B) ..... 47.820 to 47.845 mm (1.8827 to 1.8837 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

Recess for Exhaust Valve Seat for Naturally Aspirated Engines and high rated turbocharged engines

(A) ..... 9.84 to 10.04 mm (0.3874 to 0.3953 inch)
(B) ..... 42.420 to 42.445 mm (1.6701 to 1.6711 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

Recess for Inlet Valve Seat for low rated turbocharged engines and turbocharged aftercooled engines

(A) .... 10.84 to 11.04 mm (0.4268 to 0.4346 inch)
(B) ..... 47.820 to 47.845 mm (1.8827 to 1.8837 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

Recess for Exhaust Valve Seat for turbocharged engines and turbocharged aftercooled engines

(A) .... 10.84 to 11.04 mm (0.4268 to 0.4346 inch)
(B) ..... 42.420 to 42.445 mm (1.6701 to 1.6711 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

i02662502

Cylinder Head

Table 3

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21825607	Angle gauge	1

The maximum distortion of the cylinder head is given in table 4.

The cylinder head bolts are two different lengths. The following information provides the proper torque for the cylinder head bolts.

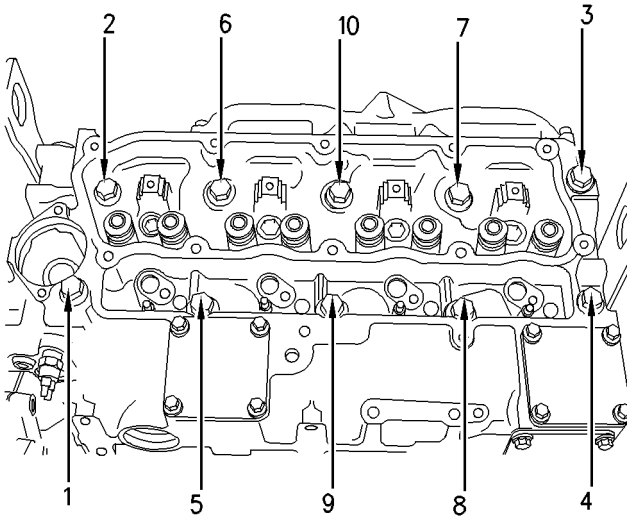


Illustration 12 g00987480

The tightening sequence

Lubricate the threads and the underside of the head bolts with clean engine oil.

Tighten the bolts in the sequence that is shown in Illustrations to the following torque. ..... 50 N·m (37 lb ft)

Tighten the bolts again to the following torque. ..... 100 N·m (74 lb ft)

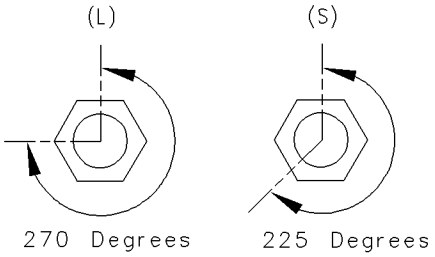


Illustration 13 g00905621

The head bolts require an additional torque turn procedure. The numbers (1, 3, 4) are three long cylinder head bolts. All the other bolts are short bolts. The tightening sequence is shown in the Illustrations .

Place the angle gauge on the top of each bolt head. Tighten the short bolts to the additional amount. ..... 225 degrees
Place the angle gauge on the top of each bolt head. Tighten the long bolts for the additional amount. ..... 270 degrees

Thickness of the cylinder head .. 117.95 to 118.05 mm (4.643 to 4.647 inch)

Minimum thickness of cylinder head ..... 117.20 mm (4.614 inch)

Note: The maximum distortion of the cylinder head is given in table 4.

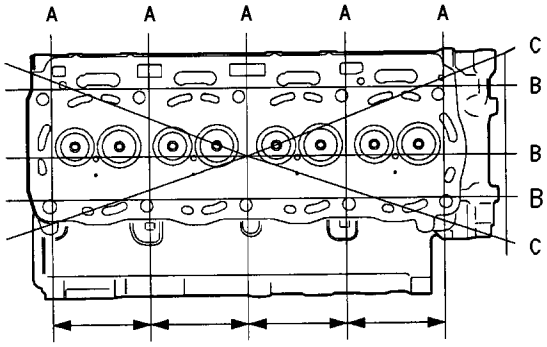


Illustration 14 g01006568

Table 4

Dimension	Maximum Permissible Distortion
Width (A)	0.03 mm (0.0012 inch)
Length (B)	0.05 mm (0.0019 inch)
Diagonal Line (C)	0.05 mm (0.0019 inch)

i02662519

Turbocharger

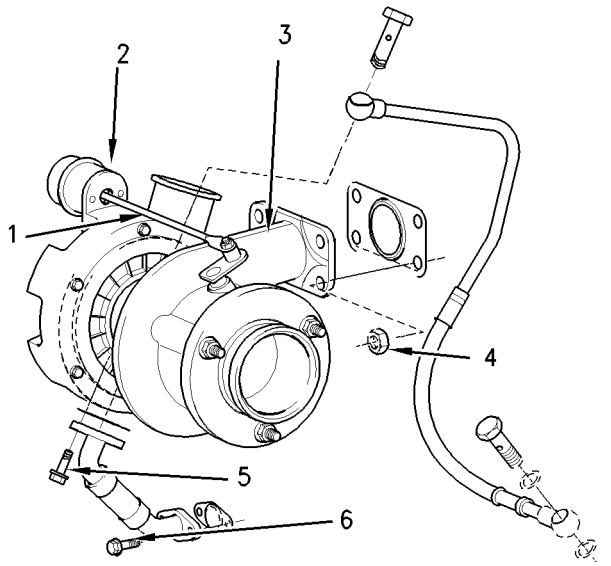


Illustration 15 g00991357

Typical turbocharger

(1) Actuator rod

(2) Actuator

(3) Turbocharger

(4) Tighten the nuts to the following torque. .. 44 N·m (32 lb ft)

(5) Tighten the bolt to the following torque. ..... 9 N·m (80 lb in)

(6) Tighten the bolt to the following torque. ... 22 N·m (16 lb ft)

The maximum test pressure for the wastegate ..... 205 kPa (30 psi)

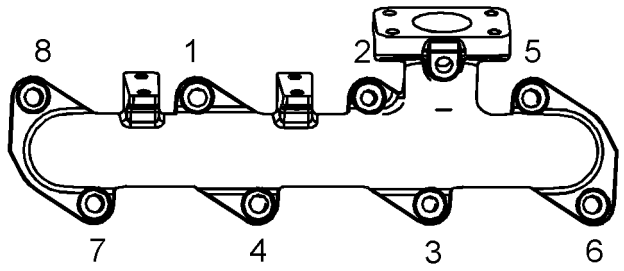
The movement for the rod actuator ..... 1 mm (0.0394 inch)

Table 5

The part number for the turbocharger	The pressure for the wastegate
2674A835	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A841	123 ± 3 kPa (17.8399 ± 0.4351 psi)
2674A843	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A816	131 ± 3 kPa (19.0002 ± 0.4351 psi)
2674A817	100 ± 3 kPa (14.5040 ± 0.4351 psi)
2674A836	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A818	123 ± 3 kPa (17.8399 ± 0.4351 psi)
2674A844	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A819	131 ± 3 kPa (19.0002 ± 0.4351 psi)
2674A821	100 ± 3 kPa (14.5040 ± 0.4351 psi)
2674A837	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A822	123 ± 3 kPa (17.8399 ± 0.4351 psi)
2674A838	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A825	123 ± 3 kPa (17.8399 ± 0.4351 psi)
2674A845	138 ± 3 kPa (20.0155 ± 0.4351 psi)
2674A826	131 ± 3 kPa (19.0002 ± 0.4351 psi)
2674A827	100 ± 3 kPa (14.5040 ± 0.4351 psi)
2674A842	138 ± 3 kPa (20.0155 ± 0.4351 psi)

i02662527

Exhaust Manifold



g01337856

Illustration 16

Typical example

Tighten the exhaust manifold bolts in the sequence that is shown in illustration 16 to the following torque. ..... 40 N·m (30 lb ft)

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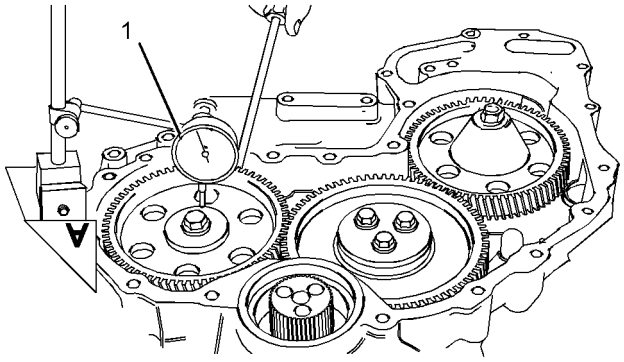
Camshaft



g01277351

Illustration 17

Checking the end play of the camshaft

(1) End play of a new camshaft ..... 0.10 to 0.55 mm (0.004 to 0.022 inch)

Maximum permissible end play of a worn camshaft ..... 0.60 mm (0.023 inch)

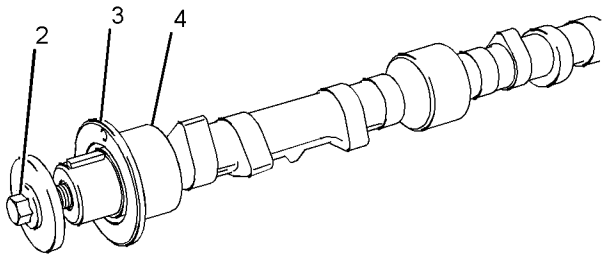


Illustration 18 g01277354

Typical camshaft

(2) Bolt

Tighten the bolt to the following torque. ... 95 N·m (70 lb ft)

(3) Camshaft thrust washer

Thickness of the thrust washer .. 5.49 to 5.54 mm (0.216 to 0.218 inch)

Depth of the recess in the cylinder block for the thrust washer ..... 5.54 to 5.64 mm (0.218 to 0.222 inch)

Tolerance of the thrust washer in cylinder block front face ..... −0.154 to −0.003 mm (−0.0006 to −0.0001 inch)

(4) The diameters of the camshaft journals are given in the following table.

Table 6

Diameters of Camshaft Journals	
Camshaft Journals	**Standard Diameter**
1	50.711 to 50.737 mm (1.9965 to 1.9975 inch)
2	50.457 to 50.483 mm (1.9865 to 1.9875 inch)
3	49.949 to 49.975 mm (1.9665 to 1.9675 inch)

Maximum wear on the camshaft journals ... 0.05 mm (0.0021 inch)

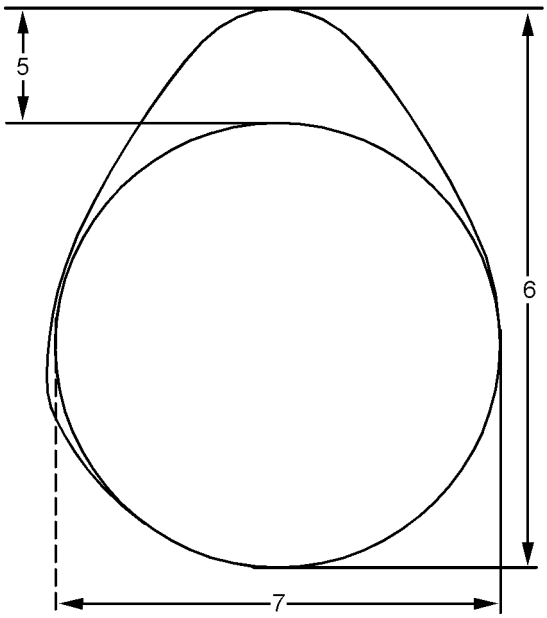


Illustration 19 g01345411

Typical example

(5) Camshaft lobe lift

Naturally aspirated

Inlet lobe ..... 7.201 to 7.301 mm (0.2835 to 0.2874 inch)

Exhaust lobe ..... 7.404 to 7.504 mm (0.2914 to 0.2954 inch)

Turbocharged

Inlet lobe ..... 7.527 to 7.627 mm (0.2963 to 0.3003 inch)

Exhaust lobe ..... 7.363 to 7.463 mm (0.2899 to 0.2938 inch)

Turbocharged aftercooled

Inlet lobe ..... 7.031 to 7.131 mm (0.2768 to 0.2807 inch)

Exhaust lobe ..... 7.363 to 7.463 mm (0.2899 to 0.2938 inch)

(6) Camshaft lobe height

(7) Base circle

To determine the lobe lift, use the procedure that follows:

1. Mount the camshaft between centers.

2. By using a dial indicator in contact with the surface of the lobe, rotate the camshaft and record the maximum and minimum lift.

Note: There may be two lobes on the camshaft. Refer to illustration 19. The surface between the lobes may not return to the radius of the base circle. Using a micrometer to measure the diameter of the base circle may give a inaccurate result.

3. Subtract the smallest dimension from the largest dimension. The difference is the actual camshaft lobe lift.

Maximum permissible deviation between the actual lobe lift and the specified lobe lift of a new camshaft ..... 0.05 mm (0.002 inch)

i02656416

Camshaft Bearings

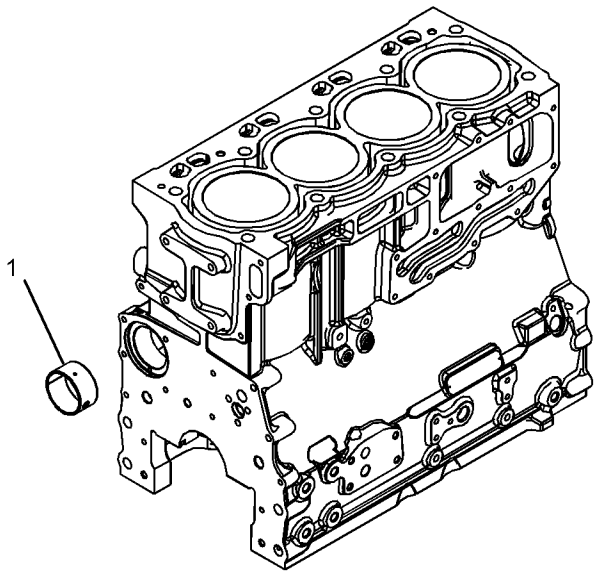


Illustration 20 g01334592

Typical example

(1) The diameter of the installed camshaft bearing ..... 50.787 to 50.848 mm (1.9995 to 2.0019 inch)

i02663064

Engine Oil Filter

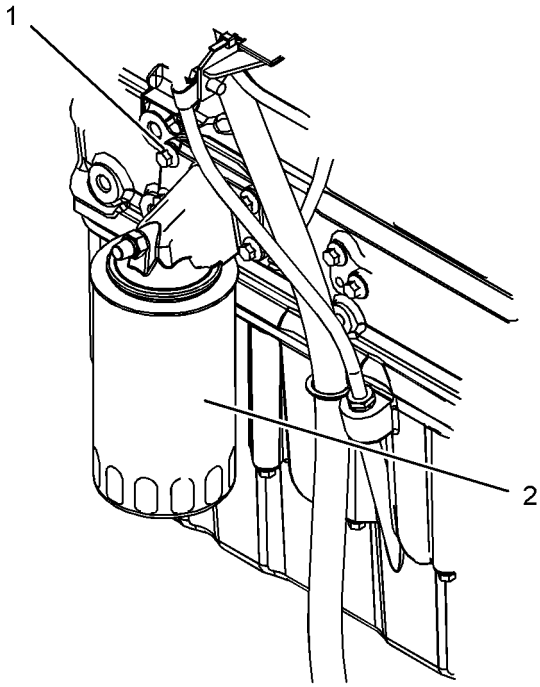


Illustration 21 g01338237

Typical example

(1) Setscrew

Tighten the setscrews to the following torque. ..... 22 N·m (16 lb ft)

(2) Engine oil filter

Tighten the engine oil filter to the following torque. ..... 12 N·m (106 lb in)

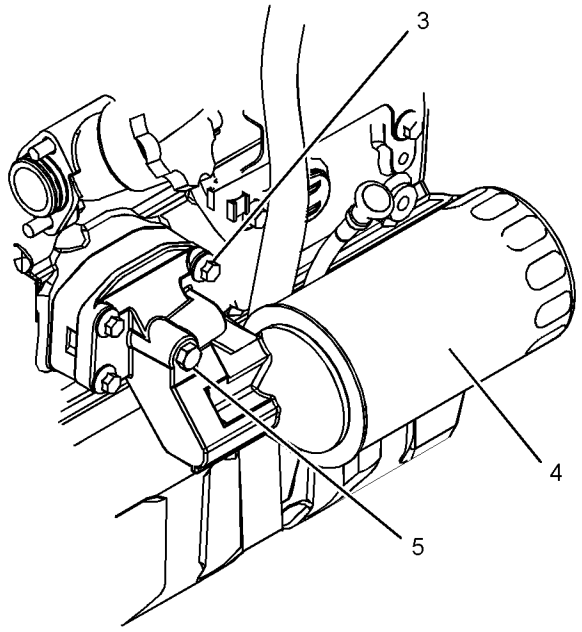


Illustration 22 g01338238

Typical example

(3) Setscrew

Tighten the setscrews to the following torque. ..... 22 N·m (16 lb ft)

(4) Engine oil filter

Tighten the engine oil filter to the following torque. ..... 12 N·m (106 lb in)

(5) Plug

Tighten the plug to the following torque. .. 12 N·m (106 lb in)

i02657143

Engine Oil Cooler

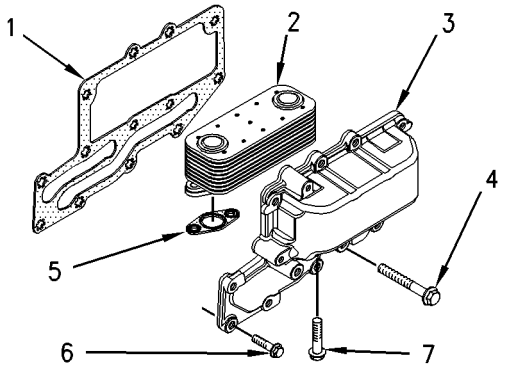


Illustration 23 g00952614

Typical example

(1) Joint
(2) Oil cooler
(3) Housing
(4) Setscrew
(5) Seal
(6) Setscrew
(7) Setscrew

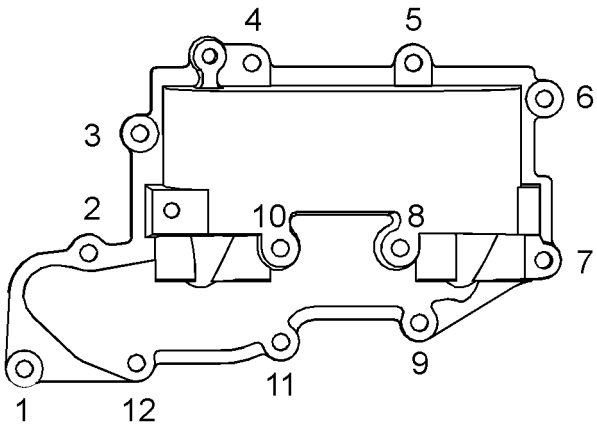


Illustration 24 g01334858

Setscrews

Tighten the setscrews (7) to the following torque. ..... 22 N·m (16 lb ft)

Setscrews

Tighten the setscrews (4) and (6) in the sequence that is in illustration 24 to the following torque. ..... 22 N·m (16 lb ft)

i02656269

Engine Oil Pump

Engines with Balancer Group

Type ..... Gear-driven differential rotor

Number of lobes

Inner rotor 6
Outer rotor 7

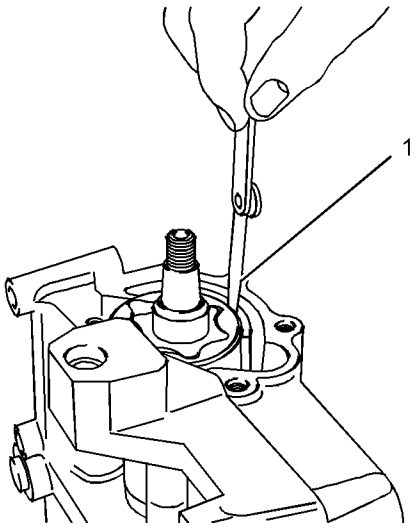


Illustration 25 g01334408

The oil pump for the balancer

(1) Clearance of the outer rotor to the body .. 0.130 to 0.24 mm (0.0050 to 0.0094 inch)

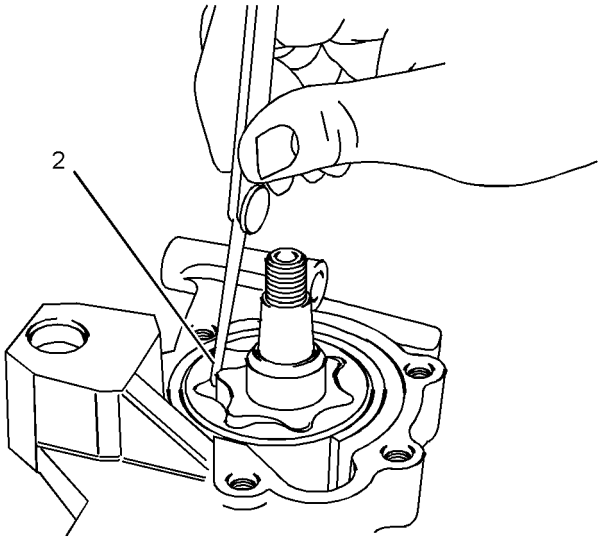


Illustration 26 g01334410

Inner rotor

(2) Clearance of inner rotor to outer rotor ..... 0.050 to 0.200 mm (0.0020 to 0.0079 inch)

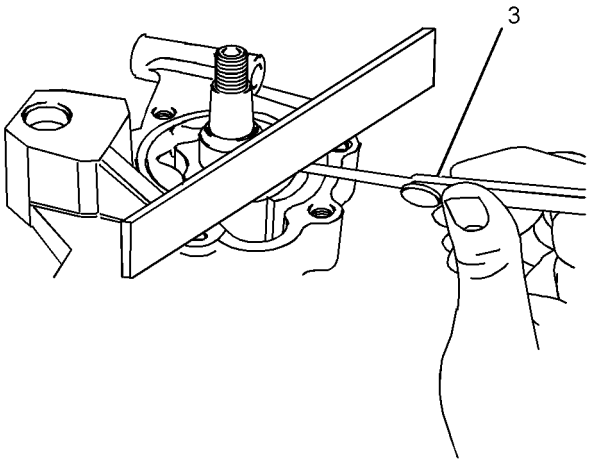


Illustration 27 g01334412

The end play for the rotor

(3) End play of rotor assembly

Inner rotor ..... 0.04 to 0.11 mm (0.0016 to 0.0043 inch)
Outer rotor ..... 0.04 to 0.11 mm (0.0016 to 0.0043 inch)

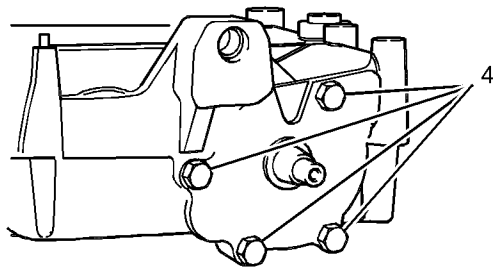


Illustration 28 g01334415
The end cover

(4) Torque for cover bolts for oil pump ..... 26 N·m (19 lb ft)

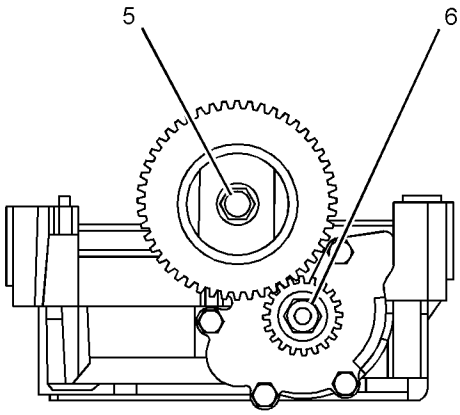


Illustration 29 g01334416
Idler gear and pump gear

Note: Replace the idler gear bolt (5) and the nut for the oil pump gear (6).

(5) Tighten the idler gear bolt to the following torque. ..... 26 N·m (19 lb ft)

Note: Set the engine to the TC position. Refer to Systems Operation, Testing and Adjusting Manual, “Finding Top Center Position for No. 1 Piston”. Install the balancer. Refer to Disassembly and Assembly, “Balancer - Install”. Install the gear for the oil pump and tighten the nut (6).

(6) Tighten the nut to the following torque. .... 95 N·m (70 lb ft)

Tighten the bolts that hold the balancer to the cylinder block to the following torque. ..... 54 N·m (40 lb ft)

Engines without Balancer Group

Type ..... Gear-driven differential rotor

Number of lobes

Inner rotor 5
Outer rotor 6

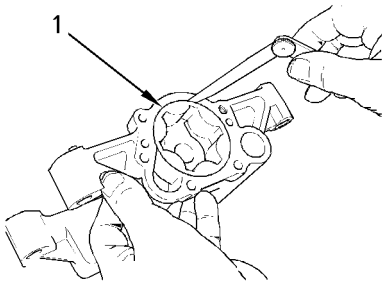


Illustration 30 g00938064
The oil pump

(1) Clearance of the outer rotor to the body ..... 0.152 to 0.330 mm (0.0059 to 0.0129 inch)

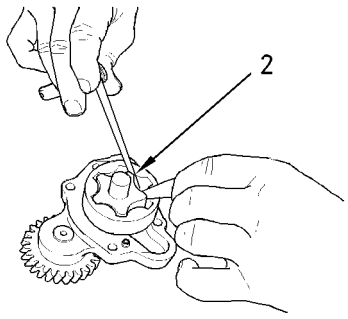


Illustration 31 g00938061
Checking the clearance

(2) Clearance of inner rotor to outer rotor ..... 0.040 to 0.127 mm (0.0015 to 0.0050 inch)

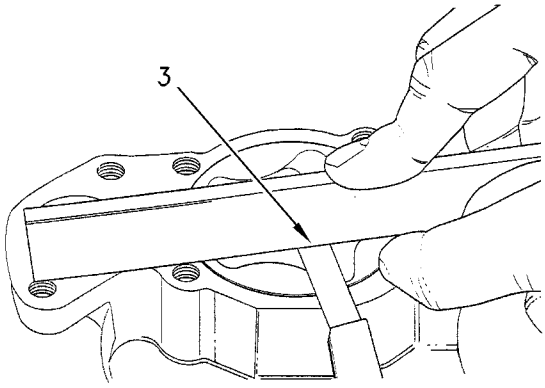


Illustration 32 g00938799
Checking the end play

(3) End play of rotor assembly

Inner rotor ..... 0.038 to 0.089 mm (0.0014 to 0.0035 inch)
Outer rotor ..... 0.025 to 0.076 mm (0.0010 to 0.0029 inch)

Tighten the bolts that hold the front cover of the oil pump assembly to the following torque. ..... 10 N·m (89 lb in)

i02731019

Engine Oil Pressure

The minimum oil pressure at the maximum engine speed and at normal operating temperature is the following value. ..... 280 kPa (41 psi)

i02505676

Engine Oil Bypass Valve

Installed in the Oil Pump

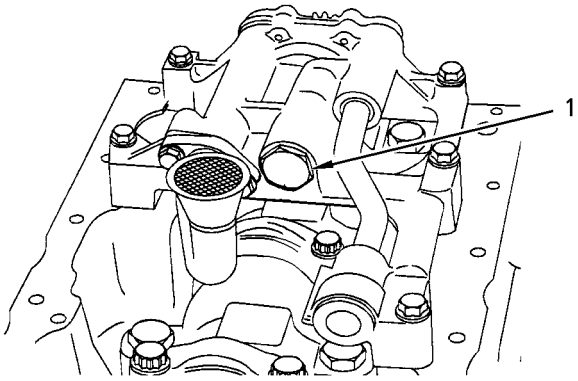


Illustration 33 g00919893
Typical engine oil pump

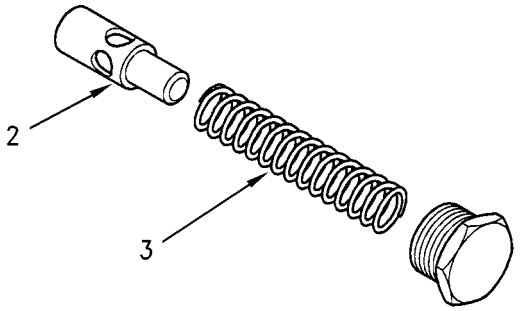


Illustration 34 g00921377
Relief valve and spring

(1) Tighten the plug for the relief valve to the following torque. ..... 35 N·m (26 lb ft)

(2) Plunger

Diameter of the plunger ..... 19.186 to 19.211 mm (0.7554 to 0.7563 inch)

Clearance of plunger in bore .. 0.039 to 0.114 mm (0.0015 to 0.0045 inch)

(3) Spring

Length of the spring ..... 80.94 mm (3.1866 inch)

Installed in the Balancer

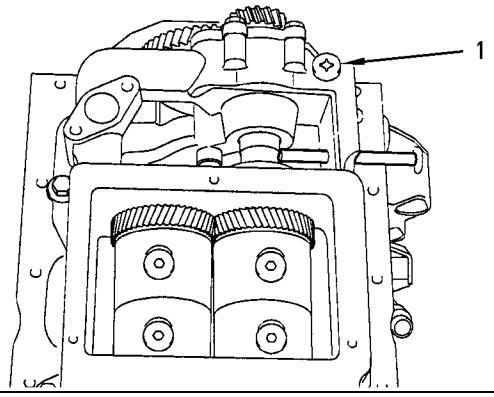


Illustration 35 g00919890

Plug

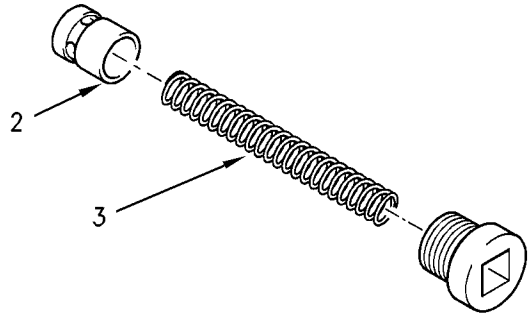


Illustration 36 g00921379

The relief valve for the balancer

(1) Tighten the plug for the relief valve to the following torque. ..... 35 N·m (26 lb ft)

(2) Plunger

Diameter of the plunger ..... 14.46 to 14.48 mm (0.5692 to 0.5700 inch)

Clearance of the plunger in the bore .... 0.04 to 0.08 mm (0.0015 to 0.0031 inch)

(3) Spring

Length of the spring ..... 67 mm (2.6378 inch)

i02662550

Engine Oil Pan

Table 7

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21826038	POWERPART Retainer	1

Front sealant

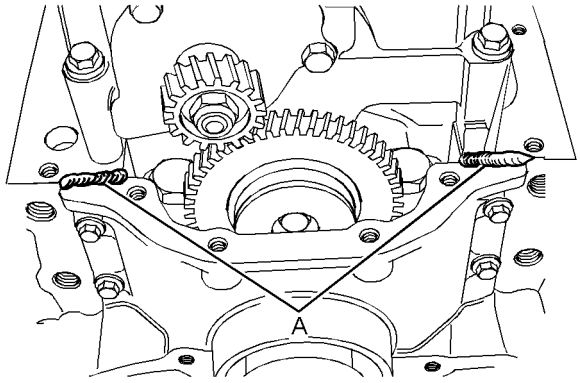


Illustration 37 g01254690

Applying sealant

If the gasket that is between the front housing and the cylinder block is not renewed, apply Tooling (A) to the cylinder block and to the front housing. If a new gasket is installed, Tooling (A) is not required.

Note: Apply a sealant bead of 3.5 mm (0.1378 inch) that is shown in illustration 37.

Rear sealant

Note: Install the rear oil seal before sealant is applied to the bridge.

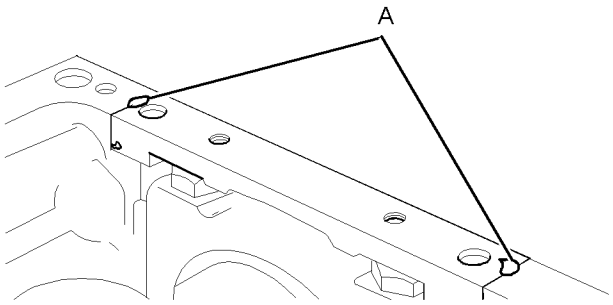


Illustration 38 g01254887

Applying sealant

Apply Tooling (A) to the bridge. The sealant must not protrude more than 5 mm (0.1969 inch) above the bridge.

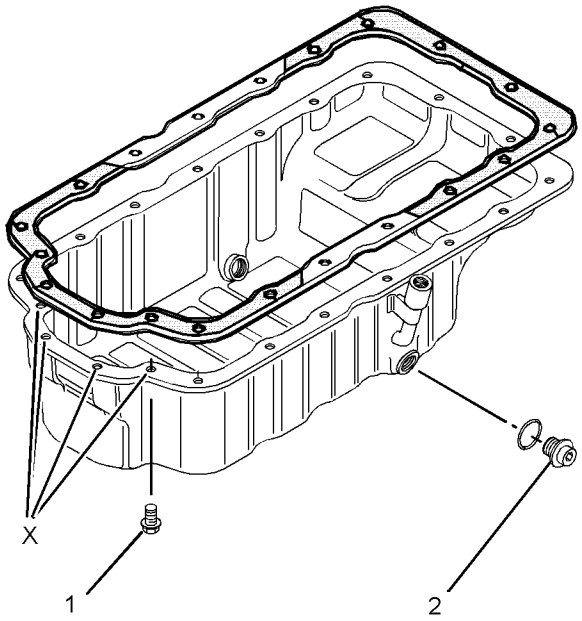


Illustration 39 g01255016

Typical example

(1) Tighten the four front bolts in position (X) to the following torque. ..... 22 N·m (16 lb ft)

Tighten the remaining bolts to the following torque. ..... 22 N·m (16 lb ft)

(2) Drain plug

Tighten the drain plug for the engine oil pan to the following torque. ..... 34 N·m (25 lb ft)

i02662638

Crankcase Breather

Table 8

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21820221	POWERPART red rubber grease	1

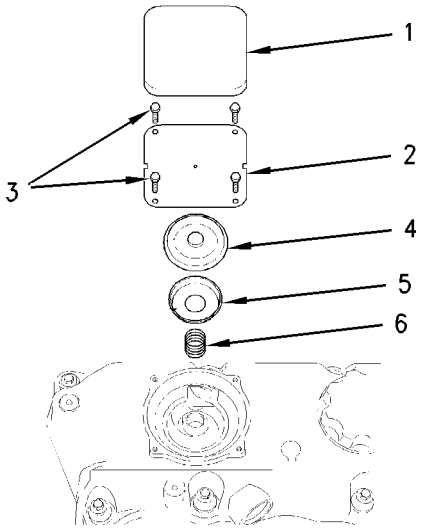


Illustration 40 g00926199

Breather valve

(1) Cover

(2) Cover plate

(3) Screws

Tighten the screws for the cover plate with a composite valve mechanism cover to the following torque. ..... 1.3 N·m (11.5 lb in)

(4) Diaphragm

(5) Cap

(6) Spring

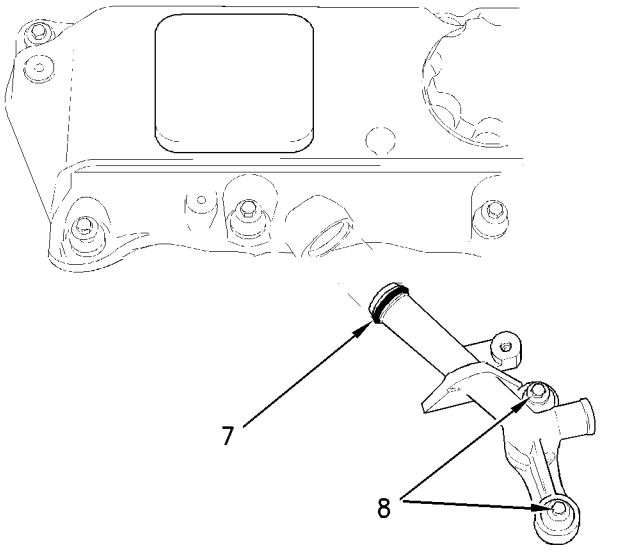


Illustration 41 g00926200
Typical example

(7) O-ring

Note: Apply Tooling (A) to the O-ring before installing the breather pipe in the valve mechanism cover.

(8) Tighten the bolts that secure the breather pipe to the cylinder head to the following torque. .. 9 N·m (80 lb in)

Breather Canister

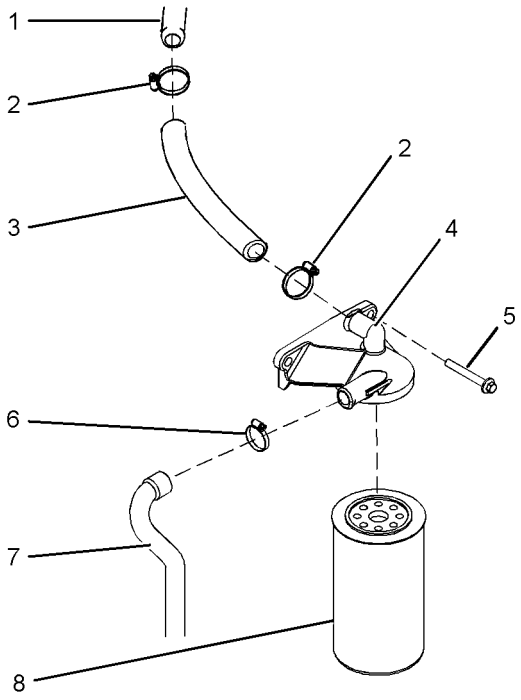


Illustration 42 g01277902
Typical example

(1) Connection
(2) Clamp
(3) Hose
(4) Filter base
(5) Bolts
(6) Clamp
(7) Hose
(8) Canister

(2) Tighten the clamps to the following torque. ..... 3 N·m (26 lb in)

(5) Tighten the bolts to the following torque. .. 22 N·m (16 lb ft)

(6) Tighten the clamp to the following torque. .. 3 N·m (26 lb in)

(8) Tighten the canister to the following torque. ..... 12 N·m (106 lb in)

i02504533

Water Temperature Regulator and Housing

Table 9

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21820221	POWERPART Red Rubber Grease	1

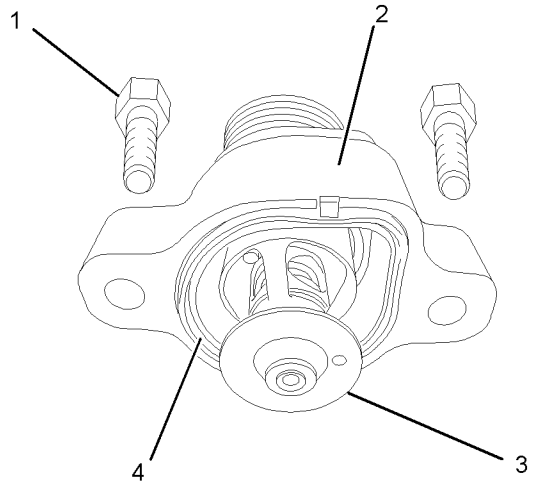


Illustration 43 g01253716

Typical example

Note: Apply Tooling (A) to the O-ring (4) in order to install the water temperature regulator housing (2).

(1) Tighten the bolts that fasten the housing to the following torque. ..... 44 N·m (32 lb ft)

(2) Water temperature regulator housing

(3) Water temperature regulator

Opening temperature ..... 82° to 87°C (179.6000° to 156.6000°F)
Full opening temperature .... 95 °C (203.0000 °F)
Minimum stroke at full temperature ..... 9 mm (0.3543 inch)

i02363605

Water Pump

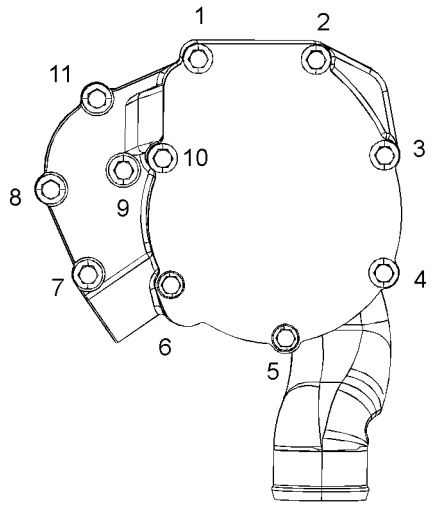


Illustration 44 g01183807

Tightening sequence

Tighten the setscrews in the numerical sequence that is shown in illustration 44 to the following torque. ..... 22 N·m (16 lb ft)

i02663067

Cylinder Block

Table 10

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21826038	POWERPART Retainer	1

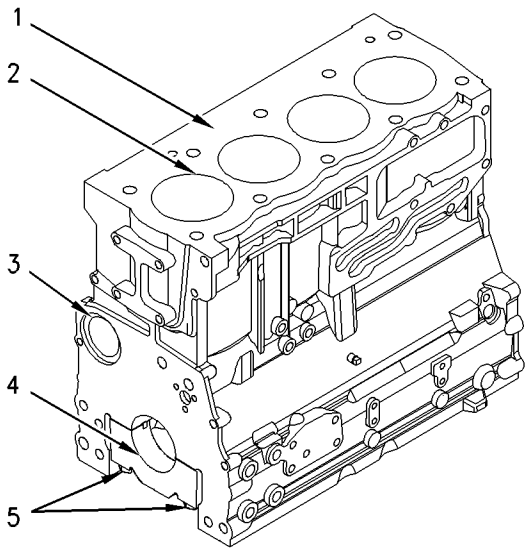


Illustration 45 g00924764
Typical example

(1) Cylinder block

(2) Cylinder bore ..... 105.000 to 105.025 mm (4.1338 to 4.1348 inch)

The first oversize bore diameter ..... 105.5 to 105.525 mm (4.1535 to 4.1545 inch)

The second oversize bore diameter ..... 106.000 to 106.025 mm (4.1732 to 4.1742 inch)

The maximum permissible wear for the cylinder bore ..... 0 to 0.15 mm (0 to 0.0059 inch)

(3) Camshaft bearings

Diameter of the bore in the cylinder block for the number 1 camshaft bearing ..... 55.563 to 55.593 mm (2.1875 to 2.1887 inch)

Diameter of the bore in the cylinder block for the number 2 camshaft journal ..... 50.546 to 50.597 mm (1.9900 to 1.9920 inch)

Diameter of the bore in the cylinder block for the number 3 camshaft journal ..... 50.038 to 50.089 mm (1.9700 to 1.9720 inch)

(4) Main bearings

Bore in the cylinder block for the main bearings ..... 80.416 to 80.442 mm (3.1660 to 3.1670 inch)

(5) Main bearing cap bolts

Use the following procedure in order to install the main bearing cap bolts:

1. Apply clean engine oil to the threads of the main bearing cap bolts.
2. Put the main bearing caps in the correct position that is indicated by a number on the top of the main bearing cap. Install the main bearing caps with the locating tabs in correct alignment with the recess in the cylinder block.
3. Evenly tighten the main bearing cap bolts.

   Torque for the main bearing cap bolts. .... 245 N·m (180 lb ft)

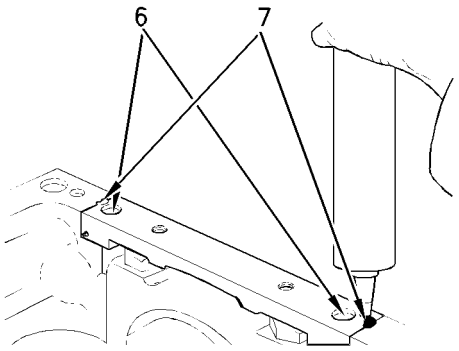


Illustration 46 g00938203

Use the following procedure in order to install the allen head bolts for the bridge.

Note: Install the rear seal before sealant is applied.

1. Use a straight edge in order to ensure that the bridge is aligned with the rear face of the cylinder block.
2. Tighten the allen head bolts (6) for the bridge.

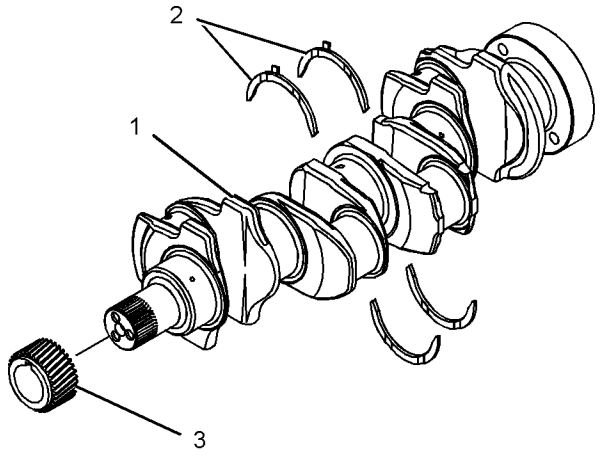
   Torque for the allen head bolts ... 16 N·m (12 lb ft)
3. When the bridge is installed on the cylinder block, apply Tooling (A) into groove (7) at each end of the bridge. Apply the sealant into the groove until the sealant is forced through the bottom end of the groove in the bridge.

Note: The oil pan must be installed within 10 minutes of applying the sealant.

Total height of the cylinder block between the top and the bottom faces. ..... 441.173 to 441.274 mm (17.3689 to 17.3729 inch)

i02663072

Crankshaft



g01338264

Illustration 47
Typical example

(1) Crankshaft

The maximum end play of the crankshaft ... 0.51 mm (0.0201 inch)

(2) Thrust washers

Standard thickness ..... 2.26 to 2.31 mm (0.089 to 0.091 inch)

Oversize thickness ..... 2.45 to 2.50 mm (0.097 to 0.098 inch)

(3) The crankshaft gear

Maximum permissible temperature of the gear for installation on the crankshaft ..... 180 °C (356 °F)

Note: The timing mark is toward the outside of the crankshaft when the gear is installed on the crankshaft.

Note: All new turbocharged engines and turbocharged aftercooled engines have crankshafts that are nitrocarburised. The crankshaft can also be nitrided for 20 hours, if the nitrocarburised process is not available. After a crankshaft has been machined, the crankshaft must be rehardened. Inspect the crankshaft for cracks before machining and after machining. Naturally aspirated engines have induction hardened crankshafts.

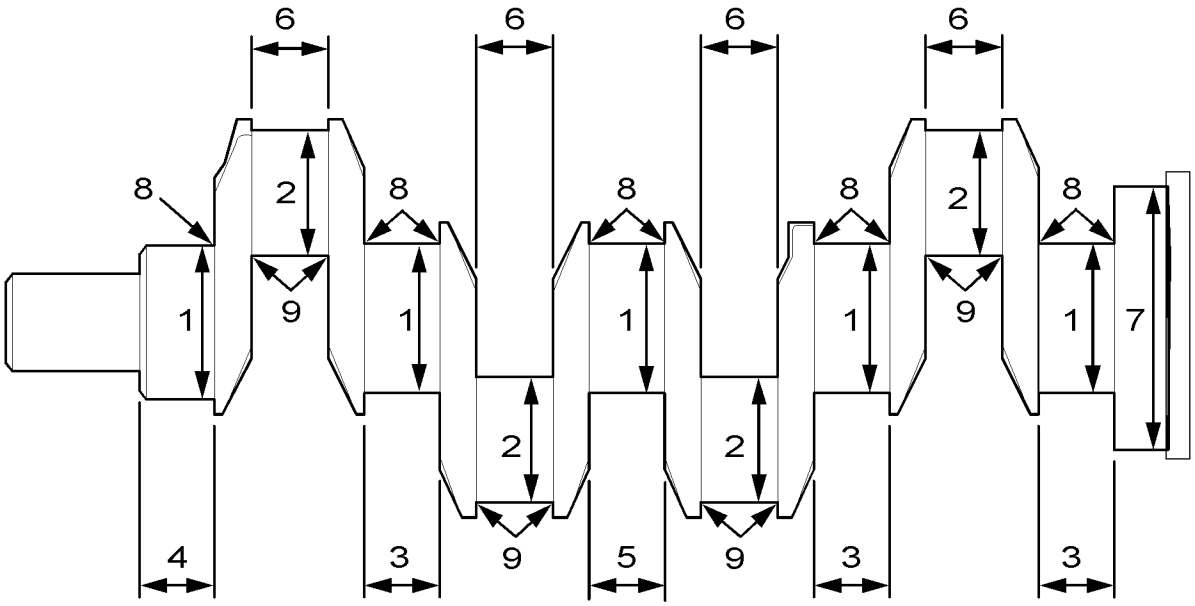


Illustration 48 g01338265

Note: Refer to illustration 48 in order to use table 11.

Table 11

The undersize diameter of the Crankshaft Journals			
NUMBER	**0.25 mm (0.010 inch)**	**0.51 mm (0.020 inch)**	**0.76 mm (0.030 inch)**
1	75.905 to 75.926 mm (2.9884 to 2.9892 inch)	75.651 to 75.672 mm (2.9784 to 2.9792 inch)	75.397 to 75.418 mm (2.9684 to 2.9692 inch)
2	63.216 to 63.236 mm (2.4888 to 2.4896 inch)	62.962 to 62.982 mm (2.4788 to 2.4796 inch)	62.708 to 62.728 mm (2.4688 to 2.4696 inch)
3	39.47 mm (1.5539 inch) maximum	N/A	N/A
4	37.44 mm (1.4740 inch) maximum	N/A	N/A
5	44.68 mm (1.7591 inch) maximum	N/A	N/A
6	40.55 mm (1.5965 inch) maximum	N/A	N/A
7	Do not machine this diameter.	N/A	N/A
8	3.68 mm (0.1449 inch) to 3.96 mm (0.1559 inch)	N/A	N/A
9	4.36 to 4.60 mm (0.1717 to 0.1811 inch)	N/A	N/A

Refer to table 12 for the maximum run out of the crankshaft journals.

Table 12

Journal	Excessive run out
(1)	Mounting
(2)	0.08 mm (0.0031 inch)
(3)	0.15 mm (0.0059 inch)
(4)	0.08 mm (0.0031 inch)
(5)	Mounting

Refer to Specifications, “Connecting Rod Bearing Journal” for more information on the connecting rod bearing journals and connecting rod bearings.

Refer to Specifications, “Main Bearing Journal” for information on the main bearing journals and for information on the main bearings.

i02658811

Crankshaft Seals

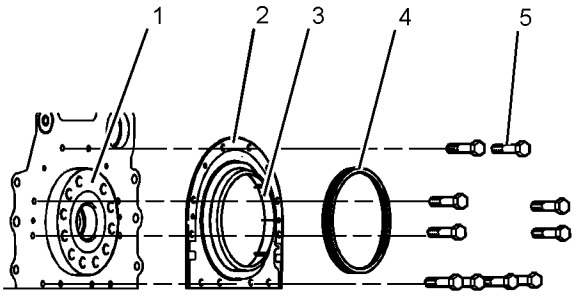


Illustration 49 g01335894

Typical example

(1) Crankshaft

(2) Crankshaft seal

(3) Plastic sleeve

(4) Alignment tool

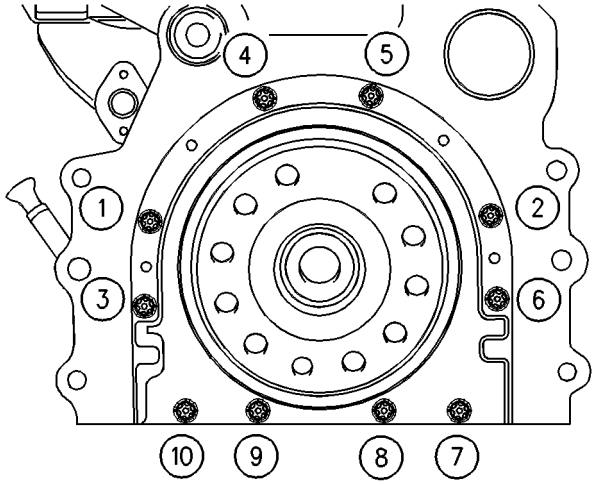


Illustration 50 g00915076

(5) Tighten bolts 1, 2, 3, 4, 5, 6, 7, and 10 in the sequence that is shown in Illustration 50 to the following torque. ..... 22 N·m (16 lb ft)

Remove the alignment tool.

Tighten bolts 8 and 9 in the sequence that is shown in Illustration 50 to the following torque. ..... 22 N·m (16 lb ft)

i02504771

Connecting Rod Bearing Journal

Refer to Specifications, “Crankshaft” for information on the undersize crankshaft journals.

The original size of the connecting rod bearing journal ... 63.47 to 63.49 mm (2.4988 to 2.4996 inch)

Maximum permissible wear of a bearing journal on a new connecting rod ..... 0.04 mm (0.0016 inch)

Width of the connecting rod bearing journals ..... 40.348 to 40.424 mm (1.5885 to 1.5915 inch)

Radius of the fillet of the connecting rod bearing journals ..... 3.68 to 3.96 mm (0.145 to 0.156 inch)

Surface finish of connecting rod bearing journals ..... Ra 0.4 microns

Surface finish of radii ..... Ra 1.3 microns

i02656267

Main Bearing Journal

Refer to Specifications, “Crankshaft” for information on the undersize main bearing journals, and information on the width of main bearing journals.

The original size of the main bearing journal ..... 76.159 to 76.180 mm (2.9984 to 2.9992 inch)

Maximum permissible wear of the main bearing journals ..... 0.040 mm (0.0016 inch)

Radius of the fillet of the main bearing journals ..... 3.68 to 3.69 mm (0.1448 to 0.1452 inch)

Surface finish of bearing journals, crank pins and radii ..... 0.4 microns (16 µ inches)

The shell for the main bearings

The shells for the main bearings are available for remachined journals which have the following undersize dimensions.

Undersize bearing shell .... 0.25 mm (0.010 inch)
Undersize bearing shell .... 0.51 mm (0.020 inch)
Undersize bearing shell .... 0.75 mm (0.030 inch)

Thickness at center of the shells .. 2.083 to 2.089 mm (0.0820 to 0.0823 inch)

Width of the main bearing shells .. 31.62 to 31.88 mm (1.244 to 1.255 inch)

Clearance between the bearing shell and the main bearing journals ..... 0.057 to 0.117 mm (0.0022 to 0.0046 inch)

i02662161

Connecting Rod

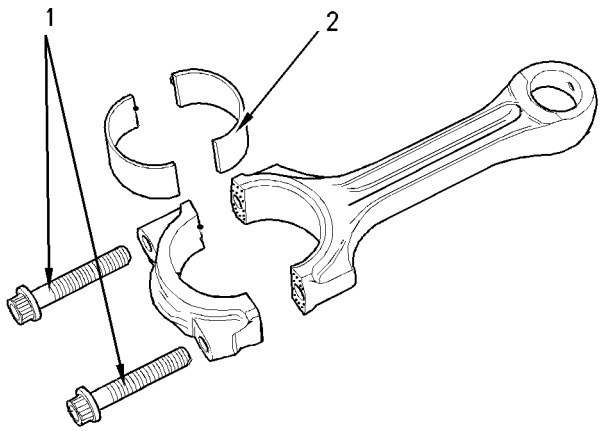


Illustration 51 g00907738

The mating surfaces of the connecting rod are produced by hydraulically fracturing the forged connecting rod.

(1) Tighten the torx screws for the connecting rod to the following torque. ..... 18 N·m (13 lb ft)

Tighten the torx screws for the connecting rod again to the following torque. ..... 70 N·m (52 lb ft)

Tighten the torx screws for the connecting rod for an additional 120 degrees. The torx screws for the connecting rod (1) must be replaced after this procedure.

Note: Always tighten the connecting rod cap to the connecting rod, when the assembly is out of the engine. Tighten the assembly to the following torque 20 N·m (14 lb ft).

(2) The bearing shell for the connecting rod

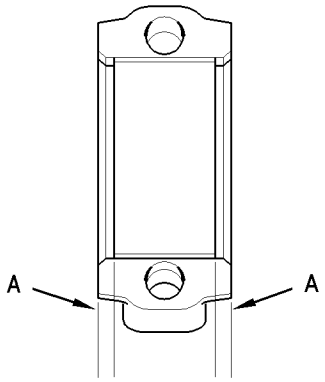


Illustration 52 g00995584

Alignment of the bearing shell

Note: The bearing shell for the connecting rod must be aligned equally from both ends of the connecting rod. Refer to (A) in figure 52. Refer to Disassembly and Assembly for information on the alignment tool.

Table 13

Bearing Width for the Connecting Rod	31.62 to 31.88 mm (1.245 to 1.255 inch)
Bearing Width for the Connecting Rod Cap	31.62 to 31.88 mm (1.2449 to 1.2551 inch)
Thickness of Connecting Rod Bearing at the Center	1.835 to 1.842 mm (0.0723 to 0.0725 inch)
Thickness of Connecting Rod Bearing for the Cap at the Center	1.835 to 1.842 mm (0.0722 to 0.0725 inch)
Bearing Clearance	0.034 to 0.081 mm (0.0013 to 0.0032 inch)

Table 14

Undersized Connecting Rod Bearing
0.25 mm (0.010 inch)
0.51 mm (0.020 inch)
0.76 mm (0.030 inch)

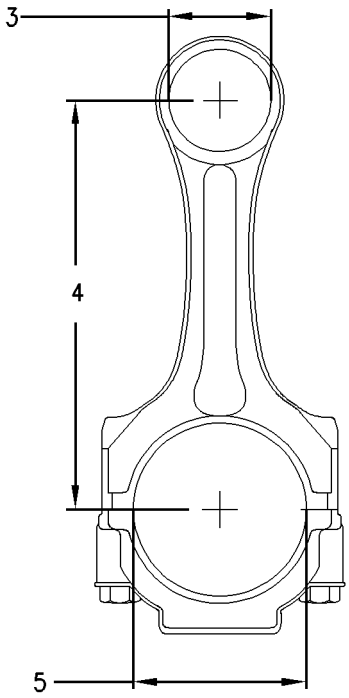


Illustration 53 g00907744

(3) Inside diameter of the small bush ..... 39.723 to 39.738 mm (1.5639 to 1.5645 inch)

(4) Distance between the parent bores ..... 219.05 to 219.10 mm (8.624 to 8.626 inch)

(5) Diameter for the parent bore for the connecting rod bearing ..... 67.21 to 67.22 mm (2.6460 to 2.6465 inch)

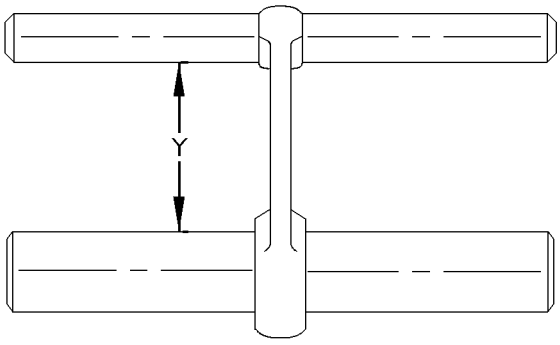


Illustration 54 g00915056

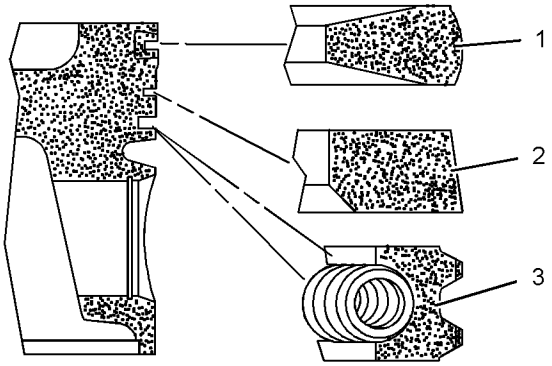
Connecting rods are color coded. The color code is a reference for the length (Y) of the connecting rod. Refer to table 15 for the different lengths of connecting rods.

Table 15

Length Grades for Connecting Rods		
Grade Letter	**Color Code**	**Length (Y)**
F	Red	165.728 to 165.761 mm (6.5247 to 6.5260 inch)
G	Orange	165.682 to 165.715 mm (6.5229 to 6.5242 inch)
H	White	165.637 to 165.670 mm (6.5211 to 6.5224 inch)
J	Green	165.591 to 165.624 mm (6.5193 to 6.5206 inch)
K	Purple	165.545 to 165.578 mm (6.5175 to 6.5188 inch)
L	Blue	165.499 to 165.532 mm (6.5157 to 6.4961 inch)

i02662142

Piston and Rings



g01363510

Illustration 55

Typical example

(1) Top compression ring

Naturally Aspirated

The shape of the top compression ring ..... Rectangular with a barrel face

Width of the top compression ring ..... 2.47 to 2.49 mm (0.0972 to 0.0980 inch)

Clearance between the top compression ring and the piston groove ..... 0.09 to 0.13 mm (0.0035 to 0.0051 inch)

Ring gap ..... 0.30 to 0.55 mm (0.0118 to 0.0217 inch)

Turbocharged

The shape of the top compression ring ..... Keystone with a barrel face

Width of the top compression ring ..... tapered

Ring gap ..... 0.30 to 0.45 mm (0.0118 to 0.0177 inch)

Note: When you install a new top compression ring, make sure that the word “TOP” is facing the top of the piston. New top piston rings for naturally aspirated engines have a red identification mark which must be on the left of the ring end gap when the top piston ring is installed on an upright piston. New top piston rings for turbocharged engines have a yellow identification mark which must be on the left of the ring end gap when the top piston ring is installed on an upright piston.

(2) Intermediate compression ring

The shape of the intermediate compression ring ..... Internal chamfer in the bottom edge with a tapered face

Width of intermediate compression ring for naturally aspirated engines ..... 2.47 to 2.49 mm (0.097 to 0.098 inch)

Width of intermediate compression ring for turbocharged engines ..... 2.470 to 2.495 mm (0.0972 to 0.0982 inch)

Clearance between the intermediate compression ring and the piston groove for naturally aspirated engines ... 0.05 to 0.09 mm (0.002 to 0.003 inch)

Clearance between the intermediate compression ring and the piston groove for turbocharged engines ..... 0.065 to 0.110 mm (0.0026 to 0.0043 inch)

Ring gap for naturally aspirated engines ..... 0.70 to 0.95 mm (0.0275 to 0.0374 inch)

Ring gap for turbocharged engines ..... 0.65 to 0.85 mm (0.0256 to 0.0335 inch)

Note: When you install a new intermediate compression ring, make sure that the word “TOP” is facing the top of the piston. New intermediate rings for naturally aspirated engines have a green identification mark which must be on the left of the ring end gap when the top piston ring is installed on an upright piston. New intermediate rings for turbocharged engines have a blue identification mark which must be on the left of the ring end gap when the top piston ring is installed on an upright piston.

(3) Oil control ring

Shape of oil control ring ..... a two-piece coil that is spring loaded

Width of oil control ring for naturally aspirated engines ..... 3.47 to 3.49 mm (0.1366 to 0.1374 inch)
Width of oil control ring for turbocharged engines ..... 2.97 to 2.99 mm (0.1169 to 0.1177 inch)

Clearance between the oil control ring and the groove in the piston for naturally aspirated engines ..... 0.03 to 0.07 mm (0.0011 to 0.0027 inch)
Ring gap ..... 0.30 to 0.55 mm (0.0118 to 0.0216 inch)

Note: A pin is used in order to hold both ends of the spring of the oil control ring in position. The ends of the spring of the oil control ring must be installed opposite the end gap of the oil control ring.

Note: Ensure that the ring end gaps of the piston rings are spaced 120 degrees from each other.

Piston

Note: An arrow which is marked on the piston crown must be toward the front of the engine.

The combustion bowl re-entrant angle for the turbocharged engine ..... 72 degrees

The combustion bowl re-entrant angle for the naturally aspirated engine ..... 70 degrees

Piston height above cylinder block .. 0.21 to 0.35 mm (0.008 to 0.014 inch)

Width of top groove in piston for the naturally aspirated engine ..... 2.58 to 2.60 mm (0.1016 to 0.1024 inch)

Width of top groove in piston for the turbocharged engine ..... Tapered

Width of second groove in piston for naturally aspirated engines ..... 2.54 to 2.56 mm (0.1000 to 0.1008 inch)

Width of second groove in piston for turbocharged engines ..... 2.56 to 2.58 mm (0.1008 to 0.1016 inch)

Width of third groove in piston for naturally aspirated engines ..... 3.52 to 3.54 mm (0.1386 to 0.1394 inch)

Width of third groove in piston for turbocharged engines ..... 3.02 to 3.04 mm (0.1189 to 0.1197 inch)

Piston pin

Diameter of a new piston pin ..... 39.694 to 39.700 mm (1.5628 to 1.5630 inch)

Diameter of the bore for the piston pin ..... 39.703 to 39.709 mm (1.5631 to 1.5633 inch)

i02665602

Piston Cooling Jet

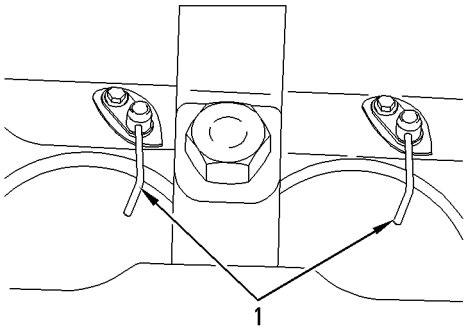


Illustration 56 g00942652

(1) Installed piston cooling jets

The valve must move freely. Tighten the bolt to the following torque. ..... 9 N·m (7 lb ft)

Piston Cooling Jet Alignment

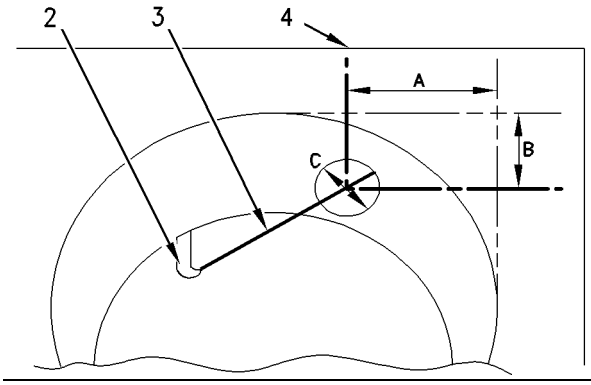


Illustration 57 g01006929

(2) Piston cooling jet
(3) Rod
(4) Cylinder block

Use the following procedure in order to check the alignment of the piston cooling jet.

1. Insert rod (3) into the end of the piston cooling jet (2). Rod (3) has a diameter of 1.70 mm (0.067 inch). Rod (3) must protrude out of the top of the cylinder block.

2. Dimension (A) is 50.75 mm (1.9980 inch) and dimension (B) is 9.35 mm (0.3681 inch). Dimension (A) and dimension (B) are tangential to the cylinder bore (4).

3. The position of the rod (3) must be within dimension (C). Dimension (C) is 10 mm (0.3937 inch).

Note: Ensure that the rod (3) can not damage the piston cooling jet when the alignment is checked. The piston cooling jets can not be adjusted. If a piston cooling jet is not in alignment the piston cooling jet must be replaced.

i02662168

Front Housing and Covers

The front housing must be aligned to the cylinder block face. ..... + 0.05 to minus 0.05 mm (+ 0.0020 to minus 0.0020 inch)

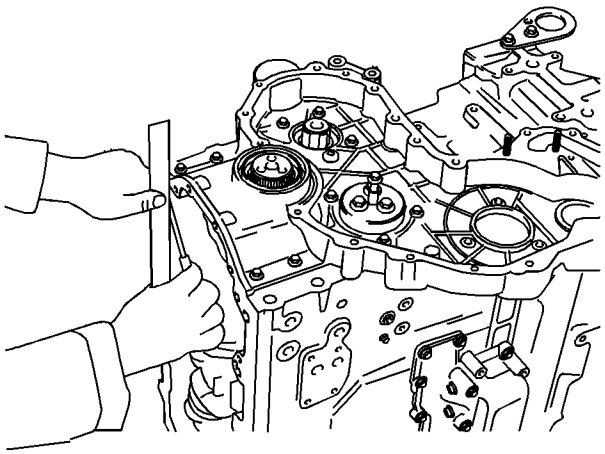


Illustration 58 g01337594
Alignment

(1) Tighten the bolts that fasten the front cover to the front housing to the following torque. ..... 22 N·m (16 lb ft)

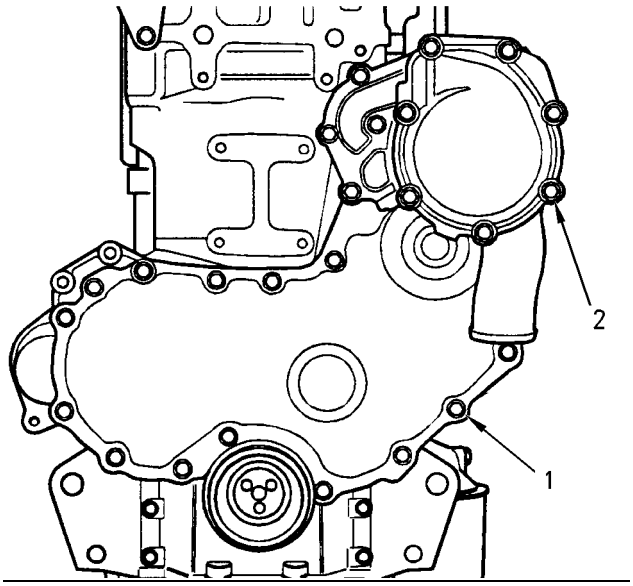


Illustration 59 g00918672
Front cover

(2) Tighten the bolts that fasten the water pump to the front housing to the following torque. ..... 22 N·m (16 lb ft)

Note: Refer to Specifications, “Water Pump” for the correct bolt tightening sequence for the water pump.

i02662183

Gear Group (Front)

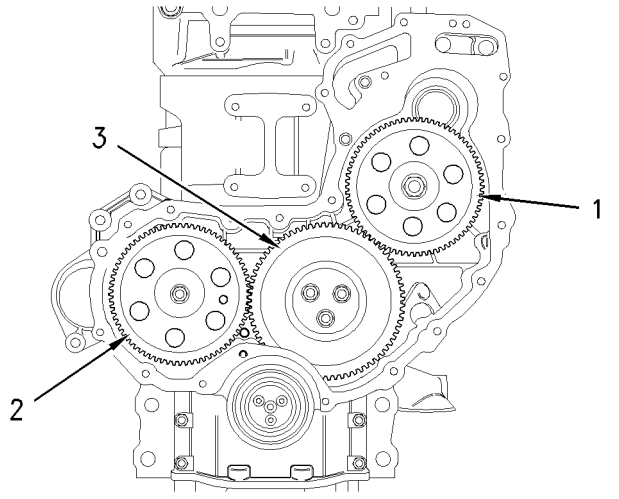


Illustration 60 g00995886
Gear train

(1) Fuel injection pump drive gear

Tighten the nut to the following torque. ... 24 N·m (18 lb ft)
Release the lock on the fuel injection pump shaft.
Torque the nut to the following torque. .... 90 N·m (66 lb ft)

Number of teeth 68

Note: Refer to Specifications, “Fuel Injection Pump” for the locking torque for the fuel injection pump shaft.

(2) Camshaft gear

Tighten the bolt for the camshaft gear to the following torque. ..... 95 N·m (70 lb ft)

Bore diameter of the camshaft gear ..... 34.93 to 34.95 mm (1.3750 to 1.3760 inch)

Outside diameter of the camshaft hub .. 34.90 to 34.92 mm (1.3741 to 1.3747 inch)

Clearance between the camshaft gear and the camshaft hub ..... 0.003 to 0.048 mm (0.0001 to 0.0019 inch)

Number of teeth 68

(3) Idler gear and hub

Tighten the bolts for the idler gear to the following torque. ..... 44 N·m (33 lb ft)

Bore diameter of the idler gear ..... 57.14 to 57.18 mm (2.2495 to 2.2512 inch)
Bore diameter of the idler gear with roller bearings ..... 72.35 to 72.36 mm (2.8484 to 2.8488 inch)

Width of idler gear and split bearing assembly ..... 30.14 to 30.16 mm (1.186 to 1.187 inch)

Inside diameter of idler gear bearings with flanges ..... 50.78 to 50.80 mm (1.999 to 2.000 inch)

Outside diameter of idler gear hub .. 50.70 to 50.74 mm (1.9961 to 1.9976 inch)
Outside diameter of idler gear hub with roller bearings ..... 49.975 to 49.988 mm (1.9675 to 1.9680 inch)

Clearance of idler gear bearing on hub ..... 0.04 to 0.10 mm (0.0016 to 0.0039 inch)

Idler gear end play ..... 0.10 to 0.20 mm (0.004 to 0.008 inch)

Idler gear end play with roller bearings ..... 0.10 to 0.75 mm (0.0039 to 0.0295 inch)

Maximum permissible end play ..... 0.38 mm (0.015 inch)

Number of teeth 73

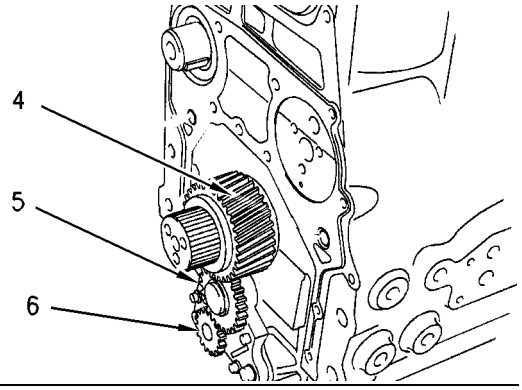


Illustration 61 g00996214
The gear train for the oil pump

(4) Crankshaft gear

Bore diameter of crankshaft gear .... 47.625 to 47.650 mm (1.8750 to 1.8760 inch)

Outside diameter of crankshaft hub ..... 47.625 to 47.645 mm (1.8750 to 1.8758 inch)

Clearance of gear on crankshaft ..... −0.020 to +0.020 mm (−0.0008 to +0.0008 inch)

Number of teeth 34

(5) Oil pump idler gear

Inside diameter of oil pump idler gear bearing ..... 16.012 to 16.038 mm (0.6304 to 0.6314 inch)

Outside diameter of oil pump idler gear shaft ..... 15.966 to 15.984 mm (0.6286 to 0.6293 inch)

Clearance of oil pump idler gear bearing on shaft ..... 0.028 to 0.072 mm (0.0011 to 0.0028 inch)

End play of the oil pump idler gear ..... 0.050 to 0.275 mm (0.0019 to 0.0108 inch)

(6) Oil pump gear

The number of teeth on the oil pump gear 17

Backlash values

Backlash between the idler gear (5) and the oil pump drive gear (6) ..... 0.046 to 0.106 mm (0.0018 to 0.0041 inch)

Backlash between the oil pump idler gear (5) and the crankshaft gear (4) ..... 0.095 to 0.160 mm (0.0037 to 0.0063 inch)

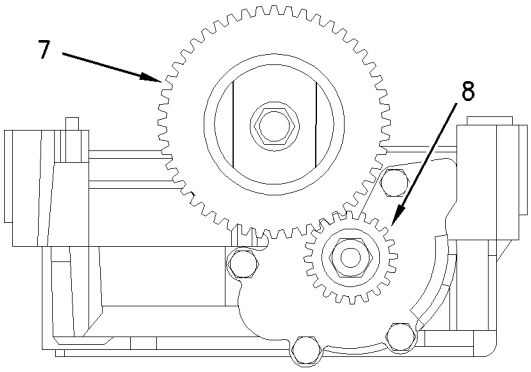
Backlash between the idler gear (3) and the crankshaft gear (4) ..... 0.064 to 0.124 mm (0.0025 to 0.0049 inch)

Backlash between the camshaft gear (2) and the idler gear (3) ..... 0.052 to 0.107 mm (0.0020 to 0.0042 inch)

Backlash between the fuel injection pump gear (1) and the idler gear (3) ..... 0.054 to 0.109 mm (0.0021 to 0.0043 inch)

Backlash between the water pump gear (not shown) and the fuel injection pump gear (1) ... 0.073 to 0.133 mm (0.0028 to 0.0052 inch)
Backlash between the power take-off drive (if equipped) and the idler gear (3) .... 0.112 to 0.172 mm (0.0044 to 0.0068 inch)

Engines that have a Balancer



g00996003

Illustration 62

Balancer gears

(7) Idler gear for the oil pump that has a balancer

The number of teeth on the gear 44
The bore diameter of the idler gear ..... 37.197 to 37.212 mm (1.4644 to 1.4650 inch)
The hub diameter for the idler gear ..... 37.152 to 37.162 mm (1.4627 to 1.4631 inch)
The end play for the idler gear .. 0.12 to 0.27 mm (0.0047 to 0.0106 inch)

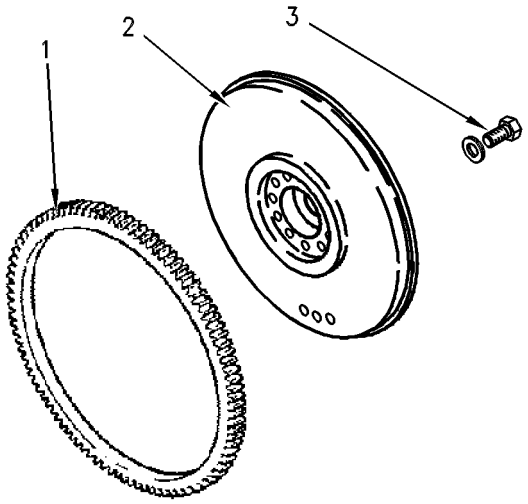
(8) Gear for the oil pump that has a balancer

The number of teeth on the gear 17

Backlash between the oil pump gear (8) and the idler gear (7) ... 0.097 to 0.17 mm (0.0038 to 0.0067 inch)

i02503254

Flywheel



g00584712

Illustration 63

Typical example

(1) Flywheel ring gear

Heat the flywheel ring gear to the following temperature. ..... 250 °C (480 °F)

Note: Do not use an oxyacetylene torch to heat the flywheel ring gear.

(2) Flywheel

(3) Bolt

Tighten the flywheel bolts to the following torque. ..... 115 N·m (85 lb ft)

i02663068

Flywheel Housing

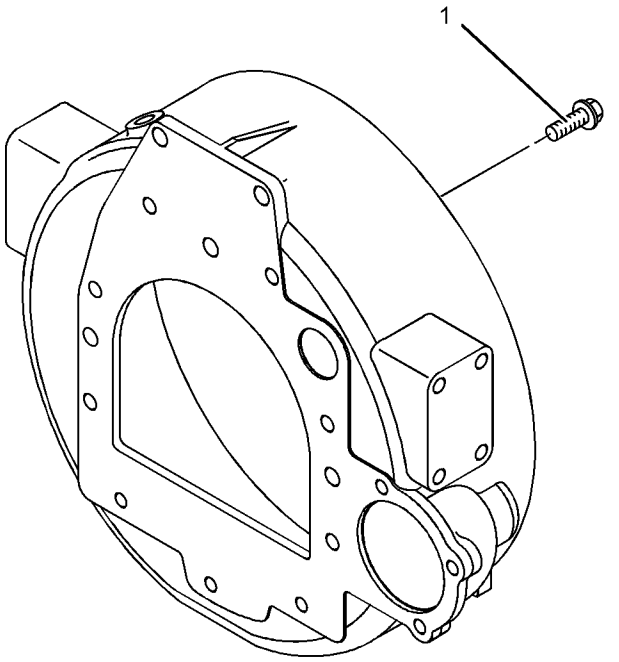


Illustration 64 g01338247

Typical example

(1) Bolt

Tighten the bolts for the cast iron flywheel housing to the following torque:

M10 “8.8” ..... 44 N·m (33 lb ft)
M10 “10.9” ..... 63 N·m (47 lb ft)
M12 “8.8” ..... 75 N·m (55 lb ft)
M12 “10.9” ..... 115 N·m (85 lb ft)

i02662798

Crankshaft Pulley

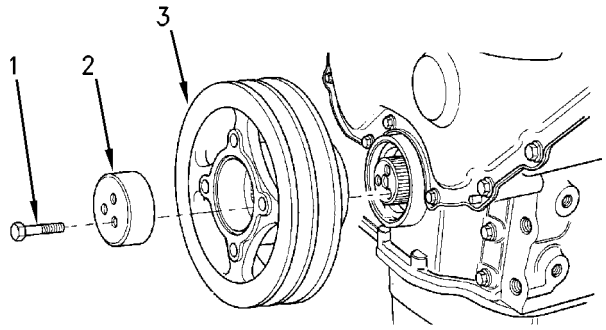


Illustration 65 g00915497

A standard pulley

(1) Tighten the three bolts for the crankshaft pulley to the following torque. ..... 115 N·m (85 lb ft)

Note: Recheck the torque of the bolts (1) once.

(2) Thrust block

Note: The chamfers on the bolt holes must face toward the front of the engine.

(3) Crankshaft pulley

Crankshaft Pulley for the Poly V-Belt

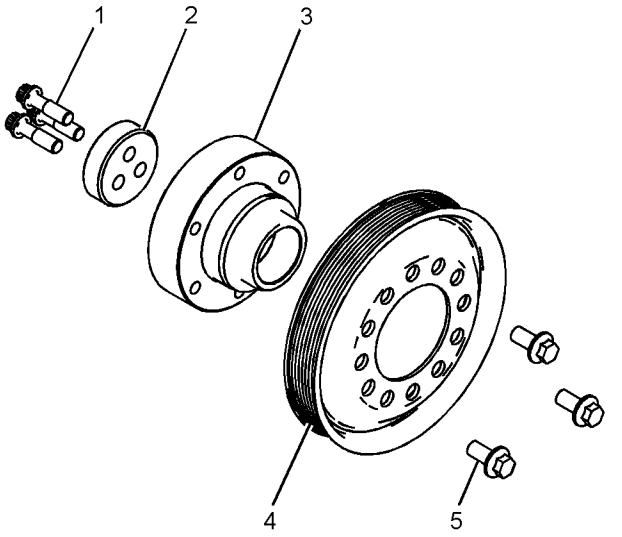


Illustration 66 g01337951

Typical example

(1) Bolt
(2) Thrust block
(3) Crankshaft adapter
(4) Crankshaft pulley
(5) Bolt

(1) Tighten the three bolts for the thrust block to the following torque. ..... 115 N·m (85 lb ft)

Note: Recheck the torque of the bolts (1) once.

Note: The chamfers on the bolt holes must face toward the front of the engine.

(5) Tighten the three bolts for the crankshaft pulley to the following torque. ..... 78 N·m (58 lb ft)

Non - Standard Pulley

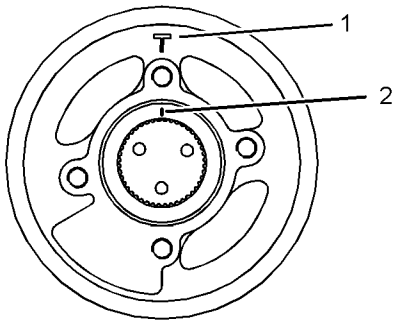


Illustration 67 g01337945

(1) T Mark
(2) Alignment mark

Note: The marks (1 and 2) on the pulley must be vertical when the pulley is installed on the engine. Number one piston of the engine must be at top dead center.

i02663070

Fan Drive

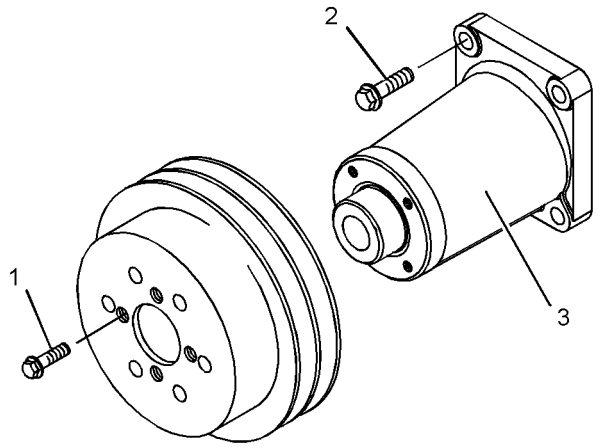


Illustration 68 g01338248

Typical example

(1) Tighten the bolts to the following torque. .. 22 N·m (16 lb ft)

Fan drive housing

Tighten the bolts (2) that secure the fan drive housing (3) to the cylinder head to the following torque. ..... 44 N·m (32 lb ft)

Maximum permissible end play of the shaft .. 0.20 mm (0.0079 inch)

i01721280

Engine Lifting Bracket

All engines are equipped with two engine lifting brackets.

Tighten the two bolts on each engine lifting bracket to the following torque. .. 44 N·m (32 lb ft)

i02656398

Alternator

The 12 Volt and 24 Volt Denso Alternators

Three types of alternator are available.

Output

Two 12 volt alternators are available. ..... 100 Amp and 120 Amp
One 24 volt alternator ..... 80 Amp

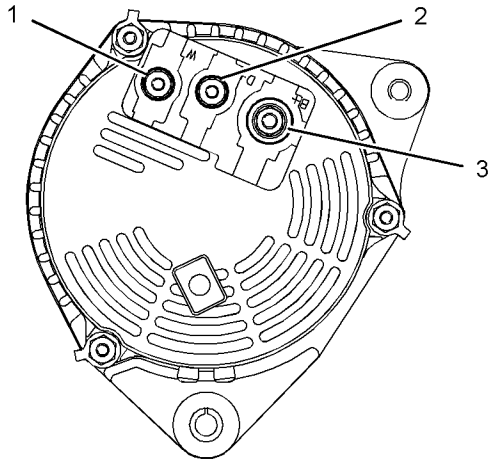


Illustration 69 g01332517
Typical example

(1) Terminal “W”

Tighten the terminal nut to the following torque. ..... 3.7 N·m (33 lb in)

(2) Terminal “D+”

Tighten the terminal nut to the following torque. ..... 3.7 N·m (33 lb in)

(3) Terminal “B+”

Tighten the terminal nut to the following torque. ..... 7 N·m (62 lb in)

The 12 Volt and 24 Volt Iskra Alternator

12 volt output

Two alternators are available. ..... 150 Amp and 175 Amp

24 volt output

The 24 volt alternator ..... 100 Amp

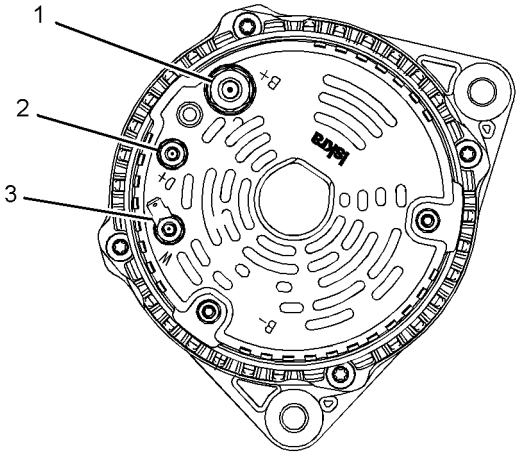


Illustration 70 g01332519
Typical example

(1) Terminal “B+”

Tighten the terminal nut to the following torque. ..... 11 N·m (97 lb in)

(2) Terminal “D+”

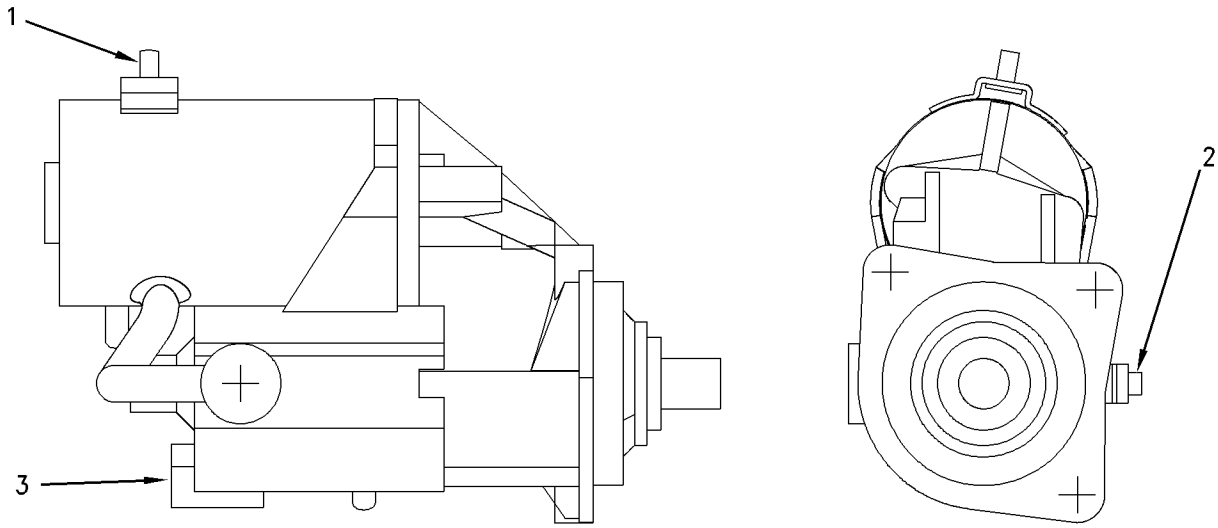
Tighten the terminal nut to the following torque. ..... 3 N·m (26 lb in)

(3) The terminal “W” is spade-type.

i02656404

Starter Motor

24 Volt Starting Motor



g00974968

Illustration 71

The 24 volt starting motor which shows the electrical connections

(1) Tighten the negative terminal nut to the following torque. ..... 16 N·m (12 lb ft)

(2) Tighten the positive terminal nut to the following torque. ..... 21 N·m (15 lb ft)

(3) Tighten the solenoid terminal to the following torque. ..... 3.6 N·m (32 lb in)

Rated voltage ..... 24 volts

12 Volt Starting Motor

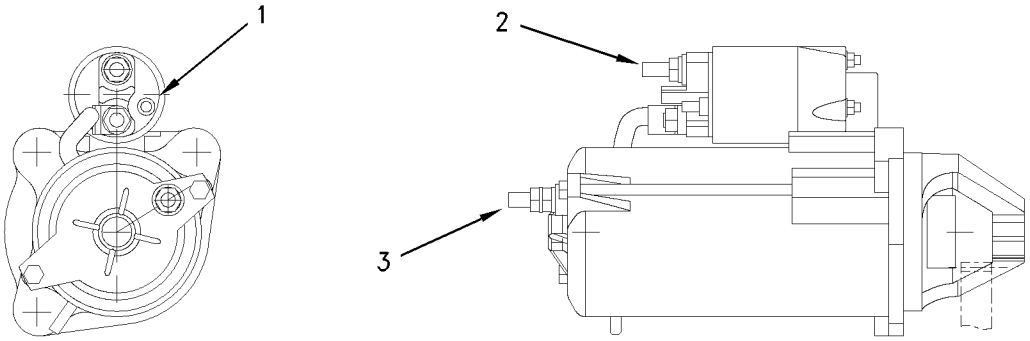


Illustration 72 g00977365

The 12 volt starting motor which shows the electrical connections

(1) Tighten the solenoid terminal to the following torque. ..... 8 N·m (70 lb in)

(2) Tighten the positive terminal nut to the following torque. ..... 6 N·m (53 lb in)

(3) Tighten the negative terminal nut to the following torque. ..... 8 N·m (70 lb in)

Rated voltage ..... 12 volts

i02656374

Glow Plugs

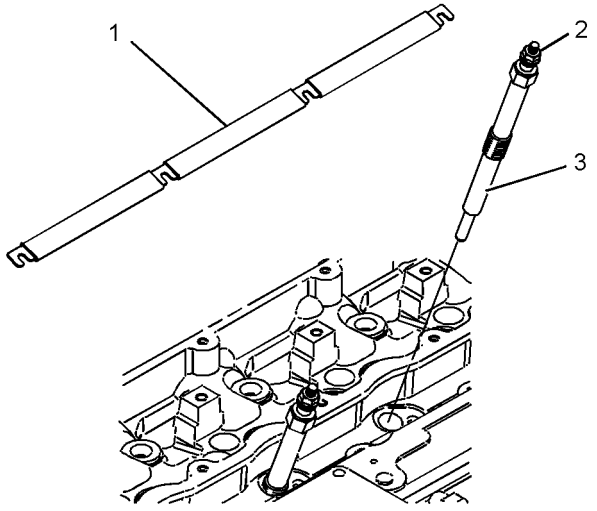


Illustration 73 g01334536

Typical example

(1) Tighten the glow plugs (3) in the cylinder head to the following torque. ..... 15 N·m (11 lb ft)

Tighten the nuts (2) for the bus bar (1) that is installed on top of the glow plugs to the following torque. ..... 2 N·m (18 lb in)

Voltage ..... 12 or 24 volts

Note: Glow plugs are not installed on all engines. Engines that do not have glow plugs are installed with threaded plugs.

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Printed in U. K.

Systems Operation Testing and Adjusting

1104D (Mech) Industrial Engine

NK (Engine)
NL (Engine)
NM (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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Systems Operation Section

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Engine Design

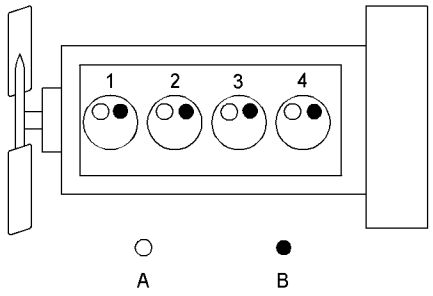

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Illustration 1

Typical example of the layout of the valves

(A) Inlet valve
(B) Exhaust valve

1104D Engine Specification

Industrial

Type ..... Four cylinder and four stroke

Type of combustion ..... Direct injection

Bore ..... 105 mm (4.134 inch)

Stroke ..... 127 mm (5.00 inch)

Displacement ..... 4.4 L (268 in^3)

Compression ratio

Naturally aspirated 19.3:1

Turbocharged 18.2:1

Turbocharged, aftercooled 18.2:1

Number of cylinders 4

Cylinder arrangement ..... In-line

Firing order 1, 3, 4, 2

The front of the engine is opposite the flywheel end of the engine. The left side of the engine and the right side of the engine are determined from the flywheel end. Number 1 cylinder is the front cylinder of the engine.

i02680006

General Information

Engine Description

Note: When you are ordering new parts, refer to the engine identification number in order to receive the correct parts. Refer to the Operation and Maintenance Manual, “Product Identification Information” for the correct numbers for your engine.

The engine cylinders are arranged in-line. The engines are controlled by a mechanically governed fuel injection pump.

The cylinder head assembly has one inlet valve and one exhaust valve for each cylinder. Each valve has one valve spring. The pistons have two compression rings and an oil control ring.

It is important to ensure the correct piston height so that the piston does not contact the cylinder head. The correct piston height also ensures the efficient combustion of fuel.

The 1104D engine crankshaft has five main journals. End play is controlled by thrust washers that are located on both sides of the center main bearing.

The timing case has a hole that corresponds with a hole in the crankshaft. Use an alignment pin to find TC. The camshaft gear has a timing hole that corresponds with a timing hole in the timing case. The timing holes ensure that the camshaft and the crankshaft are in time with each other.

The crankshaft gear rotates the idler gear. The idler gear rotates the camshaft gear and the fuel injection pump gear. The idler gear for the engine oil pump is rotated by the crankshaft gear. This idler rotates the engine oil pump.

The fuel injection pump is a gear-driven pump that is mounted to the back of the front housing. The fuel transfer pump is electrically operated. The fuel transfer pump has an integral fuel filter. The fuel transfer pump is usually located on the left hand side of the cylinder block. Some applications may have the fuel transfer pump and the water separator (if equipped) relocated off the engine.

The oil pump is driven by an idler gear. The engine oil pump sends lubricating oil to the main oil gallery. The oil relief valve is internal to the oil pump.

Coolant from the bottom of the radiator passes through the water pump. The water pump is driven by the idler gear.

Lifting the Engine

NOTICE
Failure to follow recommended procedures for handling or transporting engines can lead to engine damage.

To avoid possible engine damage, use the following procedure.

When you are lifting or moving the engine, use the following procedures in order to prevent engine damage.

1. Do not tilt the engine to an extreme angle unless the lubricating oil is first drained from the oil pan.

2. Do not turn the engine onto a side or an end surface unless the lubricating oil is first drained from the oil pan.

3. If the oil is not drained prior to tilting the engine or turning the engine onto a side or an end surface, the lubricating oil from the oil pan can flow into the intake manifold and the cylinder bores. This situation could cause a hydraulic lock in the engine. Hydraulic lock can severely damage the engine.

4. The engine oil should be refilled to the correct level before the engine is started.

1104D Engine Model Views

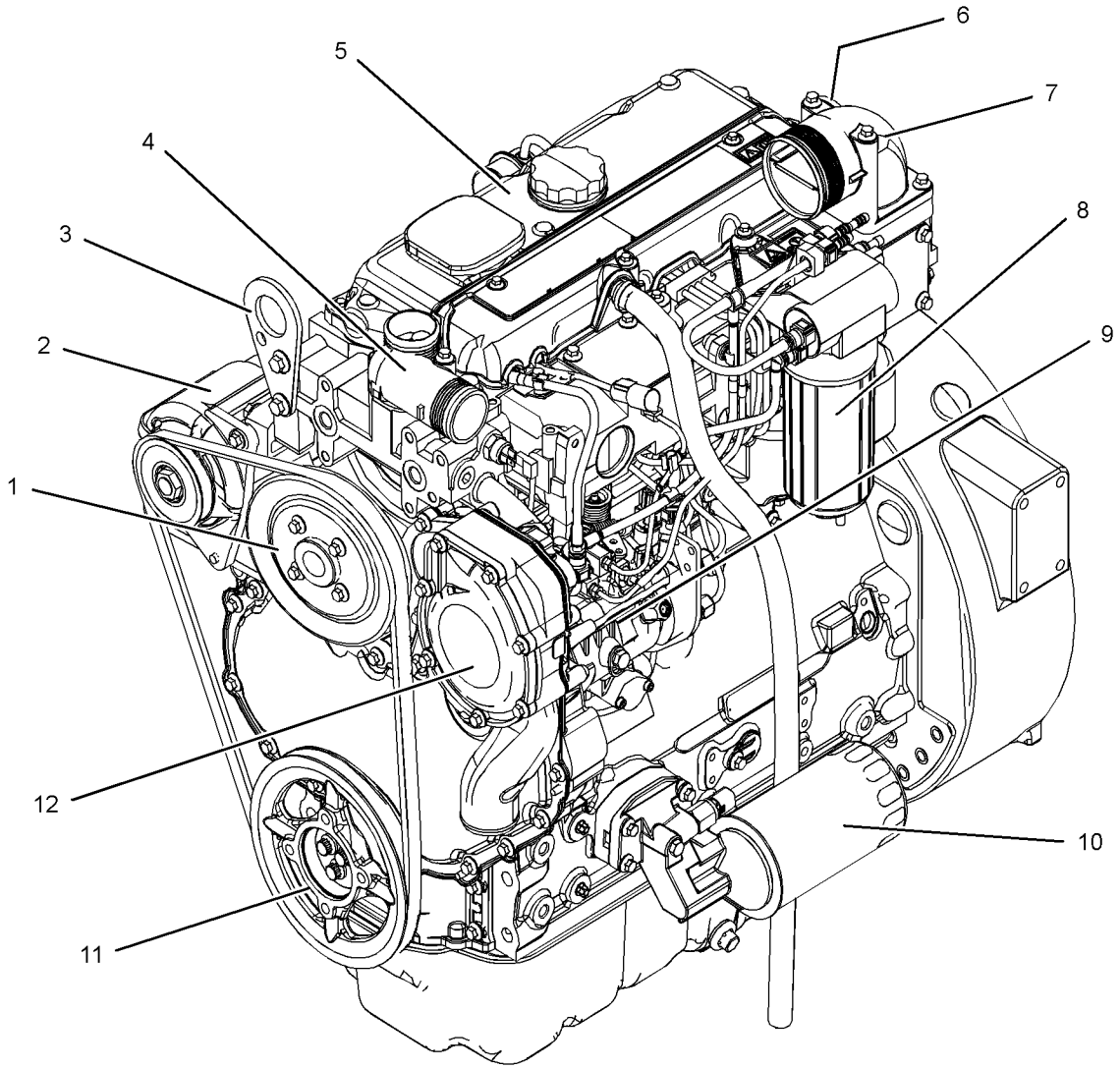

Illustration 2 g01351713

(1) Pulley
(2) Alternator
(3) Front Lifting Eye
(4) Water Outlet
(5) Valve Mechanism Cover
(6) Rear Lifting Eye
(7) Air Intake
(8) Secondary Fuel Filter
(9) Fuel Injection Pump
(10) Oil Filter
(11) Crankshaft Pulley
(12) Water Pump

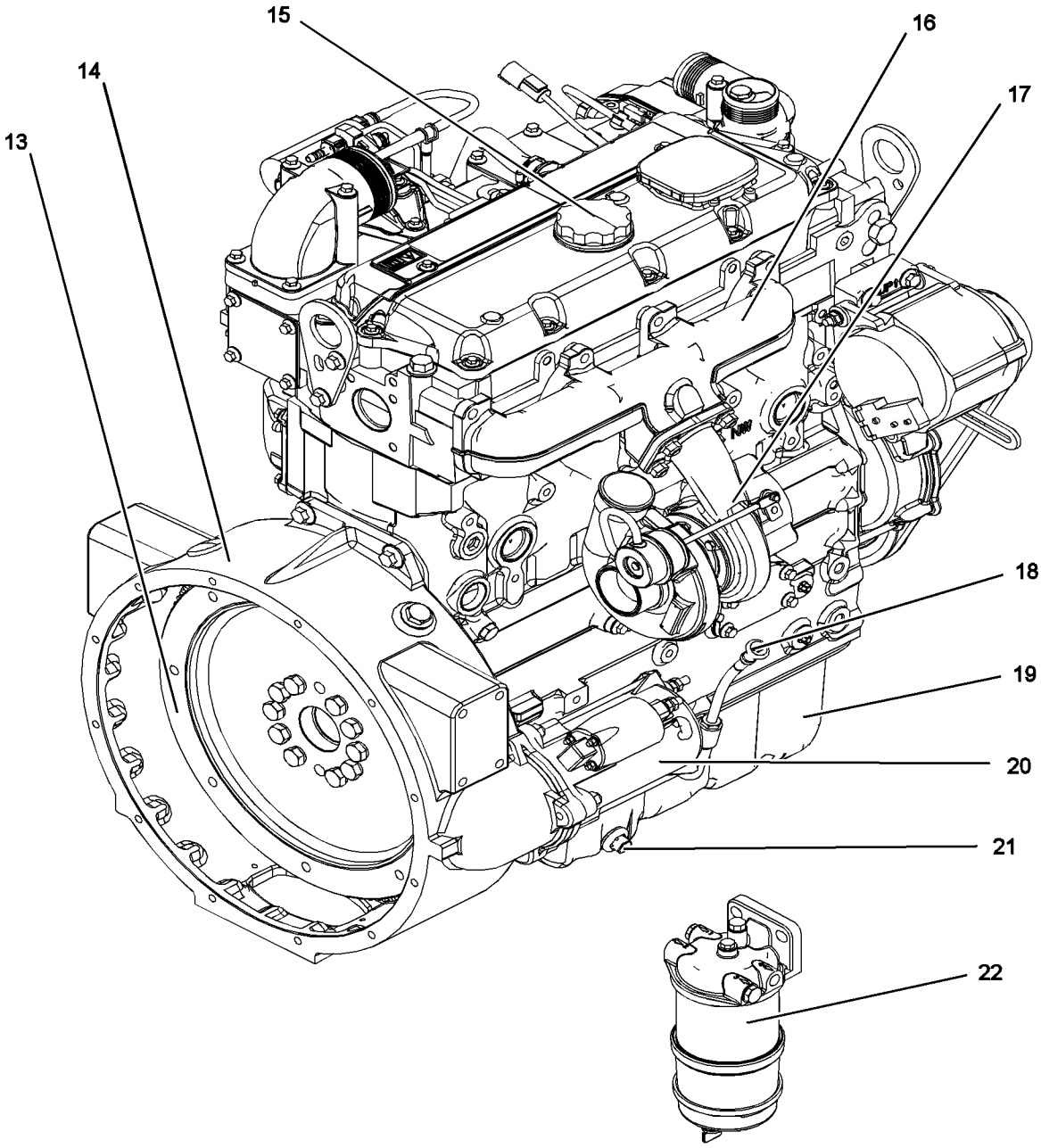

Illustration 3 g01352705

(13) Flywheel
(14) Flywheel Housing
(15) Oil Filler Cap
(16) Exhaust Manifold
(17) Turbocharger
(18) Oil Gauge
(19) Oil Pan
(20) Starting motor
(21) Oil Drain Plug
(22) Primary Fuel Filter

i02680048

Fuel System

The Delphi DP310 fuel injection pump is installed on the 1104D engine.

The fuel transfer pump draws fuel from the fuel tank and through the water separator. When the fuel goes through the water separator, any water in the fuel will go to the bottom of the bowl. The fuel transfer pump sends the fuel at a low pressure to the fuel filter. From the fuel filter, the fuel goes through the supply line to the fuel injection pump.

The fuel injection pump sends fuel through the high pressure fuel line to each of the fuel injectors. The fuel injector sprays the fuel into the cylinder. Fuel that is not injected flows through the fuel return line to the top of the fuel filter, back to the fuel tank.

The engine must not be started until the fuel injection pump is full of fuel that is free of air. The fuel injection pump requires fuel for lubrication. The precision parts of the pump are easily damaged without lubrication.

The fuel system must be primed when any of the following conditions occur:

- The fuel filter is changed.
- The fuel line is removed.
- The fuel injection pump is removed.

Fuel System Components

Fuel Injection Pump

General Operation

The fuel injection pump is a pressurized system that is totally enclosed. The pump sends the correct amount of fuel under high pressure at the correct time through the fuel injectors to the individual cylinders. The fuel injection pump regulates the amount of fuel that is delivered to the fuel injectors. This action controls the engine rpm by the governor setting or the position of the throttle control.

The fuel lines to the fuel injectors are equal lengths. This ensures even pressure and correct injection timing at each fuel injector.

During operation, extra fuel is used as coolant and lubricant for moving parts of the pump. The extra fuel is circulated through the pump housing. The extra fuel is then returned to the fuel tank.

The Delphi DP310 fuel injection pump must be serviced by an authorized Delphi technician. For repair information, contact your Perkins dealer or contact your Perkins distributor.

High idle and low idle of the fuel injection pump are factory set. Idle adjustments can not be made to the fuel pump. The Delphi DP310 fuel injection pump has a boost control. The Delphi DP310 fuel injection pump has an engine stop solenoid and a feature that vents air from the pump.

The Delphi DP310 fuel injection pump has a cold starting aid. The cold starting aid advances the timing of the pump when the engine is cold. The cold starting aid is electrically operated.

Cold Start Advance Unit

The cold start advance unit holds the timing of the fuel injection pump in an advance position when the engine is cold.

The coolant switch for the cold start advance unit is on the water temperature regulator housing on the left side of the engine.

When the engine is cold, the sender unit is energized in order to advance the fuel injection pump timing for the cold start operation. When the correct temperature is achieved the sender unit is de-energized and the fuel injection pump timing is returned to the normal operating position.

If the switch fails in the closed position, the engine will run with advanced fuel injection timing. The engine will have higher cylinder pressure and engine damage may result.

If the switch fails in the open position the engine will run with the fuel injection timing in the normal operating position. The engine will be more difficult to start. When the engine is cold the engine might emit white smoke.

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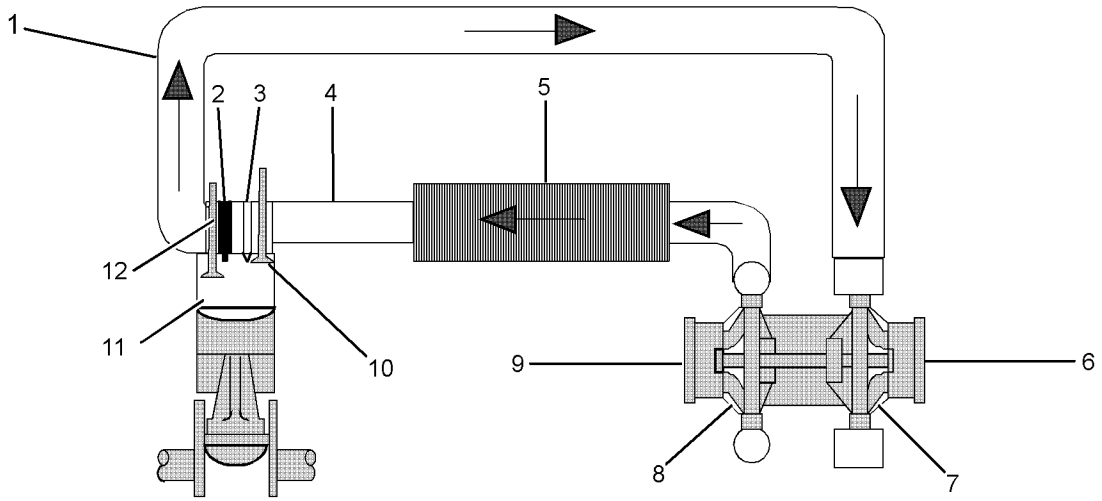
Air Inlet and Exhaust System



g01355169

Illustration 4

Air inlet and exhaust system (typical example)

(1) Exhaust manifold
(2) Injector
(3) Glow plug
(4) Intake manifold
(5) Aftercooler core (if equipped)
(6) Exhaust outlet
(7) Turbine side of turbocharger
(8) Compressor side of turbocharger
(9) Air inlet from the air cleaner
(10) Inlet valve
(11) Engine cylinder
(12) Exhaust valve

Engines which are naturally aspirated pull outside air through an air cleaner directly into the intake manifold (4). The air flows from the intake manifold to the engine cylinders (11). The air mixes with the fuel and leads to combustion. After combustion, the exhaust gases flow directly to the outside air through the exhaust manifold (1).

Turbocharged engines pull outside air through an air cleaner into the air intake (4) of the turbocharger. The suction is caused by the rotating turbocharger compressor wheel (5). The compressor wheel compresses the air which flows through the intake manifold (2). This directs an even distribution of the air to each engine cylinder (3). Air is pulled into the engine cylinder (3) during the intake stroke of the piston.

Each piston makes four strokes:

1. Intake

2. Compression

3. Power

4. Exhaust

The sequence of the strokes by all of the pistons in all of the engine cylinders provide constant air flow through the inlet system during the engine operation.

Toward the end of the compression stroke, fuel is injected into the cylinder. The mixture of fuel and air ignites and combustion takes place.

The exhaust stroke and the timing of the valve mechanism pushes combustion gases through the open exhaust valve into the exhaust manifold (1). The exhaust gases flow through the blades of the turbocharger turbine wheel (6) which causes the turbine wheel and the compressor wheel to rotate. The exhaust gases flow through the exhaust outlet (7) of the turbocharger to atmosphere.

Turbocharger

Note: The turbocharger is not serviceable.

A turbocharger increases the temperature and the density of the air that is sent to the engine cylinder. This condition causes a lower temperature of ignition to develop earlier in the compression stroke. The compression stroke is also timed in a more accurate way with the fuel injection. Surplus air lowers the temperature of combustion. This surplus air also provides internal cooling.

A turbocharger improves the following aspects of engine performance:

- Power output is increased.
- Fuel efficiency is improved.
- Engine torque is increased.
- Durability of the engine is improved.
- Emissions from the engine are reduced.

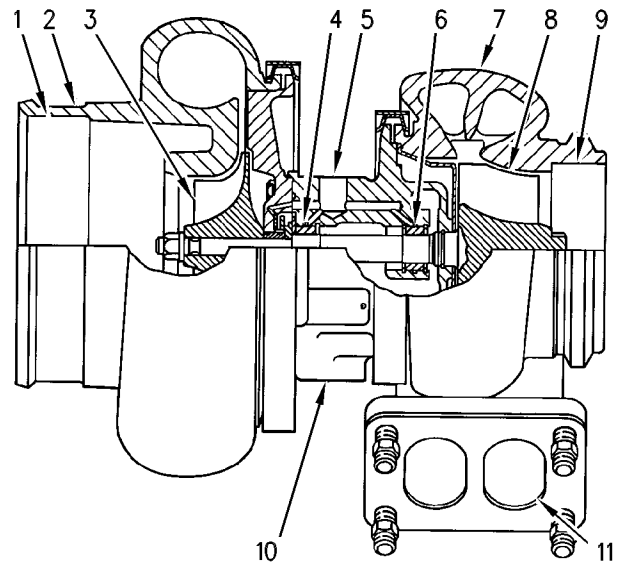


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Illustration 5

Components of a turbocharger (typical example)

(1) Air intake
(2) Compressor housing
(3) Compressor wheel
(4) Bearing
(5) Oil inlet port
(6) Bearing
(7) Turbine housing
(8) Turbine wheel
(9) Exhaust outlet
(10) Oil outlet port
(11) Exhaust inlet

A turbocharger is installed between the exhaust and intake manifolds. The turbocharger is driven by exhaust gases which flow through the exhaust inlet (11). The energy of the exhaust gas turns the turbine wheel (8). Then, the exhaust gas flows out of the turbine housing (7) through the exhaust outlet (9).

The turbine wheel and the compressor wheel (3) are installed on the same shaft. Therefore, the turbine wheel and the compressor wheel rotate at the same speed. The compressor wheel is enclosed in the compressor housing (2). The compressor wheel compresses the intake air (1). The intake air flows into the engine cylinders through the inlet valves of the cylinders.

The oil from the main gallery of the cylinder block flows through the oil inlet port (5) in order to lubricate the turbocharger bearings (4) and (6). The pressurized oil passes through the bearing housing of the turbocharger. The oil is returned through the oil outlet port (10) to the oil pan.

The turbocharger has a wastegate which is controlled by boost pressure. This allows some of the exhaust to bypass the turbocharger at higher engine speeds. The wastegate is a valve that automatically opens at a preset level of boost pressure in order to allow excess exhaust gas to bypass the turbine at high engine speeds. The wastegate allows the design of the turbocharger to be more effective at lower engine speeds.

The wastegate is controlled by a diaphragm. One side of this diaphragm is open to the atmosphere. The other side of this diaphragm is open to intake manifold boost pressure.

Cylinder Head And Valves

The valves and the valve mechanism control the flow of the air and the exhaust gases in the cylinder during engine operation. The cylinder head assembly has two valves for each cylinder. Each valve has one valve spring. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head. Sintered valve seat inserts are installed in the cylinder head for both the inlet and the exhaust valves. The valve seat inserts can be replaced.

The valves are installed in valve guides. The valve guides can be replaced. A groove is machined into the exhaust valve stem in order to prevent a deposit of carbon forming under the head of the valve.

The inlet and the exhaust valves are opened and closed by the rotation and movement of the following components:

- Crankshaft
- Camshaft
- Valve lifters
- Pushrods
- Rocker arms
- Valve springs

The camshaft gear is driven by the crankshaft gear. The camshaft and the crankshaft are timed together. When the camshaft turns, the valve lifters and the pushrods are moved up and down. The pushrods move the rocker arms. The movement of the rocker arms open the valves. The opening and closing of the valves is timed with the firing sequence of the engine. The valve springs push the valves back to the closed position.

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Lubrication System

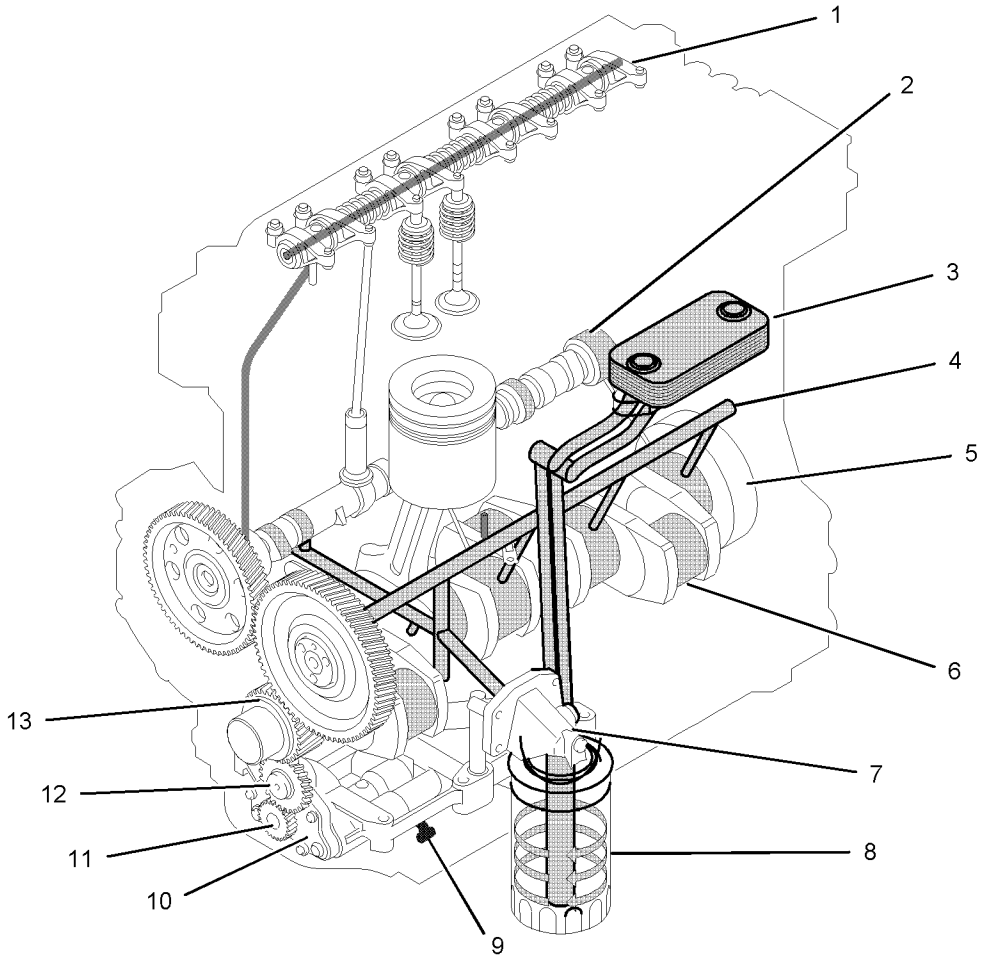

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Illustration 6

Flow diagram of the lubrication system for the 1104D engine

Lubricating oil from the oil pan flows through a strainer and a pipe (9) to the suction side of the engine oil pump (10). Pressure for the lubrication system is supplied by the oil pump . The crankshaft gear (13) drives a lower idler gear (12). The lower idler gear drives the oil pump gear (11). The pump has an inner rotor and an outer rotor. The axis of rotation of the rotors are off-center relative to each other. There is an interference fit between the inner rotor and the drive shaft.

The inner rotor has five lobes which mesh with the six lobes of the outer rotor. When the pump rotates, the distance increases between the lobes of the outer rotor and the lobes of the inner rotor in order to create suction. When the distance decreases between the lobes, pressure is created.

The lubricating oil flows from the outlet side of the oil pump (10) through a passage to the oil filter head (7). The oil then flows from the oil filter head through a passage to a plate type oil cooler for the 1104D engine (3). The oil cooler is located on the left side of the cylinder block.

From the oil cooler, the oil returns through a passage to the oil filter head. The oil then flows through a bypass valve that permits the lubrication system to function if the oil filter becomes blocked. Under normal conditions, the oil then flows to the oil filter (8).

The oil flows from the oil filter through a passage that is drilled across the cylinder block to the oil gallery (4). The oil gallery is drilled through the total length of the left side of the cylinder block. If the oil filter is on the right side of the engine, the oil flows through a passage that is drilled across the cylinder block to the pressure gallery.

Lubricating oil from the oil gallery flows through high pressure passages to the main bearings of the crankshaft (5). Then, the oil flows through the passages in the crankshaft to the connecting rod bearing journals (6). The pistons and the cylinder bores are lubricated by the splash of oil and the oil mist.

Lubricating oil from the main bearings flows through passages in the cylinder block to the journals of the camshaft. Then, the oil flows from the front journal of the camshaft at a reduced pressure to the cylinder head. The oil then flows through the center of the rocker shaft (1) to the rocker arm levers. The valve stems, the valve springs and the valve lifters are lubricated by the splash and the oil mist.

The hub of the idler gear is lubricated by oil from the oil gallery. The timing gears are lubricated by the splash from the oil.

An external line from the cylinder block supplies oil to the turbocharger. The oil then flows through a return line to the oil pan.

Engines have piston cooling jets that are supplied with oil from the oil gallery. The piston cooling jets spray lubricating oil on the underside of the pistons in order to cool the pistons.

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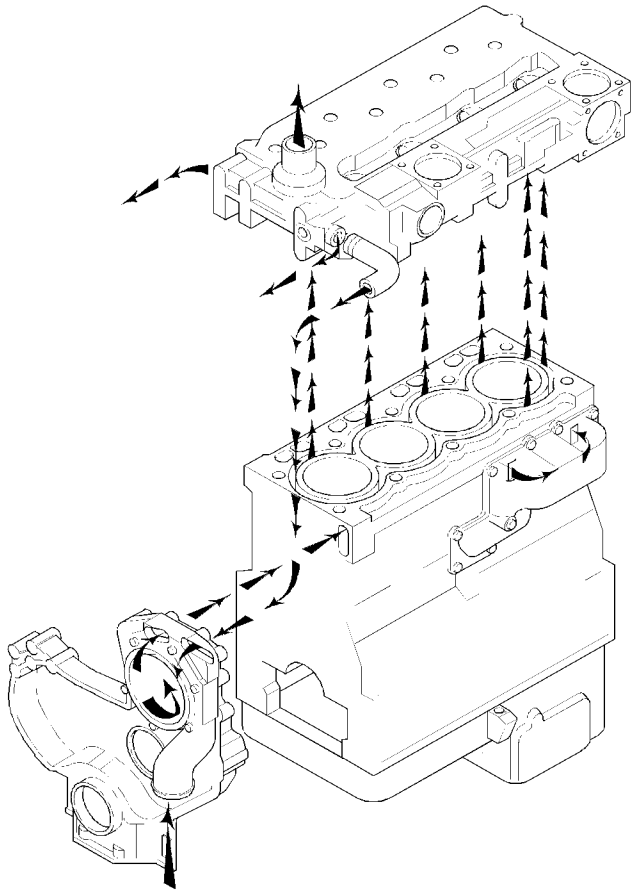
Cooling System



g00985481

Illustration 7

Flow diagram of the cooling system for the 1104D engine

The coolant flows from the bottom of the radiator to the centrifugal water pump. The water pump assists in the flow of the coolant through the system. The water pump is installed on the front of the timing case. The water pump is gear-driven by the fuel injection pump gear.

The water pump forces the coolant through a passage in the front of the timing case to the water jacket in the top left side of the cylinder block. The coolant continues to the rear of the cylinder block.

The main flow of the coolant passes from the rear of the cylinder block into the rear of the cylinder head. The coolant flows forward through the cylinder head and into the water temperature regulator housing. If the water temperature regulator is closed, the coolant goes directly through a bypass to the inlet side of the water pump. If the water temperature regulator is open, the bypass is closed and the coolant flows to the top of the radiator.

1104D engines

From the rear of the cylinder block, some of the coolant passes into the oil cooler. The oil cooler is located on the left side of the cylinder block with no external lines. The coolant flows around the element of the oil cooler before being returned to the rear of the cylinder block.

i02680926

Basic Engine

Cylinder Block and Cylinder Head

The cylinder block for the 1104D engine has four cylinders which are arranged in-line.

The cylinder block for the 1104D engine has five main bearings which support the crankshaft. Thrust washers on both sides of the center main bearing control the end play of the crankshaft.

A cylinder head gasket is used between the engine block and the cylinder head in order to seal combustion gases, water, and oil.

The engine has a cast iron cylinder head. The inlet manifold is integral within the cylinder head. An inlet valve and an exhaust valve for each cylinder are controlled by a pushrod valve system. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head.

Pistons, Rings, and Connecting Rods

The pistons have a combustion chamber in the top of the piston in order to provide an efficient mix of fuel and air. The piston pin is off-center in order to reduce the noise level.

The pistons have two compression rings and an oil control ring. The groove for the top ring has a hard metal insert in order to reduce wear of the groove. The skirt has a layer of graphite in order to reduce wear.

The correct piston height is important in order to ensure that the piston does not contact the cylinder head. The correct piston height also ensures the efficient combustion of fuel which is necessary in order to conform to requirements for emissions.

Engines are equipped with connecting rods that have bearing caps that are fracture split. The bearing caps on fracture split connecting rods are retained with torx screws. Connecting rods with bearing caps that are fracture split have the following characteristics:

- Higher integrity for the rod
- The splitting produces an accurately matched surface on each side for improved strength.
- Modern design

The connecting rod is matched to each cylinder. The piston height is controlled by the length of the connecting rod. Six different lengths of connecting rods are available in order to attain the correct piston height. The different lengths of connecting rods are made by machining the small end bearing off-center in order to form an eccentric bearing. The amount of the eccentricity of the bearing creates the different lengths of the connecting rods.

Crankshaft

The crankshaft changes the linear energy of the pistons and connecting rods into rotary torque in order to power external equipment.

A gear at the front of the crankshaft drives the timing gears. The crankshaft gear turns the idler gear which then turns the following gears:

- Camshaft gear
- Fuel injection pump
- Lower idler gear which turns the gear of the lubricating oil pump

Dynamic seals are used on both the front of the crankshaft and the rear of the crankshaft.

Camshaft

The engine has a single camshaft. The camshaft is driven by an idler gear in the front housing. The camshaft uses only one bearing on the front journal. The other journals rotate in the bore of the cylinder block. The front bearing and the camshaft bores in the cylinder block support the camshaft. As the camshaft turns, the camshaft lobes move the valve system components. The valve system components move the inlet and exhaust valves in each cylinder. The camshaft gear must be timed to the crankshaft gear. The relationship between the lobes and the camshaft gear causes the valves in each cylinder to be opened and closed at the correct time. The relationship between the lobes and the camshaft gear also causes the valves in each cylinder to close at the correct time.

i02680940

Electrical System

The electrical system is a negative ground system.

The charging circuit operates when the engine is running. The alternator in the charging circuit produces direct current for the electrical system.

Starting Motor

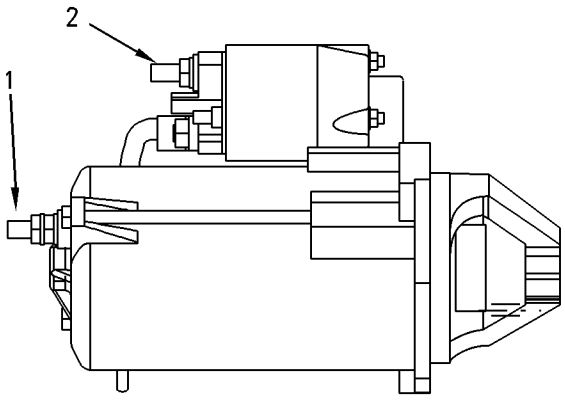


Illustration 8 g00954820

12 Volt Starting Motor

(1) Terminal for connection of the battery cable
(2) Terminal for connection of the ignition switch

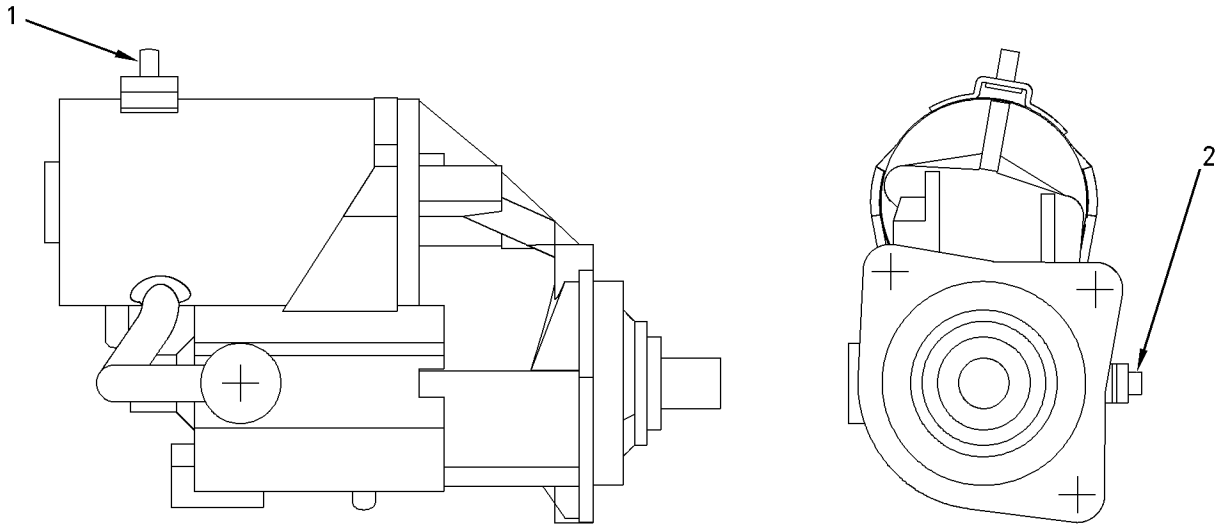


Illustration 9 g00956095

24 Volt Starting Motor

(1) Terminal for connection of the ignition switch
(2) Terminal for connection of the battery cable

The starting motor turns the engine flywheel. The rpm is high enough in order to initiate a sustained operation of the fuel ignition in the cylinders.

The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to engage the pinion in the flywheel ring gear of the engine. When the pinion gear is engaged in the flywheel ring gear, the electrical contacts in the solenoid close the circuit between the battery and the starting motor. This causes the starting motor to rotate. This type of activation is called a positive shift.

When the engine begins to run, the overrunning clutch of the pinion drive prevents damage to the armature. Damage to the armature is caused by excessive speeds. The clutch prevents damage by stopping the mechanical connection. However, the pinion will stay meshed with the ring gear until the ignition switch is released. A spring in the overrunning clutch returns the clutch to the rest position.

Alternator

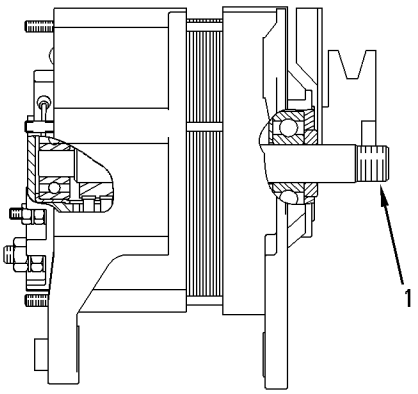


Illustration 10 g00303424

(1) Shaft for mounting the pulley

The alternator produces the following electrical output:

- Three-phase
- Full-wave
- Rectified

The alternator is an electro-mechanical component. The alternator is driven by a drive belt from the crankshaft pulley. The alternator charges the storage battery during the engine operation.

The alternator converts the mechanical energy and the magnetic energy into electrical energy. This conversion is done by rotating a direct current electromagnetic field on the inside of a three-phase stator. The electromagnetic field is generated by electrical current flowing through a rotor. The stator generates AC electrical power.

The alternating current is changed to direct current by a three-phase, full-wave rectifier. Direct current flows to the output terminal of the alternator. The rectifier has three exciter diodes. The direct current is used for the charging process.

A regulator is installed on the rear end of the alternator. Two brushes conduct current through two slip rings. The current then flows to the rotor field. A capacitor protects the rectifier from high voltages.

The alternator is connected to the battery through the ignition switch. Therefore, alternator excitation occurs when the switch is in the ON position.

Testing and Adjusting Section

Fuel System

i01804057

Fuel System - Inspect

A problem with the components that send fuel to the engine can cause low fuel pressure. This can decrease engine performance.

1. Check the fuel level in the fuel tank. Ensure that the vent in the fuel cap is not filled with dirt.
2. Check all fuel lines for fuel leakage. The fuel lines must be free from restrictions and faulty bends. Verify that the fuel return line is not collapsed.
3. Inspect the fuel filter for excess contamination. If necessary, install a new fuel filter. Determine the source of the contamination. Make the necessary repairs.
4. Service the primary fuel filter (if equipped).
5. Remove any air that may be in the fuel system. Refer to Testing and Adjusting, “Fuel System - Prime”.

i02780600

Air in Fuel - Test

This procedure checks for air in the fuel system. This procedure also assists in finding the source of the air.

1. Examine the fuel system for leaks. Ensure that the fuel line fittings are properly tightened. Check the fuel level in the fuel tank. Air can enter the fuel system on the suction side between the fuel transfer pump and the fuel tank.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

2. Install a suitable fuel flow tube with a visual sight gauge in the fuel return line. When possible, install the sight gauge in a straight section of the fuel line that is at least 304.8 mm (12 inches) long. Do not install the sight gauge near the following devices that create turbulence:
   - Elbows
   - Relief valves
   - Check valves
   - Connections

   Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If there is no fuel that is present in the sight gauge, prime the fuel system. Refer to Testing and Adjusting, “Fuel System - Prime” for more information. If the engine starts, check for air in the fuel at varying engine speeds. When possible, operate the engine under the conditions which have been suspect.

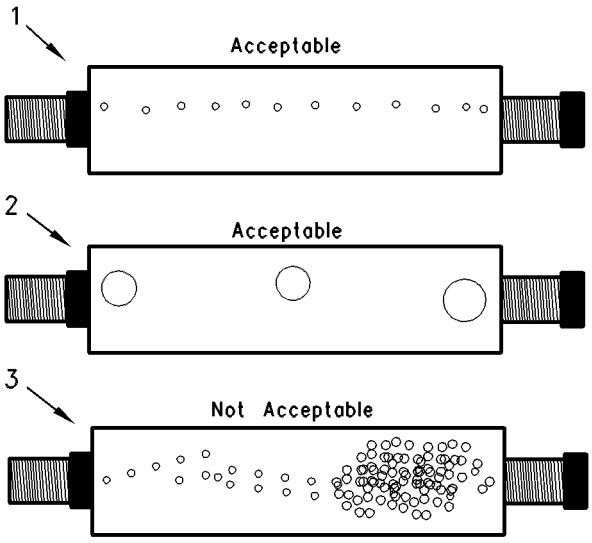


Illustration 11 g00578151

(1) A steady stream of small bubbles with a diameter of approximately 1.60 mm (0.063 inch) is an acceptable amount of air in the fuel.
(2) Bubbles with a diameter of approximately 6.35 mm (0.250 inch) are also acceptable if there is two seconds to three seconds intervals between bubbles.
(3) Excessive air bubbles in the fuel are not acceptable.

3. If excessive air is seen in the sight gauge in the fuel return line, install a second sight gauge at the inlet to the fuel transfer pump. If a second sight gauge is not available, move the sight gauge from the fuel return line and install the sight gauge at the inlet to the fuel transfer pump. Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If the engine starts, check for air in the fuel at varying engine speeds.

   If excessive air is seen at the inlet to the fuel transfer pump, air is entering through the suction side of the fuel system.

⚠ WARNING

To avoid personal injury, always wear eye and face protection when using pressurized air.

NOTICE

To avoid damage, do not use more than 55 kPa (8 psi) to pressurize the fuel tank.

4. Pressurize the fuel tank to 35 kPa (5 psi). Do not use more than 55 kPa (8 psi) in order to avoid damage to the fuel tank. Check for leaks in the fuel lines between the fuel tank and the fuel transfer pump. Repair any leaks that are found. Check the fuel pressure in order to ensure that the fuel transfer pump is operating properly. For information about checking the fuel pressure, see Testing and Adjusting, “Fuel System Pressure - Test”.

5. If the source of the air is not found, disconnect the supply line from the fuel tank and connect an external fuel supply to the inlet of the fuel transfer pump. If this corrects the problem, repair the fuel tank or the stand pipe in the fuel tank.

i01893344

Finding Top Center Position for No. 1 Piston

Table 1

Required Tools		
Part Number	**Part Description**	**Qty**
27610211	Crankshaft timing pin	1
27610212	Camshaft timing pin	1

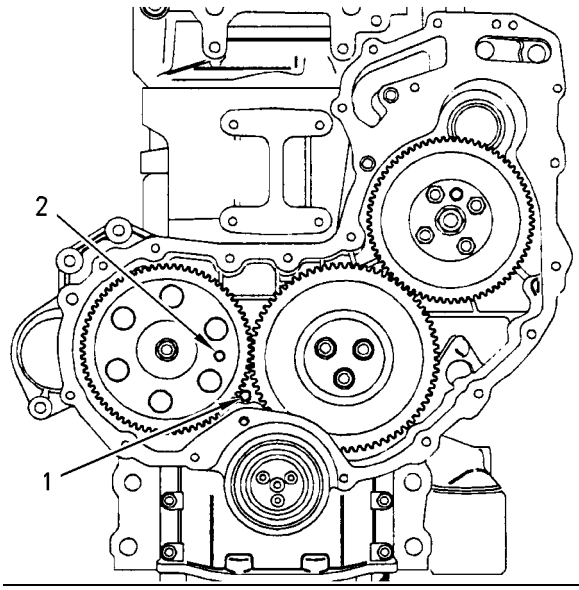


Illustration 12 g00923080

(1) Hole for crankshaft pin
(2) Hole for camshaft pin

1. Remove the valve mechanism cover, the glow plugs, and the cover for the front housing.

Note: The crankshaft timing pin can be inserted with the crankshaft pulley still on the engine.

2. Rotate the crankshaft in the normal direction of the engine until the inlet valve of the No. 4 cylinder has just opened and the exhaust valve of the No. 4 cylinder has not completely closed.

3. Carefully rotate the crankshaft in the normal direction of the engine in order to align the hole in the crankshaft with the hole in the cylinder block and the timing case. Insert the 27610211 Crankshaft Timing Pin fully into the hole in the crankshaft web.

4. Insert the 27610212 Camshaft Timing Pin through the hole in the camshaft gear and into the body of the timing case. The engine is set at the top center position for No. 1 piston.

Note: The camshaft gear can rotate a small amount when the pin is installed.

5. Remove the timing pins from the camshaft gear and the crankshaft web.

i02681015

Fuel Injection Pump Timing - Check

Delphi DP310 Fuel Injection Pump

Note: The Delphi DP310 fuel injection pump timing cannot be checked. If you suspect that the fuel injection pump timing is incorrect, contact your Perkins dealer or your Perkins distributor for further information.

Delphi DP310 fuel injection pumps must be serviced by an authorized Delphi technician. For repair information, contact your Perkins dealer or your Perkins distributor. The internal adjustment for the pump timing is tamper proof. High idle and low idle are factory set. Idle adjustments cannot be made to the fuel pump.

i02681476

Fuel Injection Pump Timing - Adjust

Delphi DP310 Fuel Injection Pumps

The Delphi DP310 fuel injection pumps must be serviced by an authorized Delphi technician. For repair information, contact your Perkins dealer or your Perkins distributor. The internal adjustment for the pump timing is tamper proof. High idle and low idle are factory set. Idle adjustments cannot be made to the fuel pump.

i01944302

Fuel Quality - Test

Use the following procedure to test for problems regarding fuel quality:

1. Determine if water and/or contaminants are present in the fuel. Check the water separator (if equipped). If a water separator is not present, proceed to Step 2. Drain the water separator, if necessary. A full fuel tank minimizes the potential for overnight condensation.

Note: A water separator can appear to be full of fuel when the water separator is actually full of water.

2. Determine if contaminants are present in the fuel. Remove a sample of fuel from the bottom of the fuel tank. Visually inspect the fuel sample for contaminants. The color of the fuel is not necessarily an indication of fuel quality. However, fuel that is black, brown, and/or similar to sludge can be an indication of the growth of bacteria or oil contamination. In cold temperatures, cloudy fuel indicates that the fuel may not be suitable for the operating conditions. Refer to Operation and Maintenance Manual, “Fuel Recommendations” for more information.

3. If fuel quality is still suspected as a possible cause of problems regarding engine performance, disconnect the fuel inlet line, and temporarily operate the engine from a separate source of fuel that is known to be good. This will determine if the problem is caused by fuel quality. If fuel quality is determined to be the problem, drain the fuel system and replace the fuel filters. Engine performance can be affected by the following characteristics:

   - Cetane number of the fuel
   - Air in the fuel
   - Other fuel characteristics

i02681497

Fuel System - Prime

If air enters the fuel system, the air must be purged before the engine can be started. Air can enter the fuel system when the following events occur:

- The fuel tank is empty or the tank has been partially drained during normal operation.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system during engine operation.
- The fuel filter or the fuel pump is replaced.
- The high pressure fuel lines are disconnected.

Delphi DP310

The Delphi DP310 fuel injection pumps will eliminate the air from the fuel system automatically. Position the starting switch to the RUN position for three minutes. Air in the fuel and the fuel lines will be purged from the system.

i02780603

Fuel System Pressure - Test

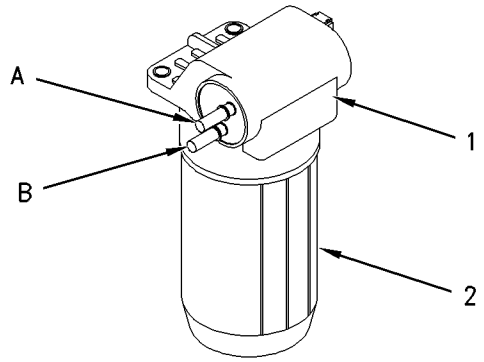


Illustration 13 g00928705

(A and B) Fuel outlet
(1) Fuel transfer pump
(2) Fuel filter

The pressure test measures the output pressure of the fuel transfer pump. Low fuel pressure and starting difficulty may be indications of problems with the fuel priming pump.

Check the Function of the Fuel Transfer Pump

1. Make a note of the location of the fuel lines from the fuel transfer pump. Remove the two lines from the outlets (A) and (B).
2. Connect two lengths of 5/16 inch rubber hose to outlets (A) and (B). Place the hoses into a suitable container that is capable of holding 3 L (3.17 qt) of fuel.
3. Energize the fuel transfer pump until a constant flow of fuel is running from the outlet for the supply for the fuel injection pump.

Note: The flow from the outlet for the return for the fuel tank will have a slower flow rate.

4. Measure the combined flow of both outlets with a stopwatch. Fuel flow should be a minimum of 2 L/min (0.53 US gpm).
5. If the combined flow is less than 2 L/min (0.53 US gpm), repair the pump or replace the pump.
6. Reconnect the outlet lines in the correct positions.
7. Start the engine and check for any leakage of fuel or air from the fuel lines.

Check the Function of the Pressure Regulator

1. Remove the fuel line from the outlet for the supply for the fuel injection pump (B).
2. Install a pipe with a tap for a pressure gauge. Connect a 0 to 80 kPa (0 to 12 psi) pressure gauge.
3. Start the engine and run the engine at idle for two minutes in order to remove any trapped air.
4. Record the pressure reading at idle and at rated speed. The minimum pressure reading should be the following values:

   All Fuel Injection Pumps

   Idle ..... 25 kPa (3.6 psi)

   Rated speed ..... 23 kPa (3.3 psi)

Note: The maximum pressure for the fuel injection pump at idle speed or rated speed is 75 kPa (10.9 psi).

5. Reconnect the fuel line. Turn the key to the RUN position for three minutes in order to energize the fuel priming pump. Do not start the engine. Then turn the key to the OFF position.

Check for the following issues if the pressures are outside of the above specifications.

- All electrical connections are installed correctly.
- There are no leaks in the fuel lines or connections.
- The O-ring on the fuel filter housing (2) does not leak.

Air Inlet and Exhaust System

i02281171

Air Inlet and Exhaust System - Inspect

Do a general visual inspection of the air inlet and exhaust system. Make sure that there are no signs of leaks in the system.

There will be a reduction in the performance of the engine if there is a restriction or there is a leak in the air inlet system or the exhaust system.

⚠ WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

⚠ WARNING

Making contact with a running engine can cause burns from hot parts and can cause injury from rotating parts.

When working on an engine that is running, avoid contact with hot parts and rotating parts.

1. Inspect the engine air cleaner inlet and ducting in order to ensure that the passageway is not blocked or collapsed.
2. Inspect the engine air cleaner element. Replace a dirty element with a clean element.
3. Check for dirt tracks on the clean side of the engine air cleaner element. If dirt tracks are observed, contaminants are flowing past the element.

i02755777

Turbocharger - Inspect

⚠ WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

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.

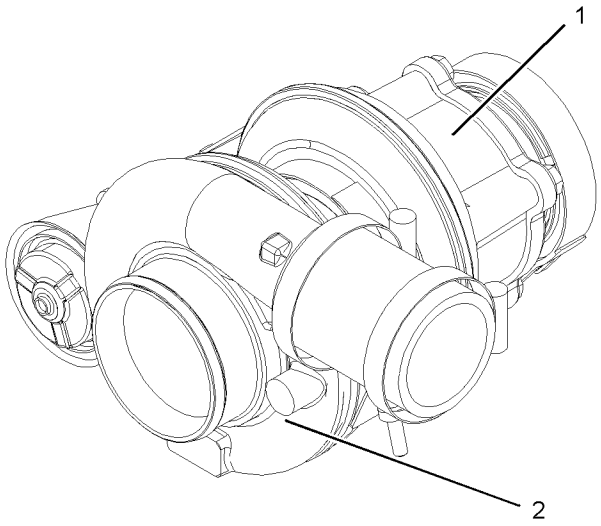
Dispose of all fluids according to local regulations and mandates.

Before you begin inspection of the turbocharger, be sure that the inlet air restriction is within the specifications for your engine. Be sure that the exhaust system restriction is within the specifications for your engine. Refer to Testing and Adjusting, “Air Inlet and Exhaust System - Inspect”.

The condition of the turbocharger will have definite effects on engine performance. Use the following inspections and procedures to determine the condition of the turbocharger.

- Inspection of the compressor and the compressor housing
- Inspection of the turbine wheel and the turbine housing
- Inspection of the wastegate

Inspection of the Compressor and the Compressor Housing



g01278821

Illustration 14

Typical example of a turbocharger

(1) Turbine housing
(2) Compressor housing

1. Inspect the compressor wheel for damage from a foreign object. If there is damage, determine the source of the foreign object. Replace the turbocharger. If there is no damage, go to Step 2.

2. Turn the rotating assembly by hand. While you turn the assembly, push the assembly sideways. The assembly should turn freely. The compressor wheel should not rub the compressor housing. The turbocharger must be replaced if the compressor wheel rubs the compressor wheel housing. If there is no rubbing or scraping, go to Step 3.

3. Inspect the compressor and the compressor wheel housing for oil leakage. An oil leak from the compressor may deposit oil in the aftercooler. If oil is found in the aftercooler, then drain and clean the aftercooler.

a. Check the oil level in the crankcase. If the oil level is too high, adjust the oil level.

b. Inspect the engine crankcase breather. Clean the engine crankcase breather or replace the engine crankcase breather if the engine crankcase breather is plugged.

c. Remove the pipe for the oil drain. Inspect the drain opening. Inspect the oil drain line. Inspect the area between the bearings of the rotating assembly shaft. Look for oil sludge. Inspect the oil drain hole for oil sludge. Inspect the oil drain line for oil sludge in the drain line. If necessary, clean the oil drain line.

d. If Steps 3.a through 3.c did not reveal the source of the oil leakage, the turbocharger has internal damage. Replace the turbocharger.

Inspection of the Turbine Wheel and the Turbine Housing

Remove the air piping from the turbine housing.

1. Inspect the turbine for damage by a foreign object. If there is damage, determine the source of the foreign object. Replace turbocharger (2). If there is no damage, go to Step 2.

2. Inspect the turbine wheel for the carbon and other foreign material. Inspect turbine housing (1) for carbon and foreign material. Replace the turbocharger, if necessary. If there is no buildup of carbon or foreign material, go to Step 3.

3. Turn the rotating assembly by hand. While you turn the assembly, push the assembly sideways. The assembly should turn freely. The turbine wheel should not rub turbine wheel housing (1). Replace turbocharger (2) if turbine wheel rubs turbine housing (1). If there is no rubbing or scraping, go to Step 4.

4. Inspect the turbine and turbine housing (1) for oil leakage. Inspect the turbine and turbine housing (1) for oil coking. Heavy oil coking may require replacement of the turbocharger. If the oil is coming from the turbocharger center housing go to Step 4.a. Otherwise go to “Inspection of the Wastegate”.

a. Remove the pipe for the oil drain. Inspect the drain opening. Inspect the area between the bearings of the rotating assembly shaft. Look for oil sludge. Inspect the oil drain hole for oil sludge. Inspect the oil drain line for oil sludge. If necessary, clean the drain line.

b. If crankcase pressure is high, or if the oil drain is restricted, pressure in the center housing may be greater than the pressure of turbine housing (1). Oil flow may be forced in the wrong direction and the oil may not drain. Check the crankcase pressure and correct any problems.

c. If the oil drain line is damaged, replace the oil drain line.

d. Check the routing of the oil drain line. Eliminate any sharp restrictive bends. Make sure that the oil drain line is not too close to the engine exhaust manifold.

e. If Steps 4.a through 4.d did not reveal the source of the oil leakage, turbocharger (3) has internal damage. Replace turbocharger (3).

Inspection of the Wastegate

The wastegate controls the amount of exhaust gas that is allowed to bypass the turbine side of the turbocharger. This valve then controls the rpm of the turbocharger.

When the engine operates in conditions of low boost (lug), a spring presses against a diaphragm in the canister. The actuating rod will move and the wastegate actuator will close. The turbocharger can then operate at maximum performance.

When the boost pressure increases against the diaphragm in the canister, the wastegate will open. The rpm of the turbocharger becomes limited. The rpm limitation occurs because a portion of the exhaust gases bypass the turbine wheel of the turbocharger.

The following levels of boost pressure indicate a problem with the wastegate:

- Too high at full load conditions
- Too low at all lug conditions

The boost pressure controls the maximum rpm of the turbocharger, because the boost pressure controls the position of the wastegate. The following factors also affect the maximum rpm of the turbocharger:

- The engine rating
- The horsepower demand on the engine
- The high idle rpm
- Inlet air restriction
- Exhaust system restriction

Check the Wastegate for Proper Operation

Table 2

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21825617	Dial Gauge	1

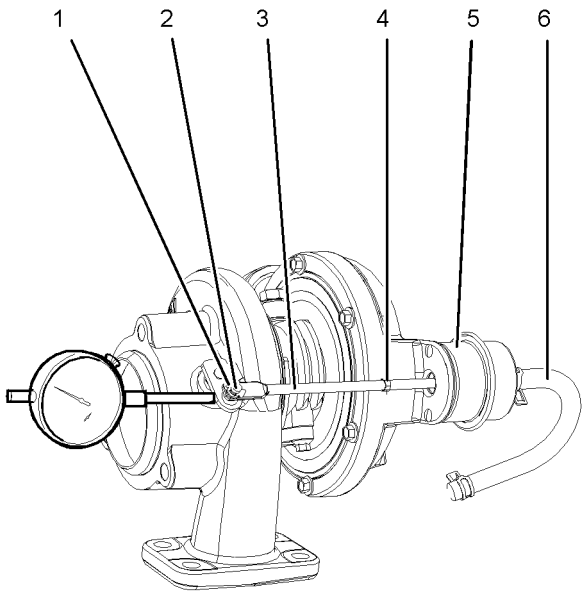


Illustration 15 g01289484

Typical example

Note: The turbocharger is a nonserviceable item. The pressure for the wastegate can be checked, but not adjusted.

1. Remove the boost line (6) from the wastegate actuator (5). Connect an air supply to the wastegate actuator that can be adjusted accurately.
2. Install Tooling (A) to the turbocharger so that the end of the actuator rod (1) is in contact with Tooling (A). This will measure axial movement of the actuator rod (4).
3. Slowly apply air pressure to the wastegate so that the actuator rod (4) moves 1.0 mm (0.039 inch). The air pressure should be within 107 to 117 kPa (15.5 to 17.0 psi). Ensure that the dial indicator returns to zero when the air pressure is released. Repeat the test several times. This will ensure that an accurate reading is obtained.
4. If the air pressure is correct, remove the air supply. Remove Tooling (A). Reinstall the boost line (6).
5. If the operation of the wastegate is not correct, the actuator rod (4) cannot be adjusted. The turbocharger must be renewed.

i02675596

Compression - Test

The cylinder compression test should only be used in order to compare the cylinders of an engine. The pressure in the cylinder should be between 300 to 500 kPa (43.5120 to 72.5200 psi). If one or more cylinders vary by more than 350 kPa (51 psi), the cylinder and related components may need to be repaired.

A compression test should not be the only method which is used to determine the condition of an engine. Other tests should also be conducted in order to determine if the adjustment or the replacement of components is required.

Before the performance of the compression test, make sure that the following conditions exist:

- The battery is in good condition.
- The battery is fully charged.
- The starting motor operates correctly.
- The valve lash is set correctly.
- All fuel injectors are removed.
- The fuel supply is disconnected.

1. Install a gauge for measuring the cylinder compression in the hole for a fuel injector.
2. Operate the starting motor in order to turn the engine. Record the maximum pressure which is indicated on the compression gauge.
3. Repeat Steps 1 and 2 for all cylinders.

i02696124

Engine Valve Lash - Inspect/Adjust

⚠ WARNING

To prevent possible injury, do not use the starter to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring valve clearance.

Valve Lash Setting

Valve lash setting

Inlet valve ..... 0.2 mm (0.008 inch)
Exhaust valve ..... 0.45 mm (0.018 inch)

Refer to Systems Operation, “Engine Design” for the location of the cylinder valves.

Valve Lash Adjustment

If the valve lash requires adjustment several times in a short period of time, excessive wear exists in a different part of the engine. Find the problem and make necessary repairs in order to prevent more damage to the engine.

Not enough valve lash can be the cause of rapid wear of the camshaft and valve lifters. Not enough valve lash can indicate that the seats for the valves are worn.

Valves become worn due to the following causes:

- Fuel injectors that operate incorrectly
- Excessive dirt and oil are present on the filters for the inlet air.
- Incorrect fuel settings on the fuel injection pump.
- The load capacity of the engine is frequently exceeded.

Too much valve lash can cause broken valve stems, springs, and spring retainers. Too much valve lash can be an indication of the following problems:

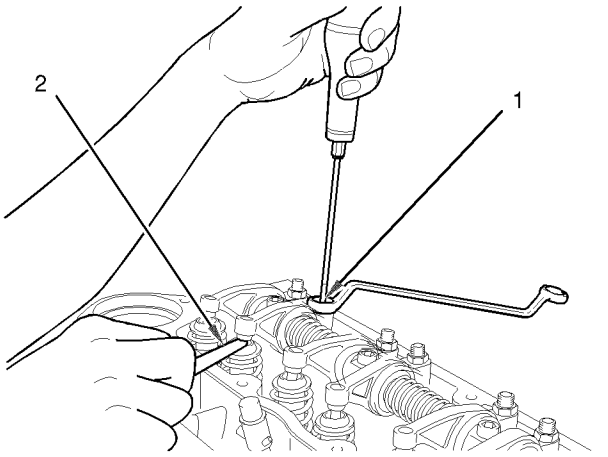
- Worn camshaft and valve lifters
- Worn rocker arms
- Bent pushrods
- Broken socket on the upper end of a pushrod
- Loose adjustment screw for the valve lash

If the camshaft and the valve lifters show rapid wear, look for fuel in the lubrication oil or dirty lubrication oil as a possible cause.

The valve lash is measured between the top of the valve stem and the rocker arm lever.

Note: An adjustment is not necessary if the measurement of the valve lash is in the acceptable range. Inspect the valve lash while the engine is stopped and when the engine is cold.

Note: When the following procedures are performed, the front housing must be installed.



g01016764

Illustration 16

Setting the valve lash

(1) Adjustment screw
(2) Feeler gauge

Valve Lash Adjustment for the 1104D (Mechanical) engine

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly, “Valve Mechanism Cover - Remove and Install”.

2. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 4 cylinder has opened and the exhaust valve of the No. 4 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 1 cylinder. If necessary, make adjustment.

   a. Loosen the valve adjustment screw locknut that is on adjustment screw (1).

   b. Place the appropriate feeler gauge (2) between the rocker arm and the valve. Turn adjustment screw (1) while the valve adjustment screw locknut is being held from turning. Adjust the valve lash until the correct specification is achieved.

   c. After each adjustment, tighten the valve adjustment screw locknut to a torque of 27 N·m (19.9 lb ft) while adjustment screw (1) is being held.

3. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 2 cylinder has opened and the exhaust valve of the No. 2 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 3 cylinder.

   If adjustment is necessary, refer to Steps 2.a, 2.b, and 2.c above.

4. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 1 cylinder has opened and the exhaust valve of the No. 1 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 4 cylinder.

   If adjustment is necessary, refer to Steps 2.a, 2.b, and 2.c above.

5. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 3 cylinder has opened and the exhaust valve of the No. 3 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 2 cylinder.

   If adjustment is necessary, refer to Steps 2.a, 2.b, and 2.c above.

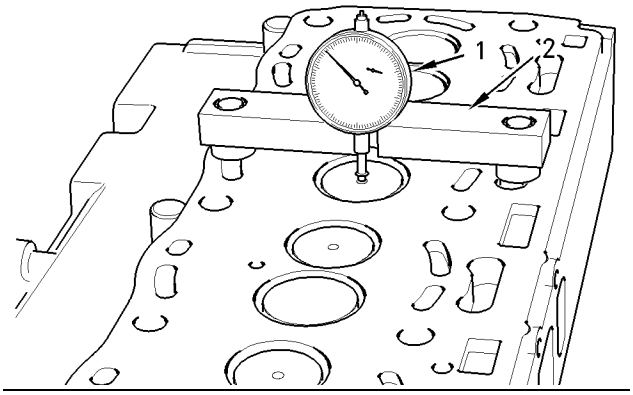
6. Install the valve mechanism cover. Refer to Disassembly and Assembly, “Valve Mechanism Cover - Remove and Install”.

i01889422

Valve Depth - Inspect

Table 3

Required Tools		
Part Number	**Part Description**	**Qty**
21825617	Dial gauge	1
21825496	Dial gauge holder	1



g00983531

Illustration 17

Measurement of the valve depth

(1) 21825617 Dial gauge
(2) 21825496 Dial gauge holder

1. Use the dial gauge (1) with the dial gauge holder (2) to check the depths of the inlet valves and the exhaust valves below the face of the cylinder head. Use the cylinder head face (3) to zero the dial gauge (1).

2. Position the dial gauge holder (2) and the dial gauge (1) in order to measure the valve depth. Measure the depth of the inlet valve and the exhaust valve before the valve springs are removed.

   Refer to Specifications, “Cylinder Head Valves” for the minimum, the maximum, and the service wear limits for the valve depth below the cylinder head face.

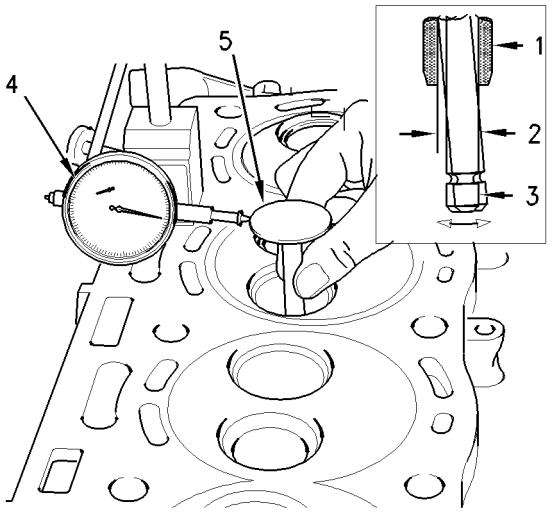
   If the valve depth below the cylinder head face exceeds the service limit, use a new valve to check the valve depth. If the valve depth still exceeds the service limit, renew the cylinder head or renew the valve seat inserts (if equipped). If the valve depth is within the service limit with a new valve, renew the valves.

3. Inspect the valves for cracks and other damage. Check the valve stems for wear. Check that the valve springs are the correct length under the test force. Refer to Specifications, “Cylinder Head Valves” for the dimensions and tolerances of the valves and the valve springs.

i01938952

Valve Guide - Inspect

Perform this inspection in order to determine if a valve guide should be replaced.



g00986821

Illustration 18

(1) Valve guide
(2) Radial movement of the valve in the valve guide
(3) Valve stem
(4) Dial indicator
(5) Valve head

1. Place a new valve in the valve guide.

2. Place a suitable dial indicator with the magnetic base on the face of the cylinder head.

3. Lift the edge of the valve head to a distance of 15.0 mm (0.60 inch).

4. Move the valve in a radial direction away from the dial indicator. Make sure that the valve moves away from the dial indicator as far as possible. Position the contact point of the dial indicator on the edge of the valve head. Set the position of the needle of the dial indicator to zero.

5. Move the valve in a radial direction toward the dial indicator as far as possible. Note the distance of movement which is indicated on the dial indicator. If the distance is greater than the maximum clearance of the valve in the valve guide, replace the valve guide.

   When new valve guides are installed, new valves and new valve seat inserts must be installed. Valve guides and valve seat inserts are supplied as an unfinished part. The unfinished valve guides and unfinished valve seat inserts are installed in the cylinder head. Then, the valve guides and valve inserts are cut and reamed in one operation with special tooling.

   Refer to Specifications, “Cylinder Head Valves” for the maximum clearance of the valve in the valve guide.

Lubrication System

i01854908

Engine Oil Pressure - Test

Low Oil Pressure

The following conditions will cause low oil pressure.

- The oil level is low in the crankcase.
- A restriction exists on the oil suction screen.
- Connections in the oil lines are leaking.
- The connecting rod or the main bearings are worn.
- The rotors in the oil pump are worn.
- The oil pressure relief valve is operating incorrectly.

A worn oil pressure relief valve can allow oil to leak through the valve which lowers the oil pressure. Refer to the Specifications Module, “Engine Oil Relief Valve” for the correct operating pressure and other information.

When the engine runs at the normal temperature for operation and at high idle, the oil pressure must be a minimum of 280 kPa (40 psi). A lower pressure is normal at low idle.

A suitable pressure gauge can be used in order to test the pressure of the lubrication system.

High Oil Pressure

High oil pressure can be caused by the following conditions.

- The spring for the oil pressure relief valve is installed incorrectly.
- The plunger for the oil pressure relief valve becomes jammed in the closed position.
- Excessive sludge exists in the oil which makes the viscosity of the oil too high.

i02696150

Engine Oil Pump - Inspect

If any part of the oil pump is worn enough in order to affect the performance of the oil pump, the oil pump must be replaced.

Perform the following procedures in order to inspect the oil pump. Refer to the Specifications Module, “Engine Oil Pump” for clearances and torques.

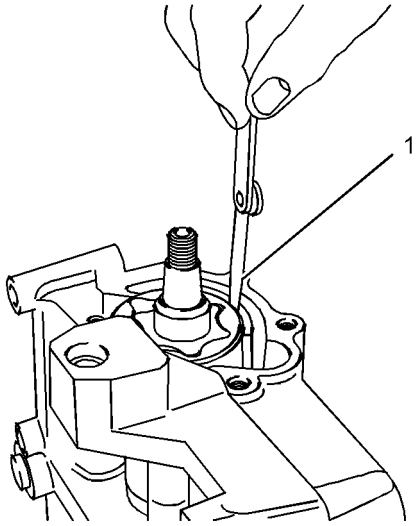
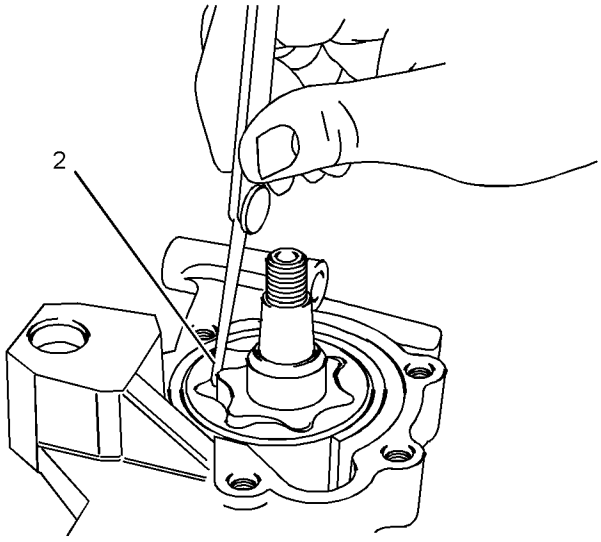


Illustration 19 g01334408

Clearance for the outer rotor body

1. Remove the oil pump from the engine. Refer to the Disassembly and Assembly, “Engine Oil Pump - Remove”. Remove the cover of the oil pump.
2. Remove the outer rotor. Clean all of the parts. Look for cracks in the metal or other damage.
3. Install the outer rotor. Measure the clearance of the outer rotor to the body (1).

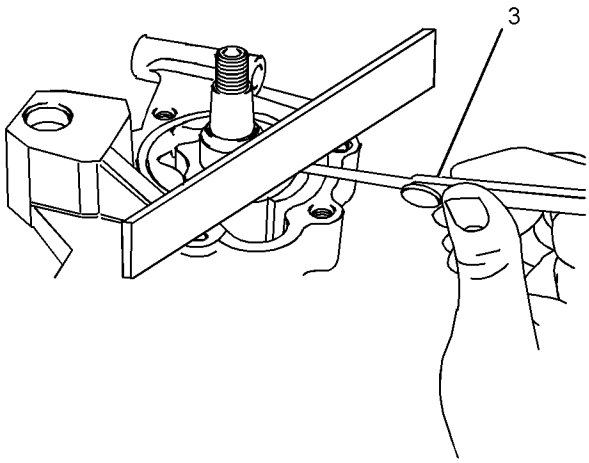


g01334410

Illustration 20

Clearance for the inner rotor body

4. Measure the clearance of the inner rotor to the outer rotor (2).



g01334412

Illustration 21

End play measurement of the rotor

5. Measure the end play of the rotor with a straight edge and a feeler gauge (3).

6. Clean the top face of the oil pump and the bottom face of the cover. Install the cover on the oil pump. Install the oil pump on the engine.

i01126690

Excessive Bearing Wear - Inspect

When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage.

An engine oil pressure indicator may show that there is enough oil pressure, but a component is worn due to a lack of lubrication. In such a case, look at the passage for the oil supply to the component. A restriction in an oil supply passage will not allow enough lubrication to reach a component. This will result in early wear.

i02487769

Excessive Engine Oil Consumption - Inspect

Engine Oil Leaks on the Outside of the Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the gasket for the engine oil pan and all lubrication system connections. Look for any engine oil that may be leaking from the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase. A dirty crankcase breather will cause the gaskets and the seals to leak.

Engine Oil Leaks into the Combustion Area of the Cylinders

Engine oil that is leaking into the combustion area of the cylinders can be the cause of blue smoke. There are several possible ways for engine oil to leak into the combustion area of the cylinders:

- Leaks between worn valve guides and valve stems
- Worn components or damaged components (pistons, piston rings, or dirty return holes for the engine oil)
- Incorrect installation of the compression ring and/or the intermediate ring
- Leaks past the seal rings in the turbocharger shaft
- Overfilling of the crankcase

- Wrong dipstick or guide tube
- Sustained operation at light loads

Excessive consumption of engine oil can also result if engine oil with the wrong viscosity is used. Engine oil with a thin viscosity can be caused by fuel leakage into the crankcase or by increased engine temperature.

i01945015

Increased Engine Oil Temperature - Inspect

Look for a restriction in the oil passages of the oil cooler (if equipped). The oil temperature may be higher than normal when the engine is operating. In such a case, the oil cooler may have a restriction. A restriction in the oil cooler will not cause low oil pressure in the engine.

Cooling System

i02696567

Cooling System - Check (Overheating)

Above normal coolant temperatures can be caused by many conditions. Use the following procedure to determine the cause of above normal coolant temperatures:

1. Check the coolant level in the cooling system. If the coolant level is too low, air will get into the cooling system. Air in the cooling system will cause a reduction in coolant flow and bubbles in the coolant. Air bubbles will keep the coolant away from the engine parts, which will prevent the transfer of heat to the coolant. Damage will be caused to internal components within the coolant pump. Low coolant level is caused by leaks or incorrectly filling the expansion tank.

2. Check the mixture of antifreeze and water. The mixture should be 50 percent water and 50 percent 21825166 POWERPART antifreeze.

3. Check for air in the cooling system. Air can enter the cooling system in different ways. The most common causes of air in the cooling system are not filling the cooling system correctly and combustion gas leakage into the cooling system. Combustion gas can get into the system through inside cracks, a damaged cylinder head, or a damaged cylinder head gasket. Air in the cooling system causes a reduction in coolant flow and bubbles in the coolant. Air bubbles keep the coolant away from the engine parts, which prevents the transfer of heat to the coolant. Damage will be caused to internal components within the coolant pump.

4. Check the sending unit. In some conditions, the temperature sensor in the engine sends signals to a sending unit. The sending unit converts these signals to an electrical impulse which is used by a mounted gauge. If the sending unit malfunctions, the gauge can show an incorrect reading. Also if the electric wire breaks or if the electric wire shorts out, the gauge can show an incorrect reading.

5. Check the radiator for a restriction to coolant flow. Check the radiator for debris, dirt, or deposits on the inside of the core. Debris, dirt, or deposits will restrict the flow of coolant through the radiator.

6. Check the filler cap. A pressure drop in the cooling system can cause the boiling point to be lower. This can cause the cooling system to boil. Cavitation (air bubbles in the system) will be present in the system. Refer to Testing and Adjusting, “Cooling System - Test”.

7. Check the cooling system hoses and clamps. Damaged hoses with leaks can normally be seen. Hoses that have no visual leaks can soften during operation. The soft areas of the hose can become kinked or crushed during operation. These areas of the hose can cause a restriction in the coolant flow. Hoses become soft and/or get cracks after a period of time. The inside of a hose can deteriorate, and the loose particles of the hose can cause a restriction of the coolant flow.

8. Check for a restriction in the air inlet system. A restriction of the air that is coming into the engine can cause high cylinder temperatures. High cylinder temperatures require higher than normal temperatures in the cooling system.

9. Check for a restriction in the exhaust system. A restriction of the air that is coming out of the engine can cause high cylinder temperatures.

   a. Make a visual inspection of the exhaust system.

   b. Check for damage to exhaust piping. Check for damage to the exhaust elbow. If no damage is found, check the exhaust system for a restriction.

10. Check the water temperature regulator. A water temperature regulator that does not open, or a water temperature regulator that only opens part of the way can cause overheating. Refer to Testing and Adjusting, “Water Temperature Regulator - Test”.

11. Check the water pump. A water pump with a damaged impeller does not pump enough coolant for correct engine cooling. Remove the water pump and check for damage to the impeller.

12. Consider high outside temperatures. When outside temperatures are too high for the rating of the cooling system, there is not enough of a temperature difference between the outside air and coolant temperatures. The maximum temperature of the ambient air that enters the engine should not exceed 50 °C (120 °F).

13. When a load that is applied to the engine is too large, the engine rpm does not increase with an increase of fuel. This lower engine rpm causes a reduction in coolant flow through the system. This combination of less air and less coolant flow during high input of fuel will cause above normal heating.

i01889427

Cooling System - Inspect

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages:

- The pressure type cooling system can operate safely at a higher temperature than the boiling point of water at a range of atmospheric pressures.
- The pressure type cooling system prevents cavitation in the water pump.

Cavitation is the sudden generation of low pressure bubbles in liquids by mechanical forces. The generation of an air or steam pocket is much more difficult in a pressure type cooling system.

Regular inspections of the cooling system should be made in order to identify problems before damage can occur. Visually inspect the cooling system before tests are made with the test equipment.

Visual Inspection Of The Cooling System

1. Check the coolant level in the cooling system.
2. Look for leaks in the system.
3. Inspect the radiator for bent fins and other restriction to the flow of air through the radiator.
4. Inspect the drive belt for the fan.
5. Inspect the blades of the fan for damage.
6. Look for air or combustion gas in the cooling system.
7. Inspect the radiator cap for damage. The sealing surface must be clean.
8. Look for large amounts of dirt in the radiator core. Look for large amounts of dirt on the engine.
9. Shrouds that are loose or missing cause poor air flow for cooling.

i01964006

Cooling System - Test

Remember that temperature and pressure work together. When a diagnosis is made of a cooling system problem, temperature and pressure must be checked. The cooling system pressure will have an effect on the cooling system temperature. For an example, refer to Illustration 22. This will show the effect of pressure on the boiling point (steam) of water. This will also show the effect of height above sea level.

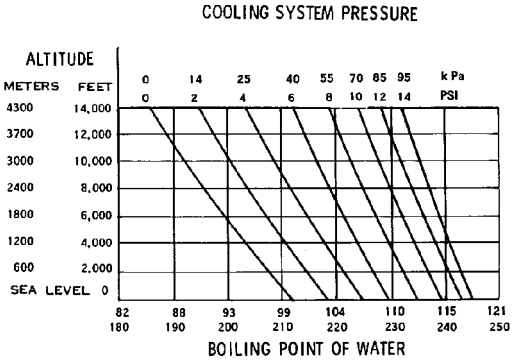


Illustration 22 g00286266

Cooling system pressure at specific altitudes and boiling points of water

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

The coolant level must be to the correct level in order to check the coolant system. The engine must be cold and the engine must not be running.

After the engine is cool, loosen the pressure cap in order to relieve the pressure out of the cooling system. Then remove the pressure cap.

The level of the coolant should not be more than 13 mm (0.5 inch) from the bottom of the filler pipe. If the cooling system is equipped with a sight glass, the coolant should be to the correct level in the sight glass.

Checking the Filler Cap

One cause for a pressure loss in the cooling system can be a faulty seal on the radiator pressure cap.

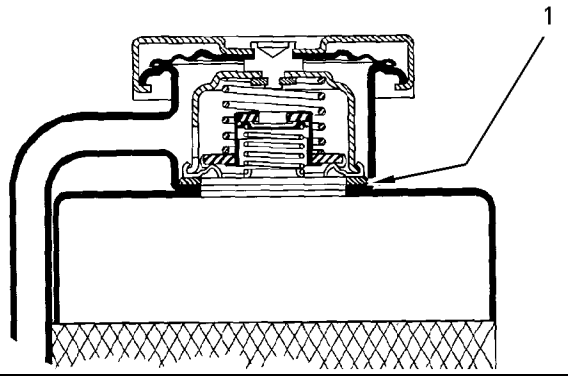


Illustration 23 g00296067

Typical schematic of filler cap

(1) Sealing surface between the pressure cap and the radiator

⚠ WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

To check for the amount of pressure that opens the filler cap, use the following procedure:

1. After the engine cools, carefully loosen the filler cap. Slowly release the pressure from the cooling system. Then, remove the filler cap.

2. Inspect the pressure cap carefully. Look for damage to the seal. Look for damage to the surface that seals. Remove any debris on the cap, the seal, or the sealing surface.

   Carefully inspect the filler cap. Look for any damage to the seals and to the sealing surface. Inspect the following components for any foreign substances:

   - Filler cap
   - Seal
   - Surface for seal

   Remove any deposits that are found on these items, and remove any material that is found on these items.

3. Install the pressure cap onto a suitable pressurizing Pump.

4. Observe the exact pressure that opens the filler cap.

5. Compare the pressure to the pressure rating that is found on the top of the filler cap.

6. If the filler cap is damaged, replace the filler cap.

Testing The Radiator And Cooling System For Leaks

Use the following procedure to test the radiator and the cooling system for leaks.

⚠ WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

1. When the engine has cooled, loosen the filler cap to the first stop. Allow the pressure to release from the cooling system. Then remove the filler cap.

2. Make sure that the coolant covers the top of the radiator core.

3. Put a suitable pressurizing Pump onto the radiator.

4. Use the pressurizing pump to increase the pressure to an amount of 20 kPa (3 psi) more than the operating pressure of the filler cap.

5. Check the radiator for leakage on the outside.

6. Check all connections and hoses of the cooling system for leaks.

   The radiator and the cooling system do not have leakage if all of the following conditions exist:

- You do NOT observe any leakage after five minutes.
- The dial indicator remains constant beyond five minutes.

The inside of the cooling system has leakage only if the following conditions exist:

- The reading on the gauge goes down.
- You do NOT observe any outside leakage.

Make any repairs, as required.

i02696569

Engine Oil Cooler - Inspect

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

Engine oil cooler for the 1104D engine

Perform the following procedure in order to inspect the engine oil cooler (if equipped):

1. Place a container under the oil cooler in order to collect any engine oil or coolant that drains from the oil cooler.
2. Refer to Disassembly and Assembly, “Engine Oil Cooler - Remove” for removal of the engine oil cooler.
3. Thoroughly clean the flange face of the cover plate and the cylinder block.

⚠ 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.

4. Inspect the cooling plates for cracks and dents. Replace the cooling plates if cracks or dents exist. If necessary, clean the outside and clean the inside of the cooling plates. Use a solvent that is not corrosive on copper. Ensure that no restrictions for the flow of lubricating oil exist in the cooling plates.

   Dry the cooling plate with low pressure air. Flush the inside of the cooling plate with clean lubricating oil.
5. Refer to Disassembly and Assembly, “Engine Oil Cooler - Install” for installation of the engine oil cooler.
6. Ensure that the cooling system and the oil system of the engine are filled to the correct level. Operate the engine. Check for oil or coolant leakage.

i01889428

Water Temperature Regulator - Test

Note: Do not remove the water temperature regulator from the water temperature regulator housing in order to perform the test.

1. Remove the water temperature regulator housing which contains the water temperature regulator from the engine. Refer to Disassembly and Assembly, “Water Temperature Regulator - Remove and Install”.
2. Heat water in a pan until the temperature of the water is equal to the fully open temperature of the water temperature regulator. Refer to Specifications, “Water Temperature Regulator” for the fully open temperature of the water temperature regulator. Stir the water in the pan. This will distribute the temperature throughout the pan.
3. Hang the water temperature regulator housing in the pan of water. The water temperature regulator housing must be below the surface of the water. The water temperature regulator housing must be away from the sides and the bottom of the pan.
4. Keep the water at the correct temperature for ten minutes.
5. After ten minutes, remove the water temperature regulator housing. Immediately measure the opening of the water temperature regulator. Refer to Specifications, “Water Temperature Regulator” for the minimum opening distance of the water temperature regulator at the fully open temperature.

If the distance is less than the amount listed in the manual, replace the water temperature regulator. Refer to Disassembly and Assembly, “Water Temperature Regulator - Remove and Install”.

Install the water temperature regulator. Refer to Disassembly and Assembly, “Water Temperature Regulator - Remove and Install”.

Basic Engine

i01889476

Piston Ring Groove - Inspect

Inspect the Piston and the Piston Rings

1. Check the piston for wear and other damage.
2. Check that the piston rings are free to move in the grooves and that the rings are not broken.

Inspect the Clearance of the Piston Ring

1. Remove the piston rings and clean the grooves and the piston rings.

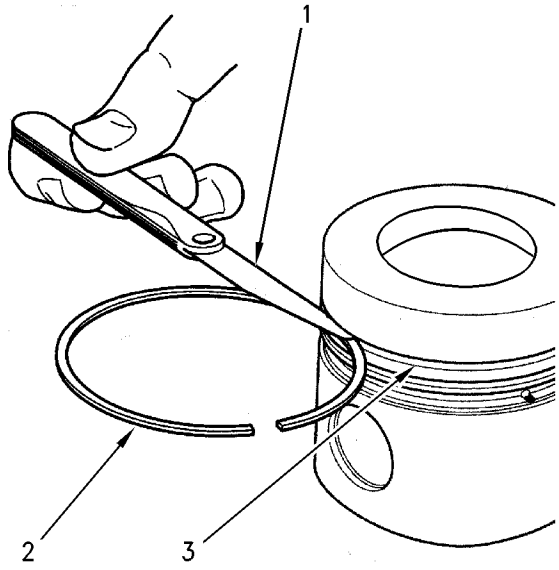


Illustration 24 g00905732

(1) Feeler gauge
(2) Piston ring
(3) Piston grooves

2. Fit new piston rings (2) in the piston grooves (3).
3. Check the clearance for the piston ring by placing a suitable feeler gauge (1) between the piston groove (3) and the top of piston ring (2). Refer to Specifications, “Piston and Rings” for the dimensions.

Note: Some pistons have a tapered top groove and the piston ring is wedged. The clearance for the top piston ring cannot be checked by the above method when this occurs.

Inspect the Piston Ring End Gap

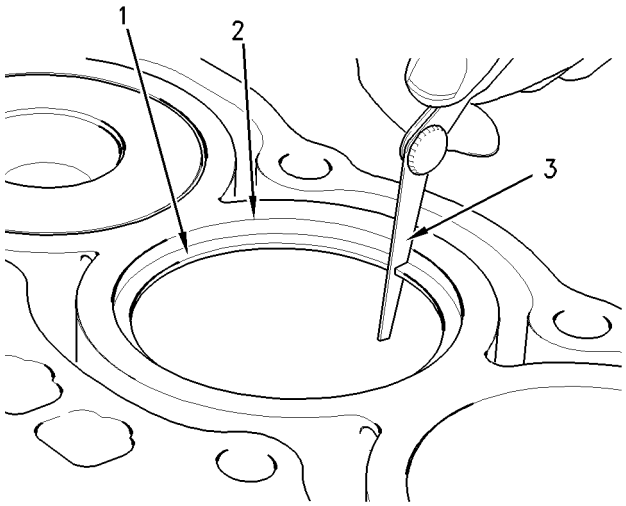


Illustration 25 g00983549

(1) Piston ring
(2) Cylinder ring ridge
(3) Feeler gauge

1. Clean all carbon from the top of the cylinder bores.
2. Place each piston ring (1) in the cylinder bore just below the cylinder ring ridge (2).
3. Use a suitable feeler gauge (3) to measure the piston ring end gap. Refer to Specifications, “Piston and Rings” for the dimensions.

Note: The coil spring must be removed from the oil control ring before the gap of the oil control ring is measured.

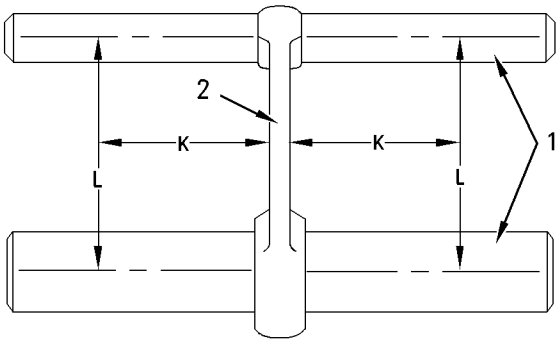
i01946425

Connecting Rod - Inspect

This procedure determines the following characteristics of the connecting rod:

- The distortion of the connecting rod

- The parallel alignment of the bores of the connecting rod



g00927038

Illustration 26

Inspection of the connecting rod parallel alignment.

(1) Measuring pins
(2) Connecting rod
(L) Measure the distance between the center of the bore for the piston pin bearing and the center of the connecting rod bearing bore.
(K) Measure the distance 127 mm (5.0 inch) from the connecting rod.

1. Use the appropriate tools in order to measure the distances for the connecting rod (2).
   - Appropriate gauges for measuring distance
   - Measuring pins (1)

Note: The connecting rod bearings should be removed before taking the measurements.

2. Measure the connecting rod for distortion and parallel alignment between the bores.

   The measurements must be taken at distance (K). Distance (K) has a value of 127 mm (5.0 inch) from both sides of the connecting rod.

   Measure length (L).

   The total difference in measurements of length (L) from each side should not vary more than ± 0.25 mm (± 0.010 inch).

   If the piston pin bearing is not removed, the limits are reduced to ± 0.06 mm (± 0.0025 inch).

3. Inspect the piston pin bearing and the piston pin for wear and other damage.

4. Measure the clearance of the piston pin in the piston pin bearing. Refer to Specifications, “Connecting Rod” for clearance dimensions.

i01748770

Connecting Rod Bearings - Inspect

Check the connecting rod bearings and the connecting rod bearing journal for wear or other damage.

Connecting rod bearings are available with a smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been ground.

i01748792

Main Bearings - Inspect

Check the main bearings for wear or other damage. Replace both halves of the bearings and check the condition of the other bearings if a main bearing is worn or damaged.

Main bearings are available with a smaller inside diameter than the original size bearings. These bearings are for main bearing journals that have been ground.

i01946424

Cylinder Block - Inspect

1. Clean all of the coolant passages and the oil passages.

2. Check the cylinder block for cracks and damage.

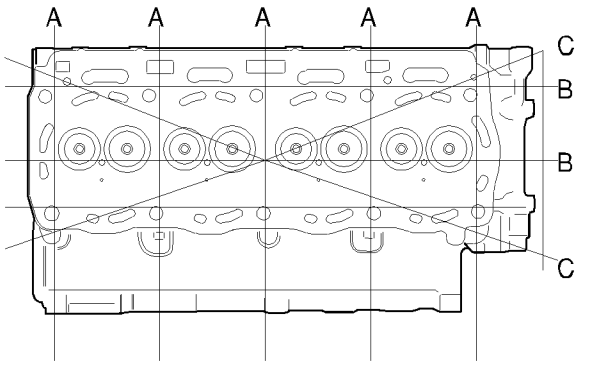
3. The top deck of the cylinder block must not be machined. This will affect the piston height above the cylinder block.

4. Check the camshaft bearing for wear. If a new bearing is needed, use a suitable adapter to press the bearing out of the bore. Ensure that the oil hole in the new bearing faces the front of the block. The oil hole in the bearing must be aligned with the oil hole in the cylinder block. The bearing must be aligned with the face of the recess. Refer to Disassembly and Assembly, “Camshaft Bearings - Remove and Install”.

i02707805

Cylinder Head - Inspect

1. Remove the cylinder head from the engine.
2. Remove the water temperature regulator housing.
3. Inspect the cylinder head for signs of gas or coolant leakage.
4. Remove the valve springs and valves.
5. Clean the bottom face of the cylinder head thoroughly. Clean the coolant passages and the lubricating oil passages. Make sure that the contact surfaces of the cylinder head and the cylinder block are clean, smooth and flat.
6. Inspect the bottom face of the cylinder head for pitting, corrosion, and cracks. Inspect the area around the valve seat inserts and the holes for the fuel injectors carefully.
7. Test the cylinder head for leaks at a pressure of 200 kPa (29 psi).



g01012606

Illustration 27

Flatness of the cylinder head (typical example)

(A) Side to side
(B) End to end
(C) Diagonal

8. Measure the cylinder head for flatness. Measure the flatness of the cylinder head with a straight edge and with a feeler gauge.
   - Measure the cylinder head from one side to the opposite side (A).
   - Measure the cylinder head from one end to the opposite end (B).
   - Measure the cylinder head from one corner to the opposite corner (C).

   Refer to Specifications, “Cylinder Head” for the requirements of flatness.

Resurfacing the Cylinder Head

The bottom face of cylinder head can be resurfaced if any of the following conditions exist:

- The bottom face of the cylinder head is not flat within the specifications.
- The bottom face of the cylinder head is damaged by pitting, corrosion, or wear.

Note: The thickness of the cylinder head must not be less than 117.20 mm (4.614 inch) after the cylinder head has been machined.

If the bottom face of the cylinder head has been remachined, the recesses in the cylinder head for the valve seat inserts must be machined. The valve seat inserts must be ground on the side which is inserted into the cylinder head. Grinding this surface will ensure that no protrusion exists above the bottom face of the cylinder head. Refer to Specifications, “Cylinder Head Valves” for the correct dimensions.

i01889496

Piston Height - Inspect

Table 4

Required Tools		
Part Number	**Part Description**	**Qty**
21825617	Dial gauge	1
21825496	Dial gauge holder	1

If the height of the piston above the cylinder block is not within the tolerance that is given in the Specifications Module, “Piston and Rings”, the bearing for the piston pin must be checked. Refer to Testing and Adjusting, “Connecting Rod - Inspect”. If any of the following components are replaced or remachined, the piston height above the cylinder block must be measured:

- Crankshaft
- Cylinder head
- Connecting rod
- Bearing for the piston pin

The correct piston height must be maintained in order to ensure that the engine conforms to the standards for emissions.

Note: The top of the piston should not be machined. If the original piston is installed, be sure that the original piston is assembled to the correct connecting rod and installed in the original cylinder.

Six grades of length of connecting rods determine the piston height above the cylinder block. The grade of length of a connecting rod is identified by a letter or a color. The letter or the color is marked on the side of the connecting rod. Refer to Testing and Adjusting, “Connecting Rod - Inspect” and Specifications, “Connecting Rod” for additional information.

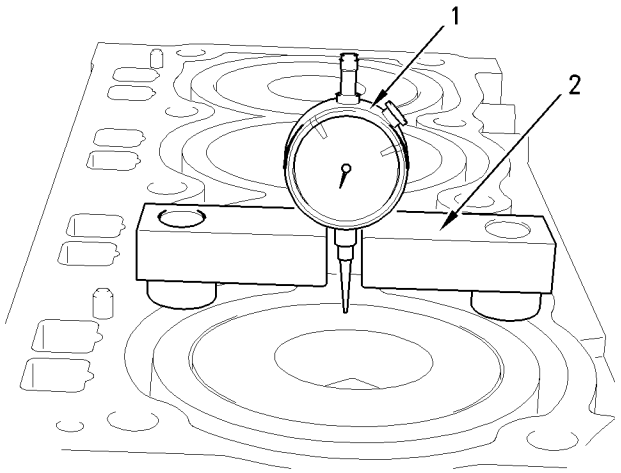


Illustration 28 g00983585

(1) Dial gauge
(2) Dial gauge holder

1. Use the dial gauge (1) and the dial gauge holder (2) in order to measure the piston height above the cylinder block. Use the cylinder block face to zero the dial gauge (1).

2. Rotate the crankshaft until the piston is at the approximate top center.

3. Position the dial gauge holder (2) and the dial gauge (1) in order to measure the piston height above the cylinder block. Slowly rotate the crankshaft in order to determine when the piston is at the highest position. Record this dimension. Compare this dimension with the dimensions that are given in Specifications, “Piston and Rings”.

i01897548

Flywheel - Inspect

Alignment of the Flywheel Face

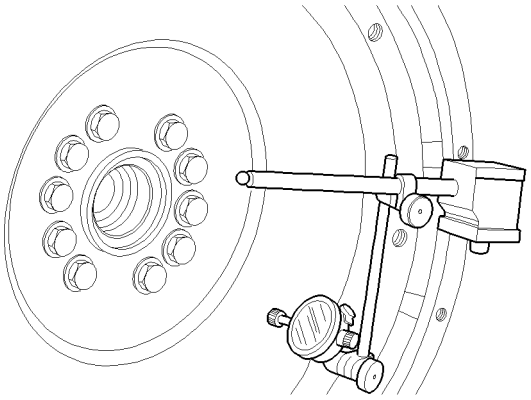


Illustration 29 g00987751

1. Install the dial indicator. Refer to Illustration 29.

2. Set the pointer of the dial indicator to 0 mm (0 inch).

3. Turn the flywheel. Read the dial indicator for every 90 degrees.

Note: During the check, keep the crankshaft pressed toward the front of the engine in order to remove any end clearance.

4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.03 mm (0.001 inch) for every 25 mm (1.0 inch) of the radius of the flywheel. The radius of the flywheel is measured from the axis of the crankshaft to the contact point of the dial indicator.

Flywheel Runout

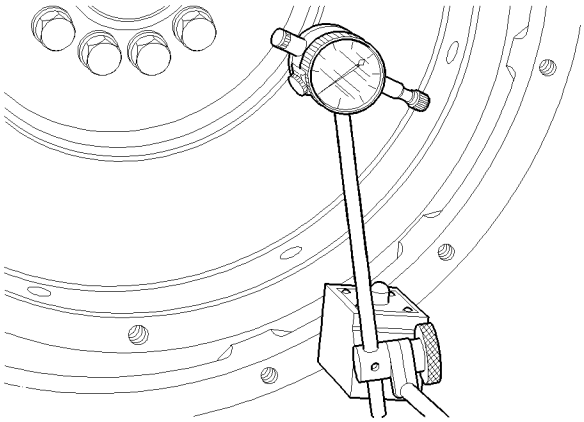


Illustration 30 g00987752

1. Install the dial indicator. Refer to Illustration 30.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 90 degrees.
4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.30 mm (0.012 inch).

i02406200

Flywheel Housing - Inspect

Table 5

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21825617	Dial Gauge	1

Concentricity of the Flywheel Housing

Note: This check must be made with the flywheel and the starter removed and the bolts for the flywheel housing tightened lightly.

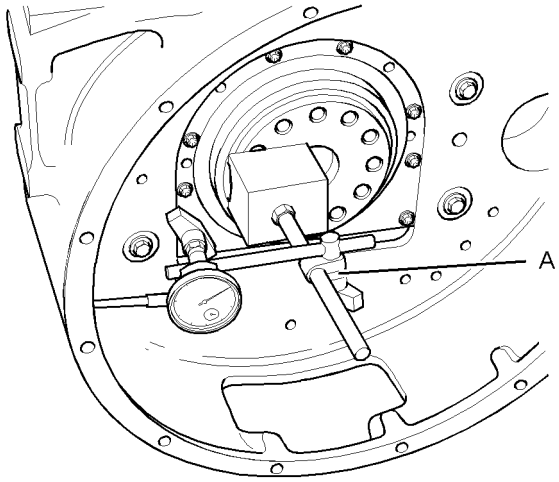


Illustration 31 g01199468

Typical example

1. Install Tooling (A). See illustration 31.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Check the concentricity at intervals of 45 degrees around the flywheel housing.
4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 6.

Note: Any necessary adjustment must be made on the flywheel housing. Then, recheck the concentricity.

Alignment of the Flywheel Housing

Note: This check must be made with the flywheel and the starter removed and the bolts for the flywheel housing tightened to the correct torque.

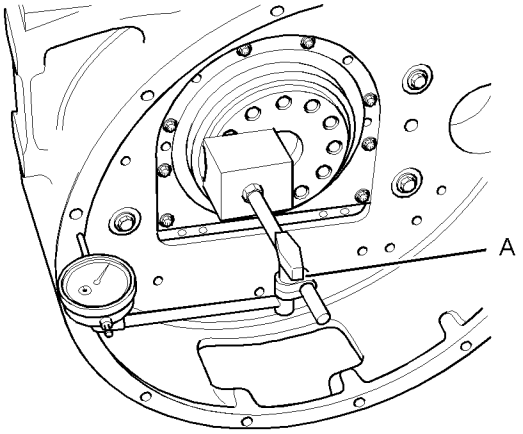


Illustration 32 g01199467

Typical example

1. Install Tooling (A). See illustration 32.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Check the alignment at intervals of 45 degrees around the flywheel housing.
4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 6.

Note: Any necessary adjustment must be made on the flywheel housing.

Table 6

Limits for Flywheel Housing Runout and Alignment (Total Indicator Reading)	
Bore of the Housing Flange	**Maximum Limit (Total Indicator Reading)**
410 mm (16.14 inch)	0.25 mm (0.010 inch)
448 mm (17.63 inch)	0.28 mm (0.011 inch)

i01958093

Gear Group - Inspect

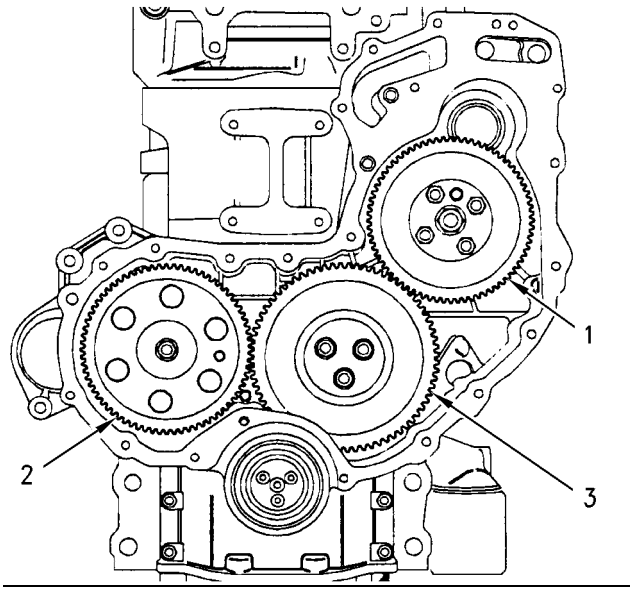


Illustration 33 g00918708

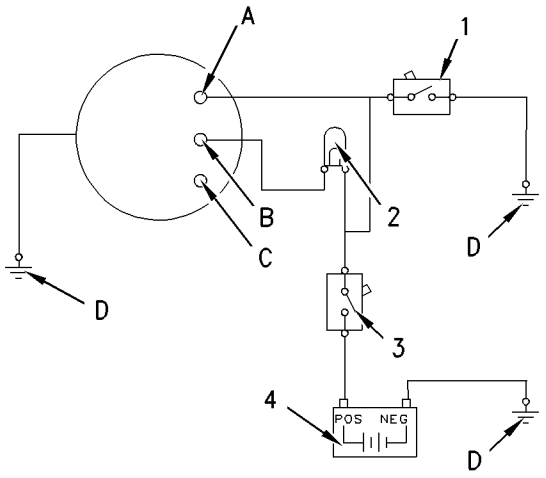
(1) Fuel pump drive gear
(2) Camshaft drive gear
(3) Idler gear

Remove the front timing cover and inspect the gears. The timing marks on the gears indicate the front side of the gears. Inspect the gears for broken teeth or worn teeth.

Electrical System

i02757133

Alternator - Test



g00931045

Illustration 34

Typical wiring schematic for an alternator

(A) Terminal “B+”
(B) Terminal “D+”
(C) Terminal “W”
(D) Ground
(1) Electrical switch
(2) Dash light
(3) Ignition switch
(4) Battery

Warning Lamp Does Not Illuminate

The warning lamp for the charging system should illuminate when the ignition switch is in the ON position. Follow the steps below in order to test the system.

1. Check the light bulb. Replace the light bulb if the element is broken.
2. Use a suitable Multimeter to check the battery voltage. Check the battery voltage with the ignition switch OFF.
3. Check the voltage between the terminal (A) and ground. The measured voltage should equal the battery voltage.
4. Turn the ignition switch to the ON position. Check the voltage between terminal (B) and ground. If the voltage is more than 2 Volts the alternator needs to be replaced.

Warning Light is On When the Engine is Running

1. Start the engine and run the engine at fast idle.
2. Measure the voltage between terminal (A) and ground.
3. Measure the voltage between terminal (B) and ground.
4. The measured voltage for terminal (A) and terminal (B) should be 13 to 15 volts for a 12 volt system. The measured voltage for terminal (A) and terminal (B) should be 26 to 30 volts for a 24 volt system.
5. If the voltages do not match replace the alternator.
6. Increase the engine to high idle. Turn an electrical load ON.
7. Measure the voltage between terminal (A) and ground.
8. Measure the voltage between terminal (B) and ground.
9. The measured voltage for terminal (A) and terminal (B) should be 13 to 15 volts for a 12 volt system. The measured voltage for terminal (A) and terminal (B) should be 26 to 30 volts for a 24 volt system.
10. Replace the alternator if the voltage does not match.

Intermittent Charging

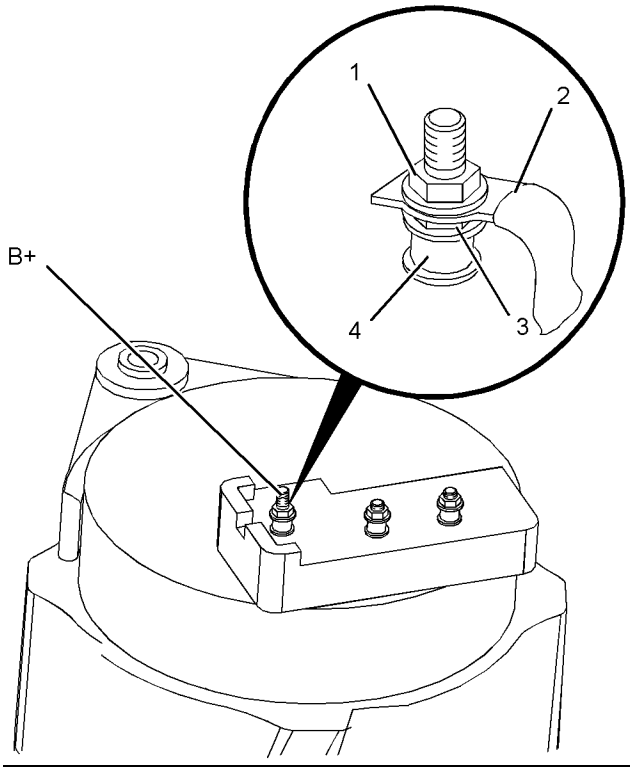


Illustration 35 g01380690

Intermittent charging may occur. if the cable connected to the terminal “B+” (A) has a faulty connection.

1. Check that the connection is secure.
2. If the connection is not secure, then remove the upper nut (1). Remove the cable (2). Check that the lower nut (3) that secures the collar (4) to the terminal “B+” is secure and undamaged. If the lower nut (9) is damaged then renew the nut. Tighten the nut to a torque of 4 N·m (2.9502 lb ft) to 5 N·m (3.6878 lb ft).
3. Check the connector on the end of the cable (2) for damage. If the connector is damaged, renew the connector.
4. Replace the cable (2) and the connector onto the terminal “B+” and tighten the upper nut (1) to a torque of7.0 ± 1.0 N·m (5.1629 ± 0.7376 lb ft).
5. Reconnect the battery. Ensure that the polarity is correct.
6. Run the engine. Measure the voltage between terminal “B+” and the body of the alternator.

   The correct reading should be between 13.5 to 14.7 volts.
7. If the voltage does not meet the specification then the Alternator should be changed.

i01899136

Battery - Test

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition. The wire and cable connections must be clean, and both components must be tight.

⚠ WARNING

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operated. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Injury to personnel can be the result.

The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery.

NOTICE
The charging unit will be damaged if the connections between the battery and the charging unit are broken while the battery is being charged. Damage occurs because the load from the battery is lost and because there is an increase in charging voltage. High voltage will damage the charging unit, the regulator, and other electrical components.

The correct procedures to test the battery can be found in the manual that is supplied by the OEM.

i01945632

Electric Starting System - Test

General Information

All electrical starting systems have four elements:

- Ignition switch
- Start relay
- Starting motor solenoid
- Starting motor

Start switches have a capacity of 5 to 20 amperes. The coil of a start relay draws about 1 ampere between test points. The switch contacts of the start relay for the starting motor are rated between 100 and 300 amperes. The start relay can easily switch the load of 5 to 50 amperes for the starting motor solenoid.

The starting motor solenoid is a switch with a capacity of about 1000 amperes. The starting motor solenoid supplies power to the starter drive. The starting motor solenoid also engages the pinion to the flywheel.

The starting motor solenoid has two coils. The pull-in coil draws about 40 amperes. The hold-in coil requires about 5 amperes.

When the magnetic force increases in both coils, the pinion gear moves toward the ring gear of the flywheel. Then, the solenoid contacts close in order to provide power to the starting motor. When the solenoid contacts close, the ground is temporarily removed from the pull-in coil. Battery voltage is supplied on both ends of the pull-in coil while the starting motor cranks. During this period, the pull-in coil is out of the circuit.

Cranking of the engine continues until current to the solenoid is stopped by releasing the ignition switch.

Power which is available during cranking varies according to the temperature and condition of the batteries. The following chart shows the voltages which are expected from a battery at the various temperature ranges.

Table 7

Typical Voltage Of Electrical System During Cranking At Various Ambient Temperatures		
Temperature	**12 Volt System**	**24 Volt System**
−23 to −7°C (−10 to 20°F)	6 to 8 volts	12 to 16 volts
−7 to 10°C (20 to 50°F)	7 to 9 volts	14 to 18 volts
10 to 27°C (50 to 80°F)	8 to 10 volts	16 to 24 volts

The following table shows the maximum acceptable loss of voltage in the battery circuit. The battery circuit supplies high current to the starting motor. The values in the table are for engines which have service of 2000 hours or more.

Table 8

Maximum Acceptable Voltage Drop In The Starting Motor Circuit During Cranking		
Circuit	**12 Volt System**	**24 Volt System**
Battery post “-” to the starting motor terminal “-”	0.7 volts	1.4 volts
Drop across the disconnect switch	0.5 volts	1.0 volts
Battery post “+” to the terminal of the starting motor solenoid “+”	0.5 volts	1.0 volts
Solenoid terminal “Bat” to the solenoid terminal “Mtr”	0.4 volts	0.8 volts

Voltage drops that are greater than the amounts in Table 8 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

Diagnosis Procedure

The procedures for diagnosing the starting motor are intended to help the technician determine if a starting motor needs to be replaced or repaired. The procedures are not intended to cover all possible problems and conditions. The procedures serve only as a guide.

Note: Do not crank the engine for more than 30 seconds. Allow the starter to cool for two minutes before cranking the engine again.

If the starting motor does not crank or cranks slow, perform the following procedure:

1. Measure the voltage of the battery.

Measure the voltage across the battery posts with the multimeter when you are cranking the engine or attempting to crank the engine. Do not measure the voltage across the cable post clamps.

a. If the voltage is equal or greater than the voltage in Table 7, then go to Step 2.

b. The battery voltage is less than the voltage in Table 7.

A low charge in a battery can be caused by several conditions.

- Deterioration of the battery
- A shorted starting motor
- A faulty alternator
- Loose drive belts
- Current leakage in another part of the electrical system

2. Measure the current that is sent to the starting motor solenoid from the positive post of the battery.

Note: If the following conditions exist, do not perform the test in Step 2 because the starting motor has a problem.

- The voltage at the battery post is within 2 volts of the lowest value in the applicable temperature range of Table 7.
- The large starting motor cables get hot.

Use a suitable ammeter in order to measure the current. Place the jaws of the ammeter around the cable that is connected to the “bat” terminal. Refer to the Specifications Module, “Starting Motor” for the maximum current that is allowed for no load conditions.

The current and the voltages that are specified in the Specifications Module are measured at a temperature of 27°C (80°F). When the temperature is below 27°C (80°F), the voltage will be lower through the starting motor. When the temperature is below 27°C (80°F), the current through the starting motor will be higher. If the current is too great, a problem exists in the starting motor. Repair the problem or replace the starting motor.

If the current is within the specification, proceed to Step 3.

3. Measure the voltage of the starting motor.

   a. Use the multimeter in order to measure the voltage of the starting motor, when you are cranking or attempting to crank the engine.

   b. If the voltage is equal or greater than the voltage that is given in Table 7, then the battery and the starting motor cable that goes to the starting motor are within specifications. Go to Step 5.

   c. The starting motor voltage is less than the voltage specified in Table 7. The voltage drop between the battery and the starting motor is too great. Go to Step 4.

4. Measure the voltage.

   a. Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with the voltage drops which are allowed in Table 8.

   b. Voltage drops are equal to the voltage drops that are given in Table 8 or the voltage drops are less than the voltage drops that are given in Table 8. Go to Step 5 in order to check the engine.

   c. The voltage drops are greater than the voltage drops that are given in Table 8. The faulty component should be repaired or replaced.

5. Rotate the crankshaft by hand in order to ensure that the crankshaft is not stuck. Check the oil viscosity and any external loads that could affect the engine rotation.

   a. If the crankshaft is stuck or difficult to turn, repair the engine.

   b. If the engine is not difficult to turn, go to Step 6.

6. Attempt to crank the starting motor.

   a. The starting motor cranks slowly.

      Remove the starting motor for repair or replacement.

   b. The starting motor does not crank.

      Check for the blocked engagement of the pinion gear and flywheel ring gear.

Note: Blocked engagement and open solenoid contacts will give the same electrical symptoms.

i01911231

Glow Plugs - Test

Continuity Check of the Glow Plugs

The following test will check the continuity of the glow plugs.

1. Disconnect the power supply and the bus bar.

2. Use a suitable digital multimeter to check continuity (resistance). Turn the audible signal on the digital multimeter ON.

3. Place one probe on the connection for the glow plug and the other probe to a suitable ground. The digital multimeter should make an audible sound. Replace the glow plug if there is no continuity.

4. Check the continuity on all the glow plugs.

Checking The Operation of The Glow Plug

The following test will check the operation of the glow plugs.

1. Disconnect the power supply and the bus bar.

2. Connect the power supply to only one glow plug.

3. Place a suitable ammeter on the power supply wire.

4. Connect a suitable digital multimeter to the terminal on the glow plug and to a suitable ground.

5. Turn the switch to the ON position in order to activate the glow plugs.

Table 9

12 Volt System	
Amp	**Time (sec)**
30	Initial
21	4
14	8
10	20
9	60

Table 10

24 Volt System	
Amp	**Time (sec)**
12	Initial
8.5	8
7	20
6	60

6. Check the reading on all of the glow plugs.

7. If there is no reading on the ammeter check the electrical connections. If the readings on the ammeter are low replace the glow plugs. If there is still no reading replace the glow plugs.

i02730999

V-Belt - Test

Table 11

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Belt Tension Gauge	1

Table 12

Belt Tension Chart			
Size of Belt	**Width of Belt**	**Gauge Reading**	
		Initial Belt Tension(1)	**Used Belt Tension**(2)
1/2	13.89 mm (0.547 Inch)	535 N (120 lb)	355 N (80 lb)
Measure the tension of the belts.			

(1) Initial Belt Tension refers to a new belt.
(2) Used Belt Tension refers to a belt that has been in operation for 30 minutes or more at the rated speed.

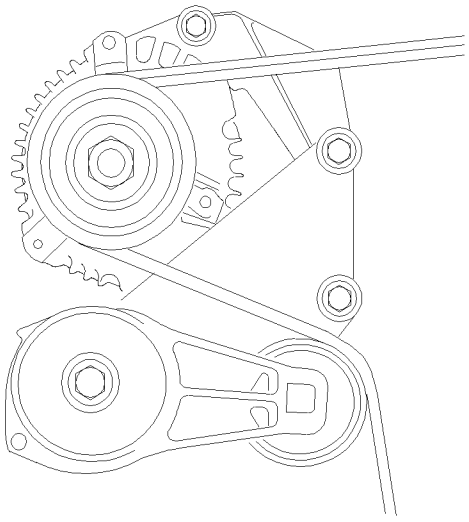
Install Tooling (A) at the center of the longest free length of belt and check the tension on both belts. Check and adjust the tension on the tightest belt. To adjust the belt tension, refer to Disassembly and Assembly, “Alternator - Install”.

Poly V-Belt

NOTICE
Ensure that the engine is stopped before any servicing or repair is performed.

To maximize the engine performance, inspect the poly v-belt (1) for wear and for cracking. Replace the poly v-belt if the belt is worn or damaged.

- If the poly v-belt (1) has more than four cracks per 25.4000 mm (1 inch) the belt must be replaced.
- Check the poly v-belt for cracks, splits, glazing, grease, and splitting.



g01216014

Illustration 36
Typical example

To replace the poly v-belt, refer to Disassembly and Assembly, “Alternator Belt - Remove and Install”.

If necessary, replace the belt tensioner. Refer to Disassembly and Assembly, “Alternator Belt - Remove and Install”.

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KENR6247
May 2007

Disassembly and Assembly

1104D (Mech) Industrial Engine

NK (Engine)
NL (Engine)
NM (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

i02628881

Fuel Priming Pump and Fuel Filter Base - 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: 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.

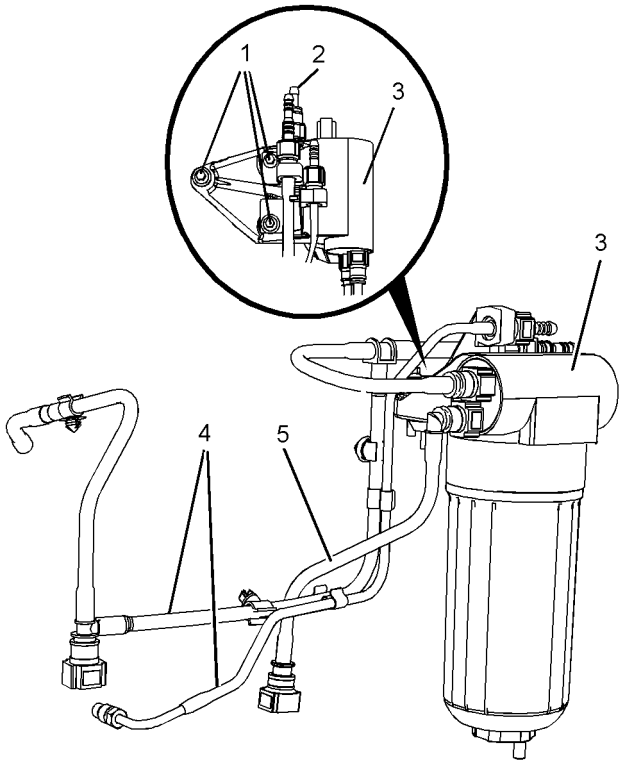


Illustration 1 g01318612
Typical example

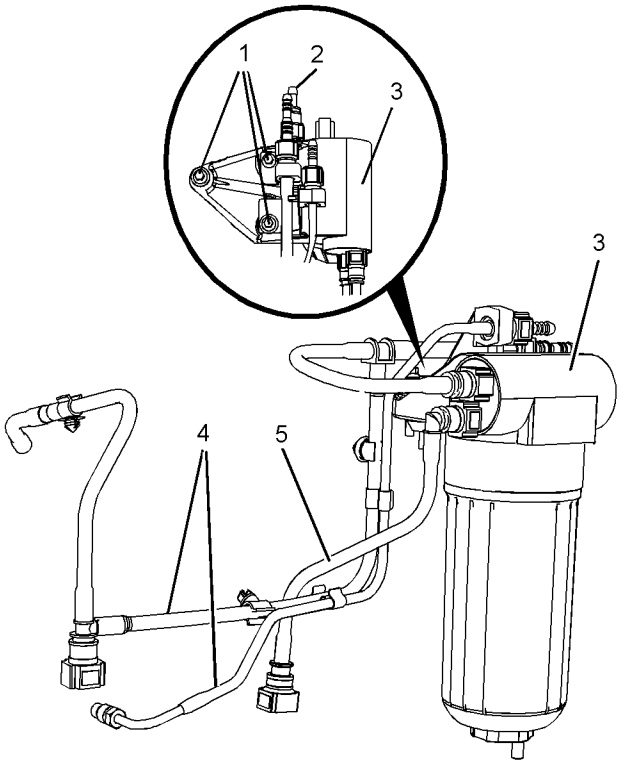
1. Isolate the fuel supply.
2. Isolate the electrical supply.
3. Disconnect plastic tube assemblies (4) and (5) from fuel priming pump (3).
4. Disconnect plastic tube assembly (2) from fuel priming pump (3).
5. Plug all the connections on fuel priming pump (3) and plastic tube assemblies (4) and (5).
6. Disconnect the harness assembly from fuel priming pump(3).
7. Support the fuel priming pump. Remove bolts and washers (1) and remove fuel priming pump (3).

Note: Note the location and the orientation of the brackets for the tube assemblies.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.



g01318612

Illustration 2

Typical example

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

2. Position the fuel priming pump (3) onto the cylinder head. Install bolts and washers (1). Ensure that any brackets that are retained by the bolts are installed in the correct position. Tighten the bolts to a torque on 9 N·m (80 lb in).

3. Remove all plugs from the fuel priming pump and from the plastic tube assemblies. Connect plastic tube assemblies (4) and (5) to fuel priming pump (3).

4. Connect plastic tube assembly (2) to fuel priming pump (3).

5. Install the harness assembly to fuel priming pump (3).

6. Restore the fuel supply.

7. Restore the electrical supply.

8. Remove the air from the fuel system. Refer to Operations and Maintenance Manual, “Fuel System - Prime”.

i02628850

Fuel Injection Lines - 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. Isolate the fuel supply.

2. Isolate the electrical supply.

3. If the engine is equipped with a cover over the fuel injectors remove the cover. Refer toDisassembly and Assembly, “Fuel Injector Cover - Remove and Install”.

4. Remove the breather tube from the valve mechanism cover. Refer toDisassembly and Assembly, “Crankcase Breather- Remove and Install”.

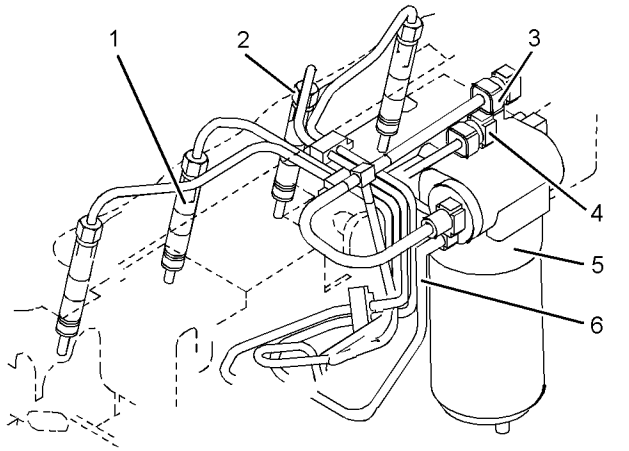


Illustration 3 g01343040

5. Loosen the clip and disconnect plastic tube assembly (3) from fuel priming pump (5).

6. Loosen the clip and disconnect plastic tube assembly (4) from the fuel return.

7. Remove plastic tube assembly (6).

8. Disconnect fuel injection lines (2) at fuel injectors (1).

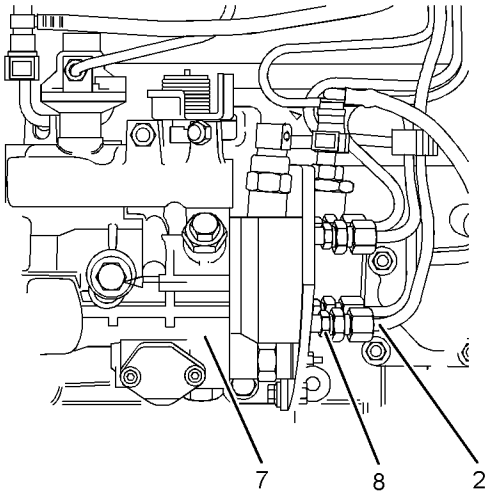


Illustration 4 g01319327

Typical example

9. Disconnect fuel injection lines (2) at fuel injection pump (7). Ensure that connections (8) do not turn.

10. Plug and cap all open ports, fuel injection lines and all tube assemblies.

Installation Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Inspect the fuel injection lines for damage. Replace any components that are damaged.

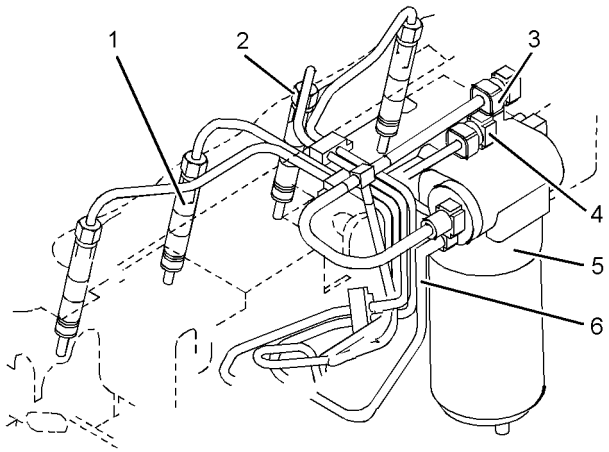


Illustration 5 g01343040

Typical example

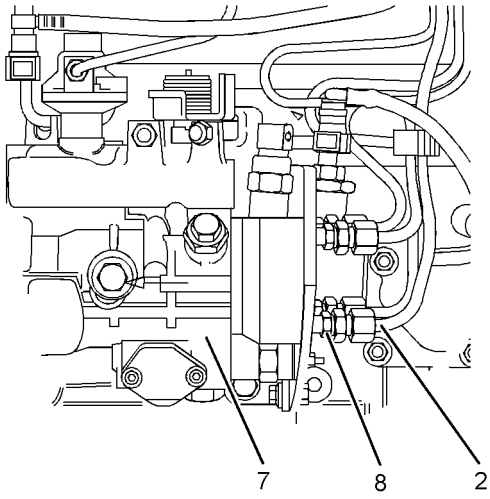


Illustration 6 g01319327

2. Remove the caps from fuel injection pump (7) and from fuel injectors (1). Remove the caps from fuel injection lines (2).

3. Install fuel injection lines(2). Loosely connect the nuts at both ends of the fuel injection lines.

4. Tighten fuel injection lines (2) at fuel injector (1) to a torque of 30 N·m (22 lb ft).

5. Tighten fuel injection lines (2) at fuel injection pump (7) to 30 N·m (22 lb ft). Ensure that the connection (8) does not turn.

Note: Ensure that each fuel injection line does not contact any other fuel injection line or any other engine component.

6. Remove the caps from fuel priming pump (5) and from the plastic tube assemblies.

7. Connect plastic tube assembly (4) to the fuel return. Secure the plastic tube assembly with the clip.

8. Connect plastic tube assembly (3) to the fuel priming pump. Secure the plastic tube assembly with the clip.

9. Install plastic tube assembly (6).

10. Install the breather tube to the valve mechanism cover. Refer toDisassembly and Assembly, “Crankcase Breather- Remove and Install”.

11. If the engine is equipped with a cover over the fuel injectors install the cover. Refer toDisassembly and Assembly, “Fuel Injector Cover - Remove and Install”.

12. Restore the fuel supply.

13. Restore the electrical supply.

14. Remove the air from the fuel system. Refer to the Operations and Maintenance Manual, “Fuel System - Prime”.

i02628851

Fuel Injector Cover - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

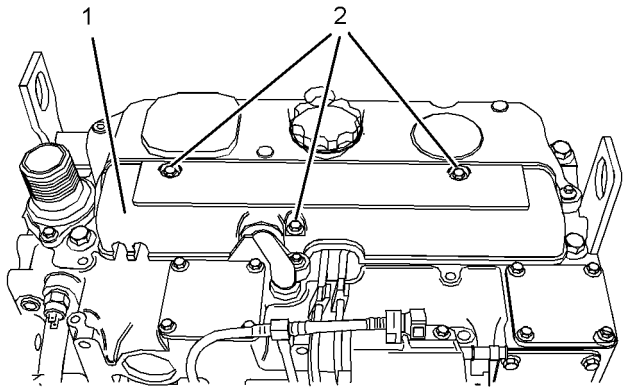


Illustration 7 g01319811
Typical example

1. Thoroughly clean all of the outer surfaces of cover (1).

2. Remove bolts (2) from the cover (1).

3. Remove cover (1).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

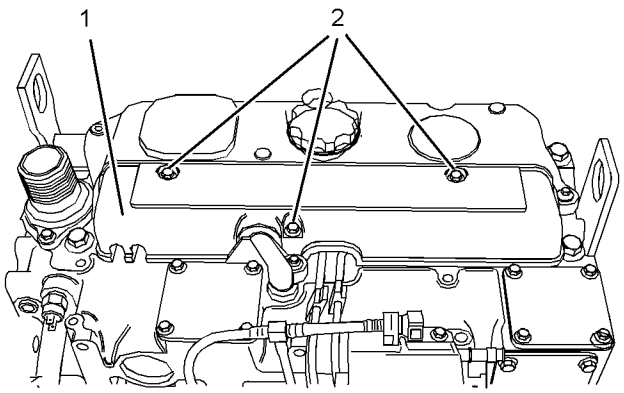


Illustration 8 g01319811
Typical example

1. Thoroughly clean all of the inner surfaces of cover (1).
2. Install cover (1).
3. Install bolts (2). Tighten bolts (2) to a torque of 9 N·m (7 lb ft).

i02744499

Fuel Injection Pump - Remove

Removal Procedure

Table 1

Required Tools			
Tool	Part Number	Part Name	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

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: 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. Isolate the fuel supply.
2. Isolate the electrical supply.

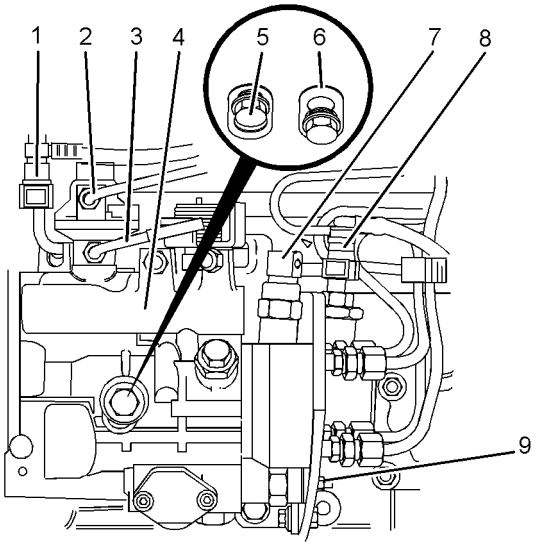


Illustration 9 g01349817
Typical example

3. Disconnect plastic tube assemblies (1) and (8) from the fuel injection pump (4).
4. Disconnect tube assembly (3) from the fuel injection pump (4).

5. Remove the fuel injection lines. Refer to Disassembly and Assembly, “Fuel Injection Lines - Remove”.

6. Remove tube assembly (2).

7. Disconnect the harness assembly from solenoid (7).

8. Disconnect the harness assembly from solenoid (9).

9. 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”.

10. 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” for the correct procedure.

11. 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 and Install” for the correct procedure.

12. Loosen locking screw (5). Rotate spacer (6) in order to allow locking screw (5) to tighten against the shaft of the fuel injection pump. Rotate the fuel injection pump gear in a counterclockwise direction in order to remove the backlash. Tighten locking screw (5) to a torque of 17 N·m (13 lb ft).

Note: Locking screw (5) must be tightened in order to prevent the shaft of the fuel injection pump from rotating. The shaft of the fuel injection pump must not be rotated after the fuel injection pump has been removed from the engine.

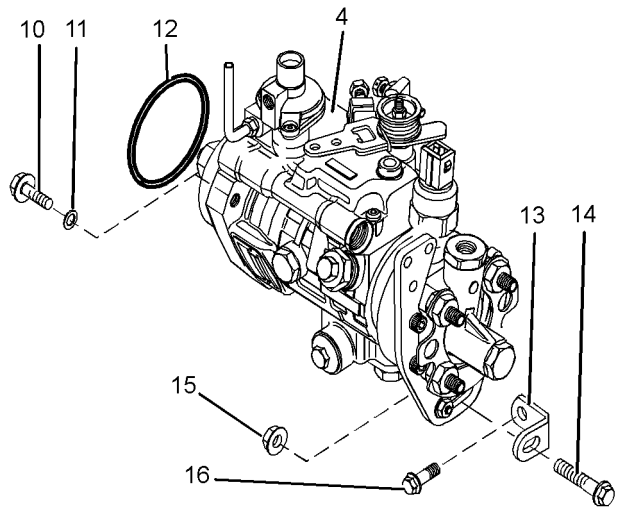


Illustration 10 g01349818

13. Remove nut (15). Remove bolt (14).

14. Remove bolt (16) and bracket (13) from the cylinder block.

15. Remove bolts (10) and washers (11) in order to remove the fuel injection pump (4).

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

16. Remove the fuel injection pump from the front housing. Remove O-ring seal (12).

i02744500

Fuel Injection Pump - Install

Installation Procedure

Table 2

Required Tools			
Tool	**Part Number**	**Part Name**	**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	21820221	POWERPART Rubber Grease	1

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. Inspect the bore in the front housing 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”.

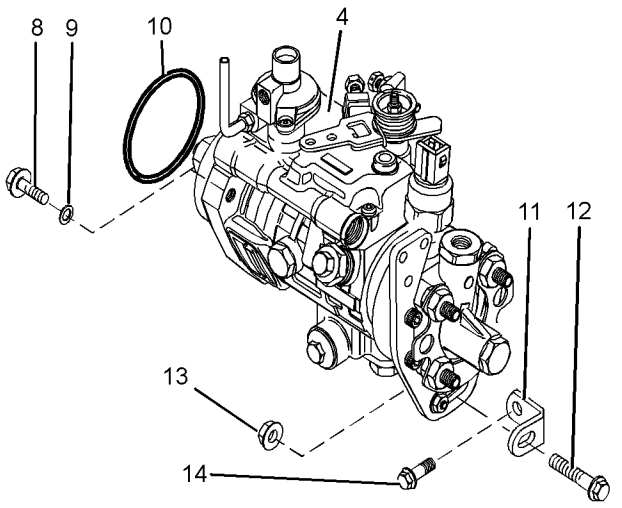


Illustration 11 g01350306
Typical example

2. Use Tooling (D) in order to lubricate O-ring seal (10). Install a new O-ring seal (10) onto the fuel injection pump (4).

3. Install the new washers (9) to bolts (8).

4. Align the holes in the fuel injection pump with the holes in the front housing. Install the fuel injection pump (4) to the housing.

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

5. Install bolts (8). Tighten bolts (8) to a torque of 25 N·m (18 lb ft).

6. Position support bracket (11) onto the cylinder block. Install bolt (14) finger tight.

7. Install bolt (12) and nut (13) finger tight.

8. Tighten bolt (14) to a torque of 44 N·m (32 lb ft). Tighten bolt (12) and nut (13) to a torque of 22 N·m (16 lb ft).

Note: Ensure that the fuel injection pump is not stressed as the bolts for the bracket are tightened.

9. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to Systems Operation, Testing and Adjusting, “Fuel Injection Timing - Check”. If necessary, 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: Either Tooling (A) can be used. Use the Tooling that is most suitable.

10. 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” for the correct procedure.

11. Install the fuel injection pump gear to fuel injection pump (4). 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 in the unlocked position after the installation of the fuel injection pump gear is completed.

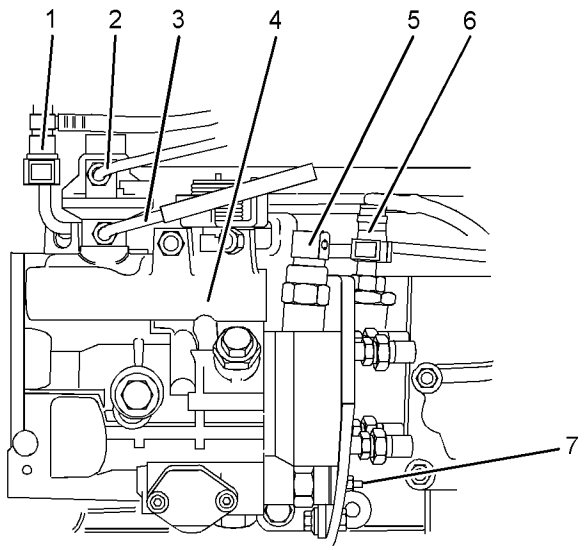


Illustration 12 g01350305
Typical example

12. Remove the plugs and caps from ports and tube assemblies.

13. Install the fuel injection lines. Refer to Disassembly and Assembly, “Fuel Injection Lines - Install”.

14. Connect plastic tube assemblies (1) and (6) to fuel injection pump(4).

15. Connect tube assembly (3) to fuel injection pump (4).

16. Install tube assembly (2).

17. Connect the harness assembly to solenoid (7). Tighten nut (7) to a torque of 4 N·m (35 lb in).

18. Connect the harness assembly to solenoid (5).

19. Restore the fuel supply.

20. Restore the electrical supply.

End By:

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

i02744530

Fuel Injection Pump Gear - Remove

Removal Procedure

Table 3

Required Tools			
Tool	**Part Number**	**Part Name**	**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

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”.

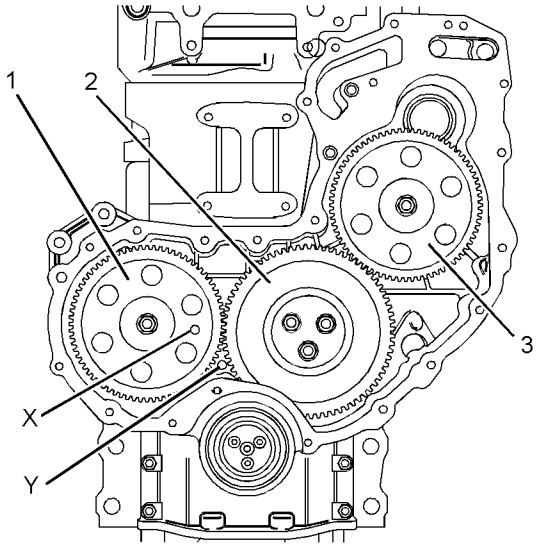


Illustration 13 g01343056

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.

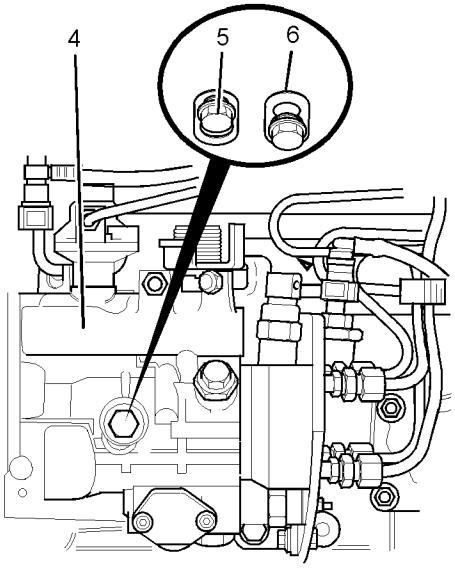


Illustration 14 g01320304

4. Apply sufficient pressure to fuel injection pump gear (3) in a counterclockwise direction in order to remove the backlash. Lock fuel injection pump (4) in this position. Loosen locking screw (5). Rotate spacer (6) in order to allow locking screw (5) to tighten against the shaft of the fuel injection pump. Tighten locking screw (5) to a torque of 17 N·m (13 lb ft).

Note: Locking screw (5) must be tightened in order to prevent the shaft of the fuel injection pump from rotating. The shaft of the fuel injection pump must not be rotated after the fuel injection pump has been removed from the engine.

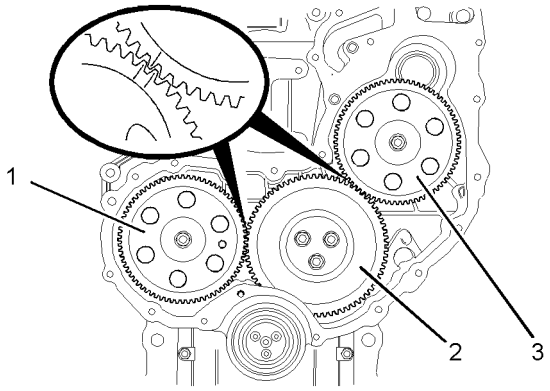


Illustration 15 g01335384

Alignment of timing marks

5. Mark gears (1), (2) and (3) in order to show alignment. Refer to Illustration 15.

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

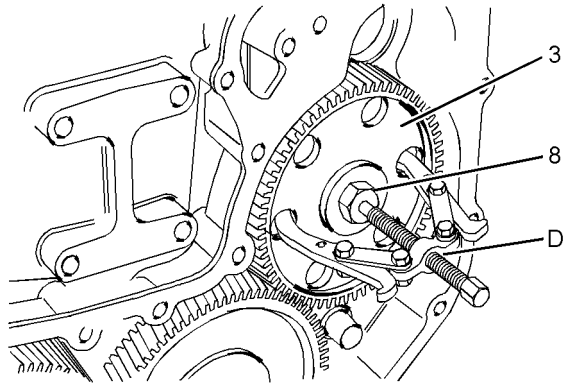


Illustration 16 g01335385

6. Loosen nut (8) on fuel pump gear (3).

7. Install Tooling (D) through two opposite holes in fuel pump gear (3). Tighten Tooling (D) until the fuel pump gear is released.

8. Remove Tooling (D) from fuel pump gear (3).

9. Remove nut (8) and the washer from fuel pump gear (3). Remove the fuel pump gear.

i02744534

Fuel Injection Pump Gear - Install

Installation Procedure

Table 4

Required Tools			
Tool	**Part Number**	**Part Name**	**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	21825617	Dial Indicator Group	1
	-	Finger Clock	1

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 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 the Systems Operation, Testing and Adjusting, “Finding Top Center Position for No. 1 Piston”.

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

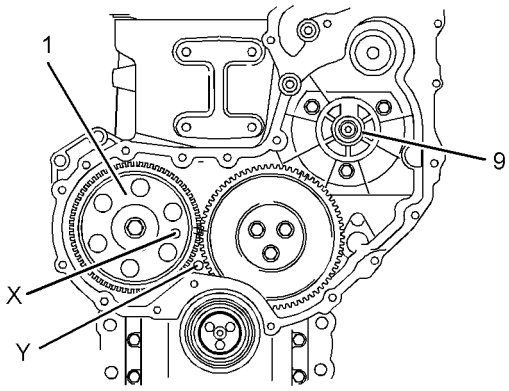


Illustration 17 g01343058
Typical example

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.

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

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

4. Ensure that shaft (9) 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.

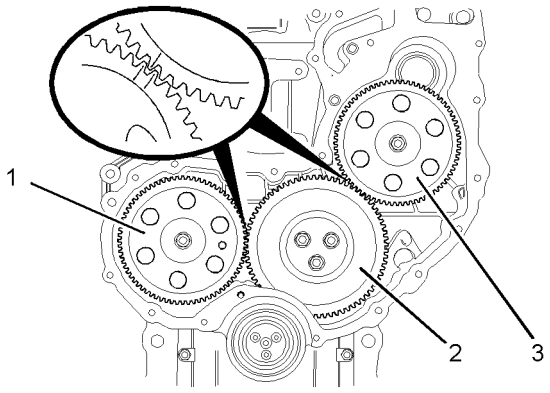


Illustration 18 g01335384
Alignment of timing marks

7. Install fuel pump gear (3) to shaft (9) of the fuel injection pump. Ensure that the timing marks on gears (2) and (3) are in alignment and that the mesh of the gears is correct.

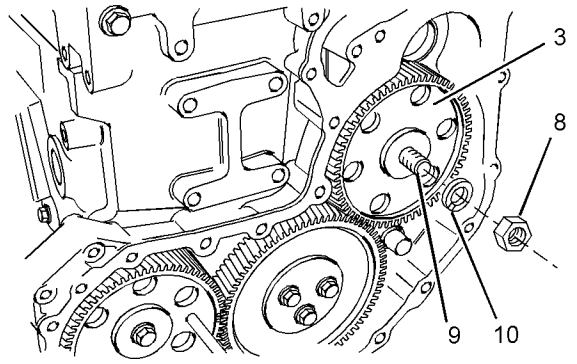


Illustration 19 g01343060
Typical example

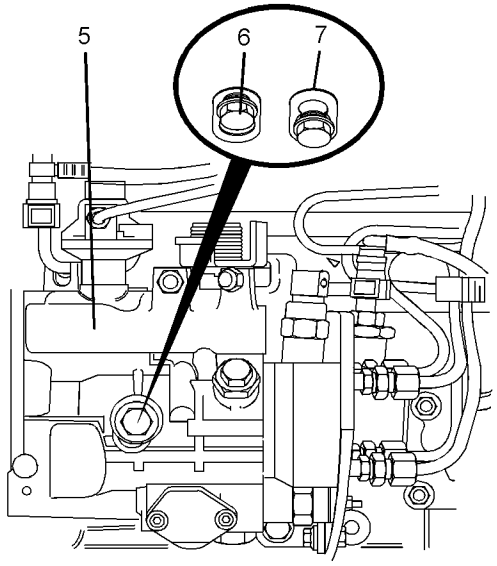


Illustration 20 g01320629
Typical example

8. Install a new spring washer (10) and install nut (8) to shaft (9) of the fuel injection pump. Apply sufficient pressure to the fuel injection pump gear (3) in a counterclockwise direction in order to remove the backlash. Tighten nut (8) to a torque of 24 N·m (17 lb ft). Unlock the fuel injection pump (5).

In order to unlock the fuel injection pump, loosen locking screw (6) on the fuel injection pump. Rotate spacer (7) in order to allow locking screw (6) to tighten against the spacer. Tighten the locking screw against the spacer to a torque of 17 N·m (13 lb ft). This will prevent the locking screw from tightening against the shaft of the fuel injection pump.

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

10. Tighten nut (8) to a torque of 88 N·m (65 lb ft).

11. Use Tooling (D) to measure the backlash of gears (2) and (3). 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”.

i02628874

Fuel Injector - Remove

Removal Procedure

Start By:

a. 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
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 plastic tube assemblies for installation purposes. Plug all plastic tube assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Isolate the fuel supply.

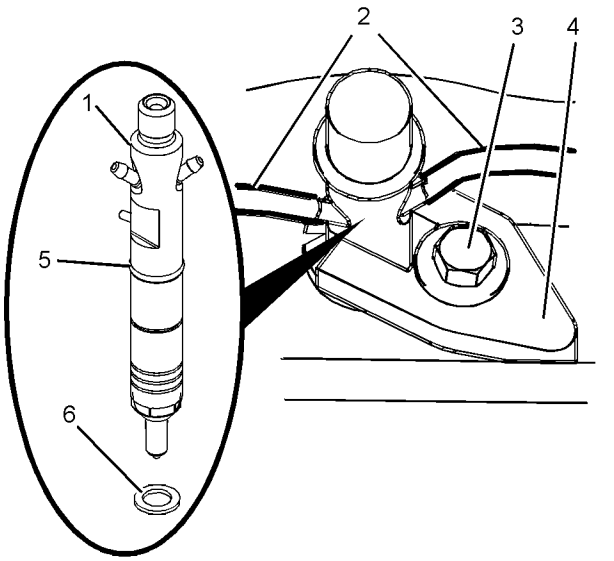


Illustration 21 g01320676
Typical example

2. Remove fuel return lines (2) from fuel injector (1).

3. Remove bolt (3). Remove clamp (4) from fuel injector (1).

4. Remove fuel injector (1) from the cylinder head. Remove O-ring seal (5) from fuel injector (1).

5. Remove seat washer (6).

i02628873

Fuel Injector - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

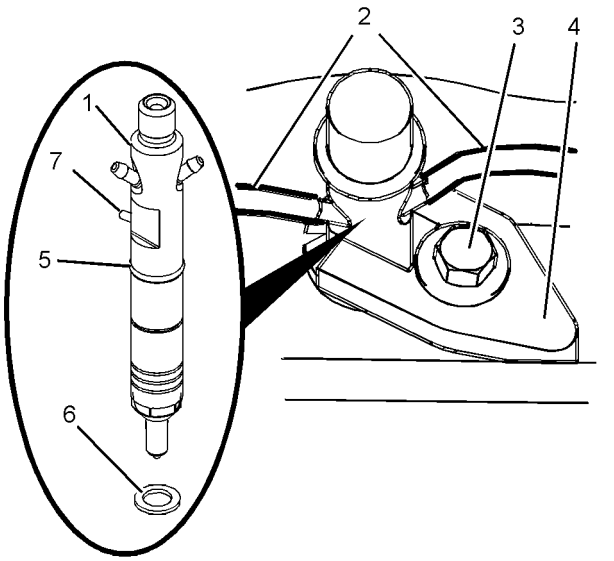


Illustration 22 g01320782

1. Ensure that the seat for the fuel injector in the cylinder head is clean and free from damage. Position a new sealing washer (6) on the seat for the fuel injector in the cylinder head.

2. Install a new O-ring seal (5) on fuel injector (1).

3. Install fuel injector (1) into the cylinder head.

Note: Alignment Pin (7) must be located opposite clamp (4).

4. Position clamp (4) on fuel injector (1). Install bolt (3). Tighten the bolt to a torque of 27 N·m (20 lb ft).

5. Install fuel return lines (2) to fuel injector (1).

End By:

a. Install the fuel injection lines. Refer to Disassembly and Assembly, “Fuel Injection Lines - Install”.

i02628909

Turbocharger - 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.

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

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

2. Loosen the hose clamp and disconnect the air inlet hose from the turbocharger.

3. Loosen the hose clamp and disconnect the air outlet hose from the turbocharger. If the engine is equipped with an air pipe, remove the air pipe and remove the gasket from the cylinder head.

4. If the valve mechanism cover is equipped with a heat shield, remove the heat shield.

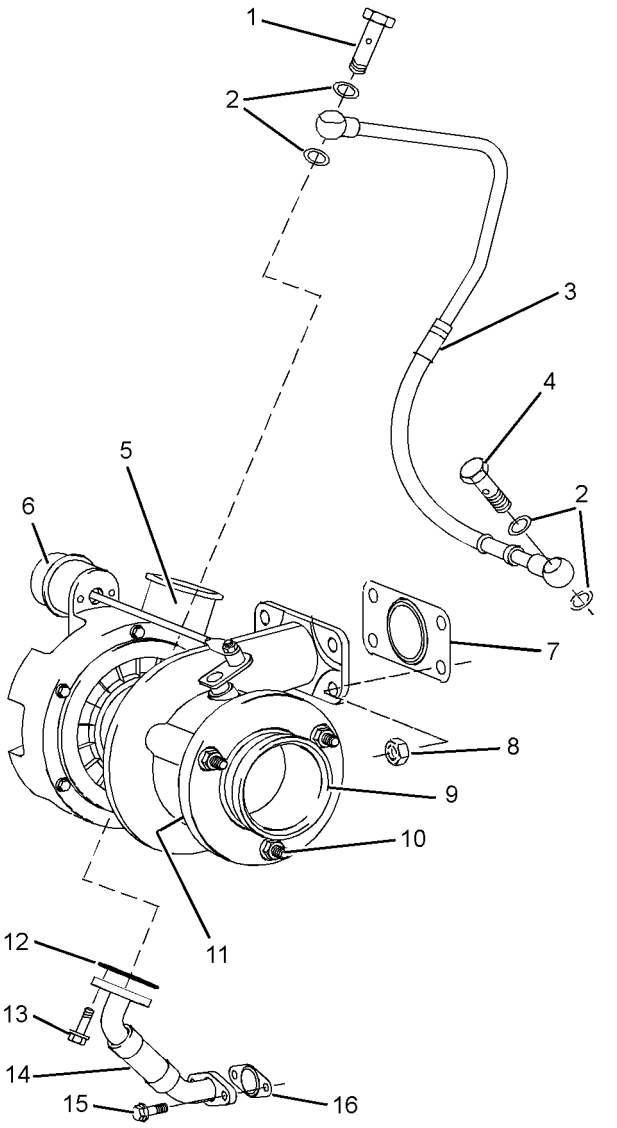


Illustration 23 g01343533
Typical example

5. If the turbocharger is equipped with an adapter (9), Remove nuts (10) and remove adapter (9) from turbocharger (5). Remove gasket (11) (not shown).

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

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

8. Remove bolts (13). Disconnect tube assembly (14) from turbocharger (5). Remove joint (12).

If necessary, remove bolts (15) and remove tube assembly (14) from the cylinder block. Remove joint (16).

If tube assembly (14) is secured with tube clips, loosen the fasteners for the tube clips. If the engine has a top mounted turbocharger, the exhaust manifold must be removed in order to remove tube assembly (13). Refer to Disassembly and Assembly , “Exhaust Manifold - Remove and Install”.

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

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

10. Remove gasket (7).

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

i02628908

Turbocharger - Install

Installation Procedure

Table 5

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.

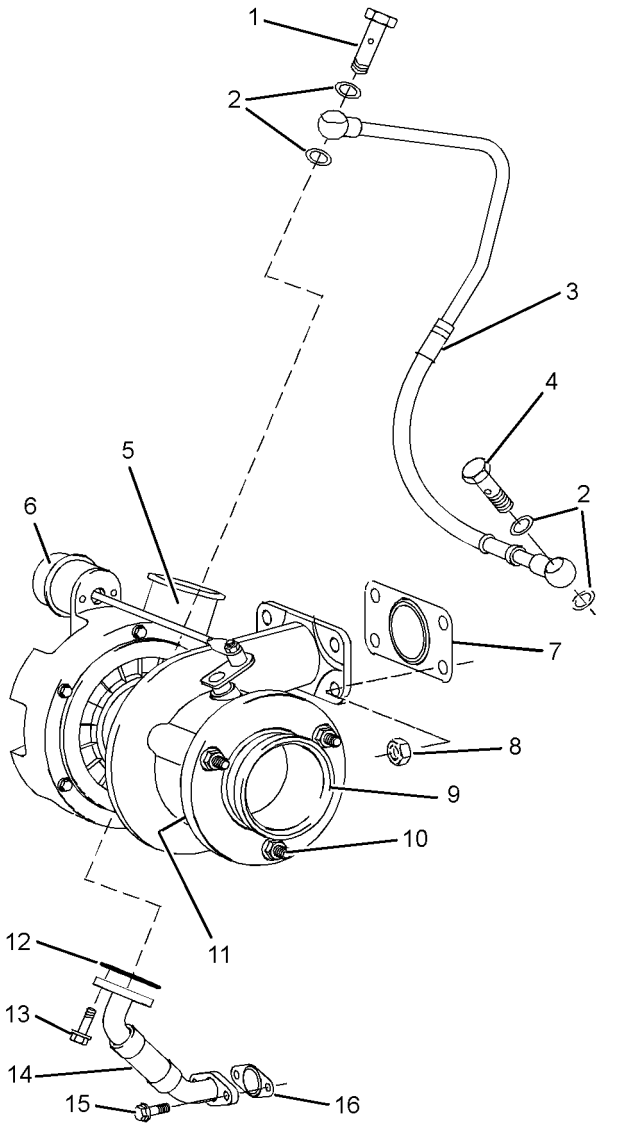


Illustration 24 g01343533
Typical example

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 mating 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 joint (12) and tube assembly (14) onto turbocharger (5). Install bolts (13) finger tight.

7. The turbocharger has different sized bolts (13). Tighten M6 bolts to a torque of 9 N·m (80 lb in).

Tighten M8 bolts to a torque of 22 N·m (16 lb ft).

8. Position a new joint (16) onto the cylinder block. Install bolts (15) finger tight.

9. Tighten bolts (15) to a torque of 22 N·m (16 lb ft).

If tube assembly (14) is secured with tube clips, tighten the fasteners for the tube clips to a torque of 22 N·m (16 lb ft).

10. 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.

11. 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.

12. 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.

13. Tighten banjo bolts (1) and (4) to a torque of 20 N·m (15 lb ft).

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

14. The turbocharger is equipped with a adapter (9). Install a new gasket (11) (not shown) and position the adapter (9) onto the turbocharger. Install nuts (10). Tighten the nuts to a torque of 44 N·m (33 lb ft).

15. If the turbocharger is equipped with an exhaust elbow, install the exhaust elbow. Refer to Disassembly and Assembly, “Exhaust Elbow - Remove and Install”.

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

If the engine is equipped with 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.

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

18. If the valve mechanism cover is equipped with a heat shield, install the heat shield. Tighten the fasteners for the heat shield to a torque of 9 N·m (80 lb in).

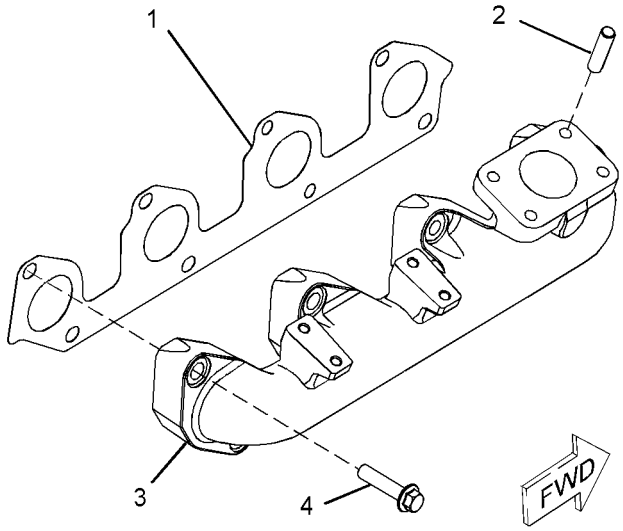
i02628843

Exhaust Manifold - Remove and Install

Removal Procedure

Start By:

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



g01343539

Illustration 25

Typical example

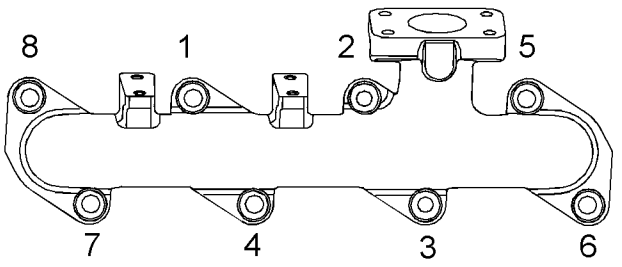


Illustration 26 g01363916

Sequence for loosening the exhaust manifold

1. Loosen bolts (4) in reverse numerical order to the sequence that is shown in Illustration 26.

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

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

Note: Bolts (4) may be equipped with spacers. Record the position of the spacers. 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

Table 6

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Guide Bolt (M10 by 100 mm)	2

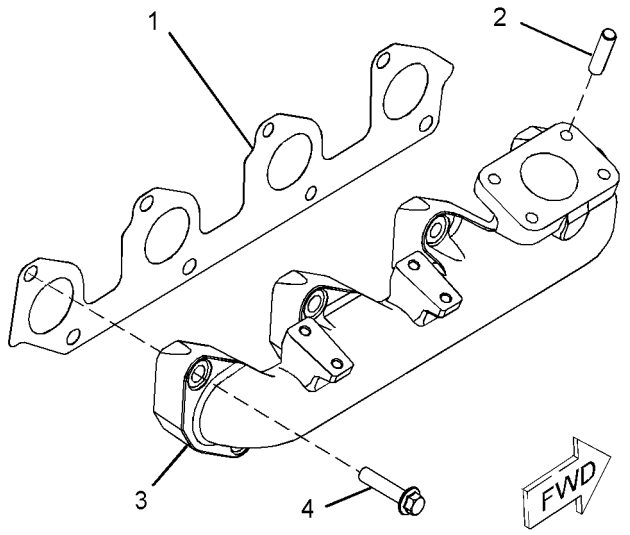


Illustration 27 g01343539

Typical example

1. Ensure that the exhaust manifold is clean and free from damage. Clean the joint face 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).

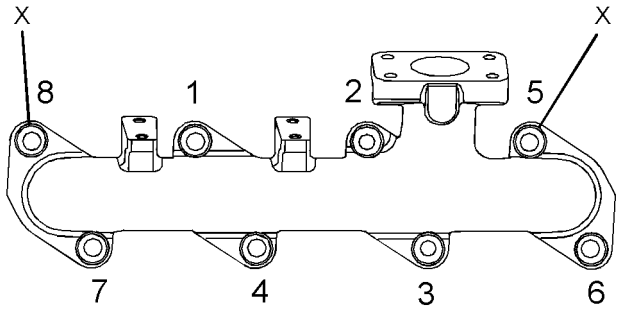


Illustration 28 g01363918

Tightening sequence for the exhaust manifold

3. Install Tooling (A) to the cylinder head in positions (X). Refer to Illustration 28.

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.

Note: If the engine has a top mounted turbocharger, the tube assembly for the oil drain must be connected to the cylinder block before the exhaust manifold is installed.

6. Install new bolts (4) finger tight.

Note: Bolts (4) that were equipped with spacers. Install the spacer in the original position.

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

8. Tighten bolts (4) to a torque of 40 N·m (30 lb ft) in the sequence that is shown in Illustration 28.

End By:

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

i02628842

Exhaust Elbow - Remove and Install

Removal Procedure

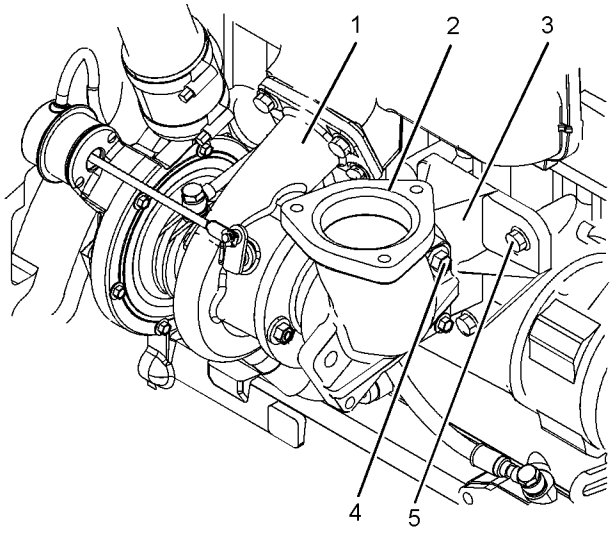


Illustration 29 g01343547

Typical example

1. Remove bolts (4) and remove exhaust elbow (2). Note the orientation of the exhaust elbow.

2. Remove bolts (5) and remove support bracket (3) from the cylinder block.

Installation Procedure

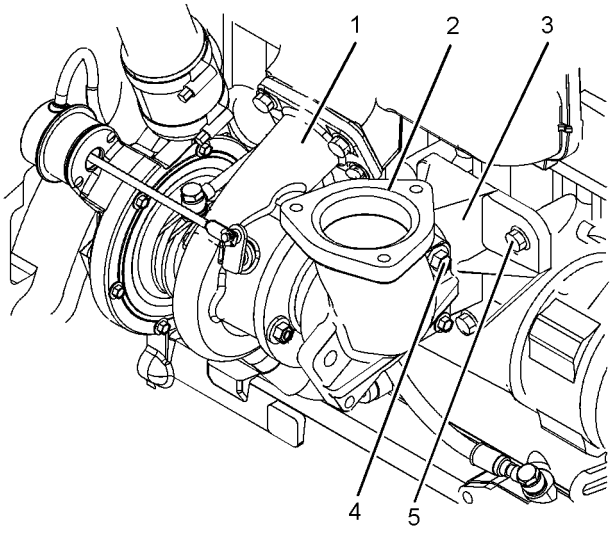


Illustration 30 g01343547

Typical example

1. Ensure that the exhaust elbow is clean and free from wear or damage.

2. Position support bracket (3) to the cylinder block and install bolts (5). Tighten bolts (5) to a torque of 44 N·m (33 lb ft).

3. Position exhaust elbow (2).

Note: Ensure the correct orientation of the exhaust elbow.

4. Install bolts (4) to support bracket (3). Tighten bolts (4) to a torque of 44 N·m (33 lb ft).

i02628893

Inlet and Exhaust Valve Springs - Remove and Install

Removal Procedure

Table 7

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	21825739	Valve Spring Compressor	1
	27610235	Adapter	1
	27610295	Head	1

Start By:

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

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.

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.

1. Follow Steps 1.a through 1.d in order to position the appropriate piston at top 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 (3) and open the valve slightly.

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

c. Use Tooling (A) 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.

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

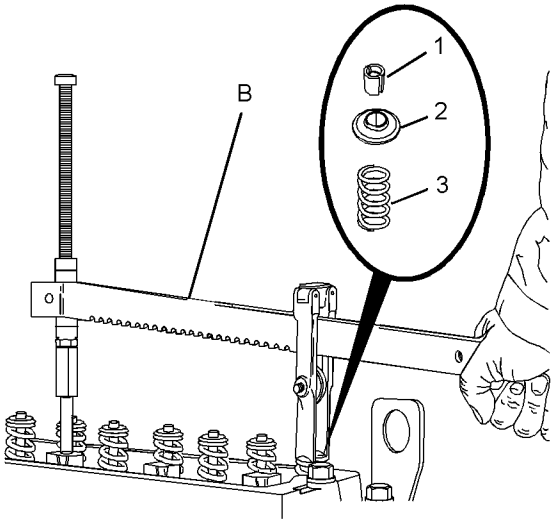


Illustration 31 g01343550
Typical example

2. Apply sufficient pressure to Tooling (B) in order to allow removal of the valve keepers (1). Remove valve keepers (1).

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

3. Slowly release the pressure on Tooling (B).

4. Remove valve spring retainer (2) and remove valve spring (3).

5. If necessary, remove the valve stem seals.

6. Repeat Steps 2 through 5 in order to remove the remaining valve spring from the appropriate cylinder.

7. Remove Tooling (B).

Installation Procedure

Table 8

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	21825739	Valve Spring Compressor	1
	27610235	Adapter	1
	27610295	Head	1

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

1. Inspect the valve springs for the correct length. Refer to Specifications, “Cylinder Head Valves ” for more information.

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.

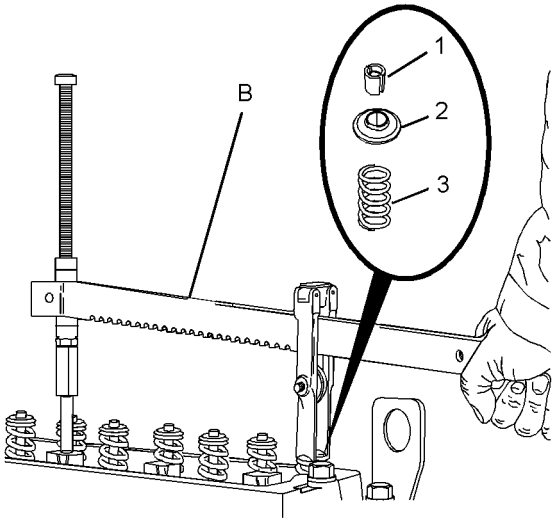


Illustration 32 g01343550
Typical example

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

⚠ 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.

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

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

5. Apply sufficient pressure to Tooling (B) in order to install valve keepers (1). Install the valve spring keepers (1).

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

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

Note: Ensure that the valve keepers are correctly seated.

7. Repeat Steps 2 to 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).

End By:

a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, “Rocker Shaft and Pushrod - Install”.

i02628894

Inlet and Exhaust Valves - Remove and Install

Removal Procedure

Table 9

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21825739	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.

⚠ 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.

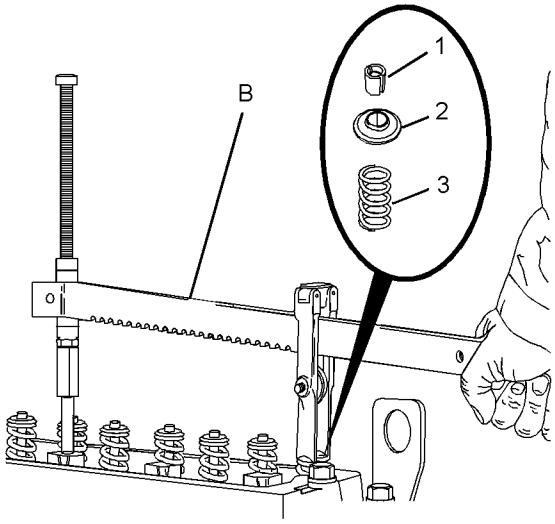


Illustration 33 g01343550

Typical example

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.

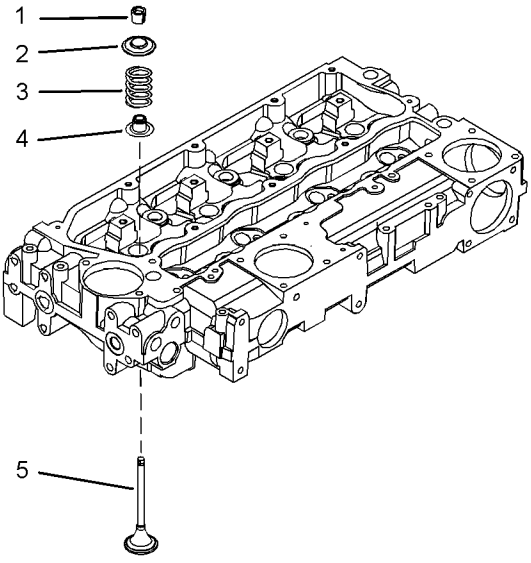


Illustration 34 g01352229

Typical example

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 Steps 4 to 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 10

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	21825739	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 Steps 1.a through 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 the correct length. Refer to Specifications, “Cylinder Head Valves”.

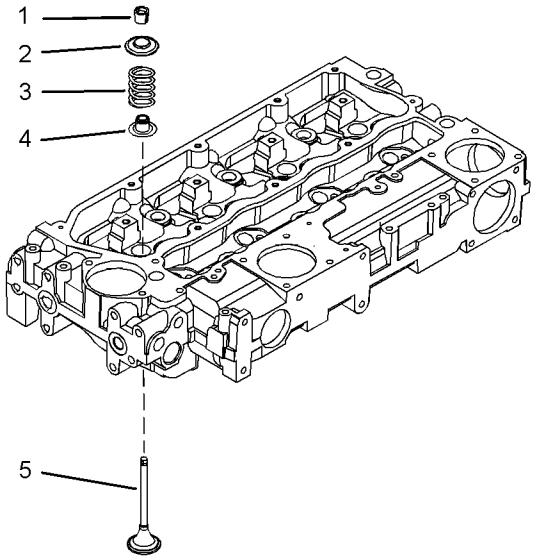


Illustration 35 g01352229

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).

⚠ 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.

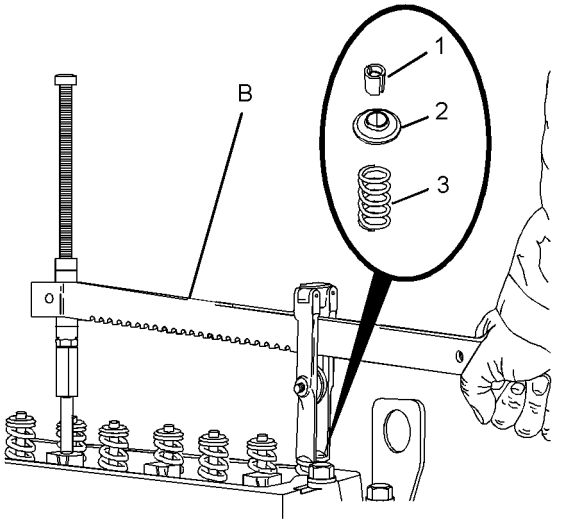


Illustration 36 g01343550

Typical example

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 Steps 5 to 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. Lightly strike the top of the valves with a soft hammer in order to ensure that valve keepers (1) are properly installed.

End By:

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

i02628834

Engine Oil Filter Base - Remove and Install

Removal Procedure

Table 11

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

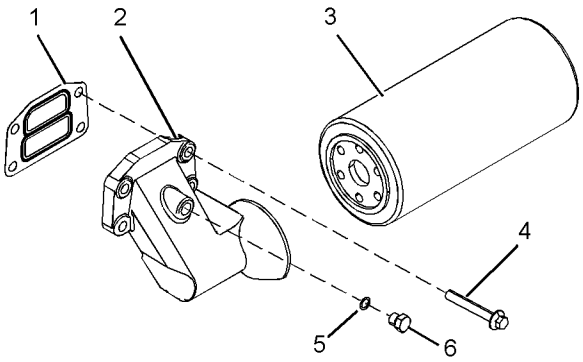
Note: The oil filter may be installed vertically or the oil filter may be installed horizontally.

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.



g01343554

Illustration 37

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 joint (1).

5. If the engine oil filter base has a spacer plate, remove the spacer plate and remove the joint.

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

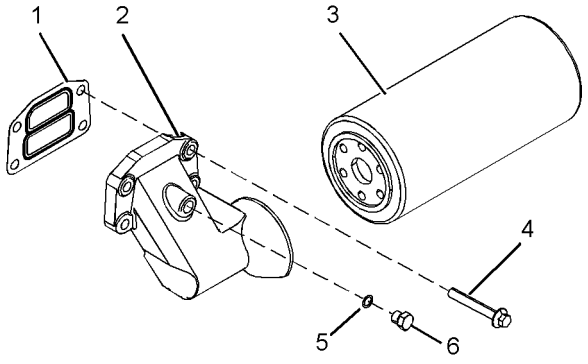
Installation Procedure

Table 12

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.



g01343554

Illustration 38

Typical example

1. Ensure that the engine oil filter base is clean. Clean the mating surfaces 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 joint (1) onto bolts (4). If the engine oil filter base has a spacer plate, install the spacer plate and a new joint onto the bolts.

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 Level - Check”.

i02628833

Engine Oil Cooler - 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.

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”.

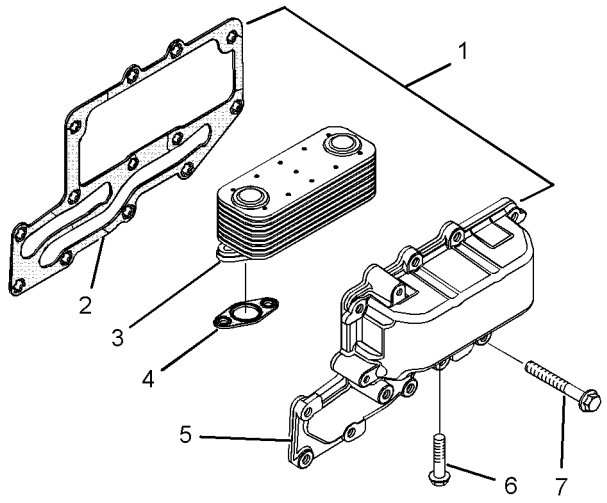


Illustration 39 g01343557
Typical example

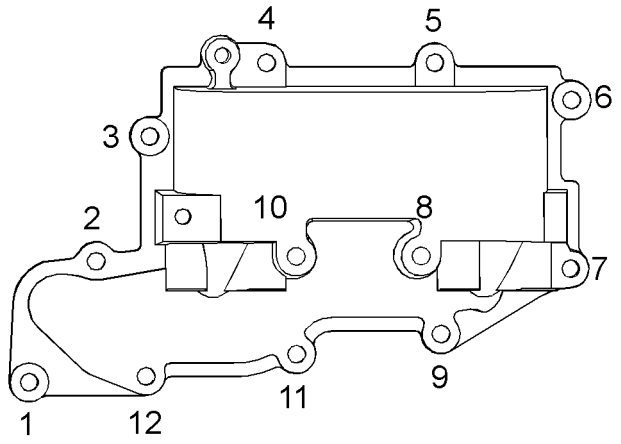


Illustration 40 g01343558
Tightening sequence for the engine oil cooler

4. Loosen fasteners (7) in reverse numerical order to the sequence that is shown in Illustration 40. Remove fasteners (7). Support the assembly of the engine oil cooler (1) as the fasteners are removed.

Note: fasteners (7) are different lengths. Note the correct position of the fasteners. Note the position of any brackets that are secured by the fasteners. Do not remove fasteners (6) at this time.

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

6. Remove joint (2).

7. Follow Steps 7.a through 7.c in order to disassemble the engine oil cooler.

   a. Remove bolts (6).

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

   c. Remove joints (4).

i02628832

Engine Oil Cooler - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

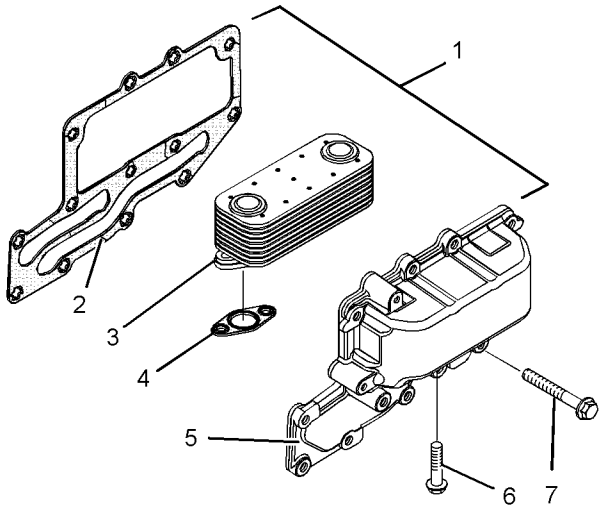


Illustration 41 g01347869
Typical example

1. Follow Steps 1.a through 1.d 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.

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

   c. Apply Tooling (A) to the threads of bolts (6).

   d. Install bolts (6). Tighten the bolts to a torque of 22 N·m (16 lb ft).

2. Clean the mating surface of the cylinder block.

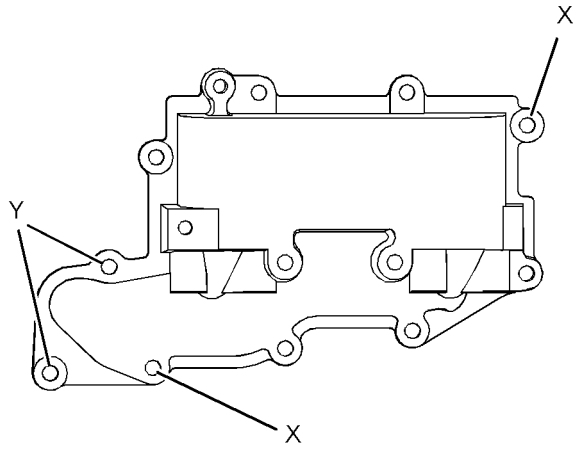


Illustration 42 g01347870
Typical example

3. Position a new joint (2) on the assembly of engine oil cooler (1). Install fasteners (7) to positions (X) on the assembly of engine oil cooler (1).

Note: The holes in the joint have serrations that hold the fasteners captive.

4. Install the assembly of engine oil cooler (1) to the cylinder block. Tighten bolts (7) finger tight.

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

5. Apply Tooling (B) to the fasteners (7) at positions (Y).

Note: The fasteners in this position are allen head screws.

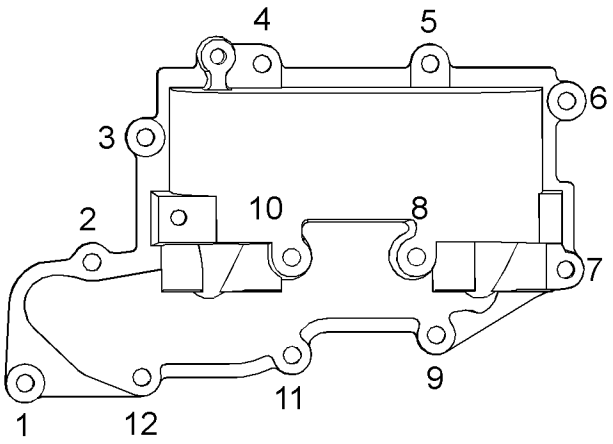


Illustration 43 g01343558

Tightening sequence for the engine oil cooler

6. Install the remaining fasteners (7) into the engine oil cooler (1). Tighten the fasteners to a torque of 22 N·m (16 lb ft). Tighten the bolts in the sequence that is shown in Illustration 43.

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 Filter and Change” for the correct procedure.

i02628841

Engine Oil Relief Valve - Remove and Install (Engines Without a Balancer Unit)

Removal Procedure

Table 13

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.

⚠ 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.

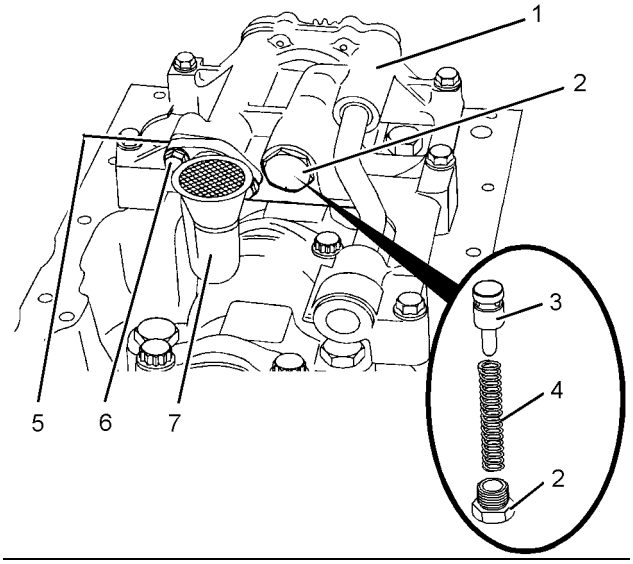


Illustration 44 g01343561

Typical example

1. Remove bolts (6) and suction pipe (7).

2. Remove the joint from suction pipe (5) (not shown).

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

Table 14

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
B	-	Loctite 577	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

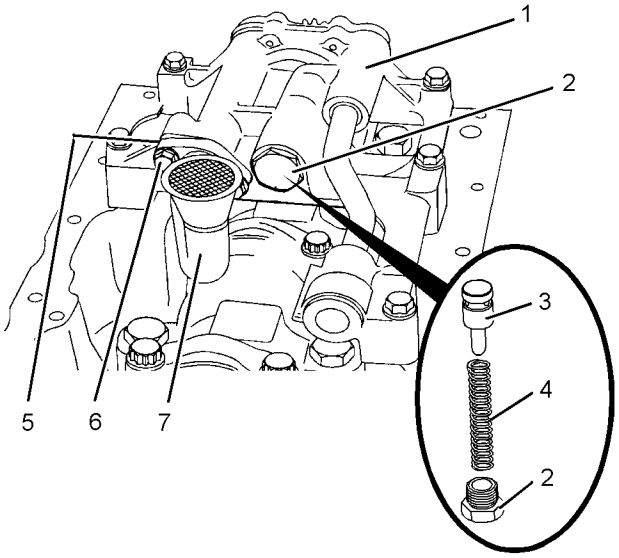


Illustration 45 g01343561
Typical example

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.

⚠ 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.

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. Apply Tooling (A) to the threads of cap (2). Install cap (2) to engine oil pump (1). Tighten the cap to a torque of 35 N·m (26 lb ft).

Note: Ensure that the spring is properly located inside the plunger and the cap. Ensure that Tooling (A) does not contaminate the bore for the relief valve in the housing of engine oil pump.

4. Install suction pipe (7) and a new joint (5) 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”.

i02628840

Engine Oil Relief Valve - Remove and Install (Engines with a Balancer Unit)

Removal Procedure

Table 15

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.

⚠ 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.

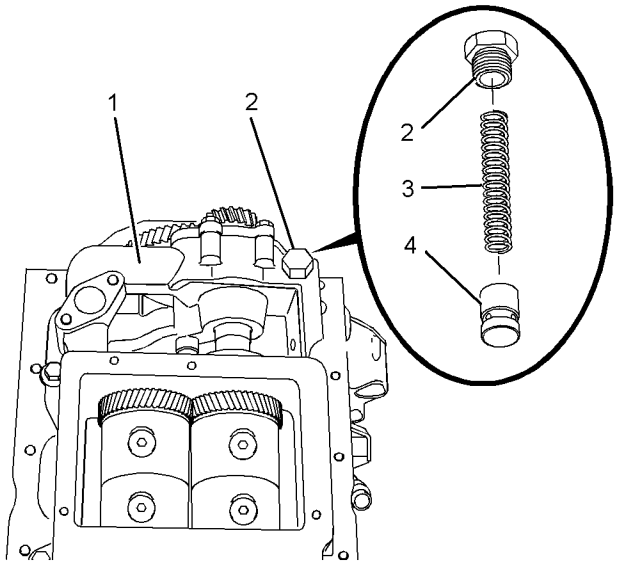


Illustration 46 g01343600
Typical example

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 16

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
B	-	Loctite 577	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

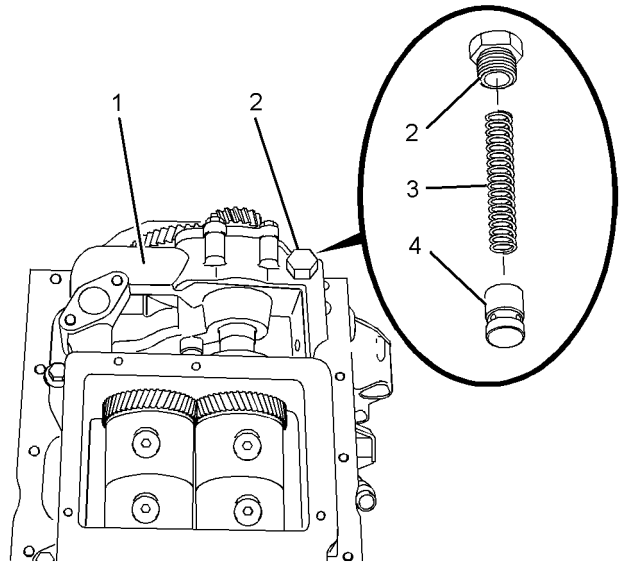


Illustration 47 g01343600
Typical example

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.

⚠ 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.

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 (15.5 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”.

i02628837

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 Group - 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.

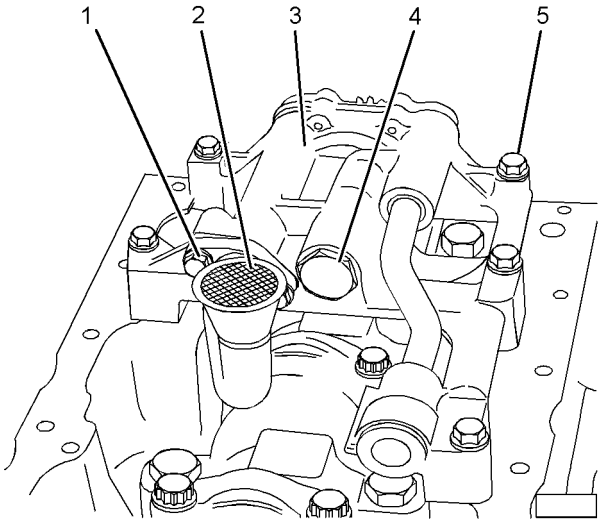


Illustration 48 g01343631
Typical example

1. Remove bolts (1) and suction pipe (2).

2. Remove the joint from suction pipe (2).

3. Remove bolts (5). Remove the assembly of 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 Vave - Remove and Install”.

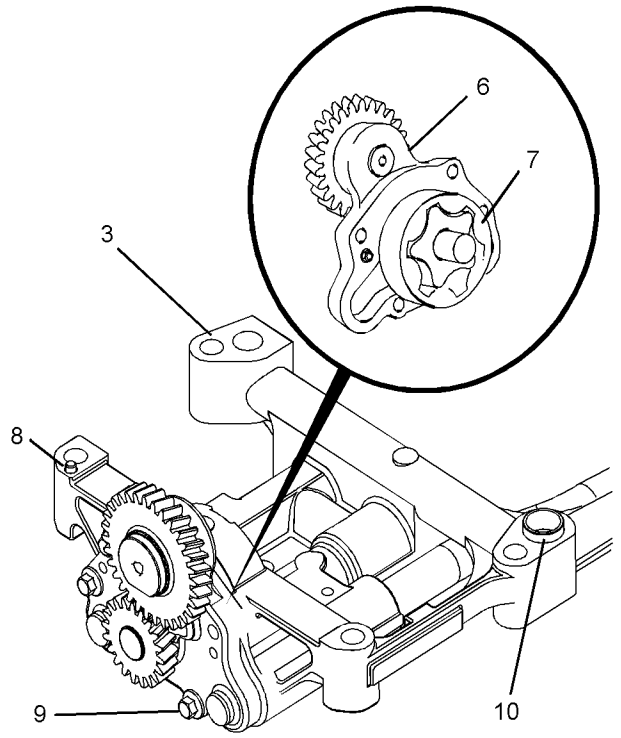


Illustration 49 g01343633

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 17

Required Tools			
Tool	**Part Number**	**Part Name**	**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 Group - 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 the 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.

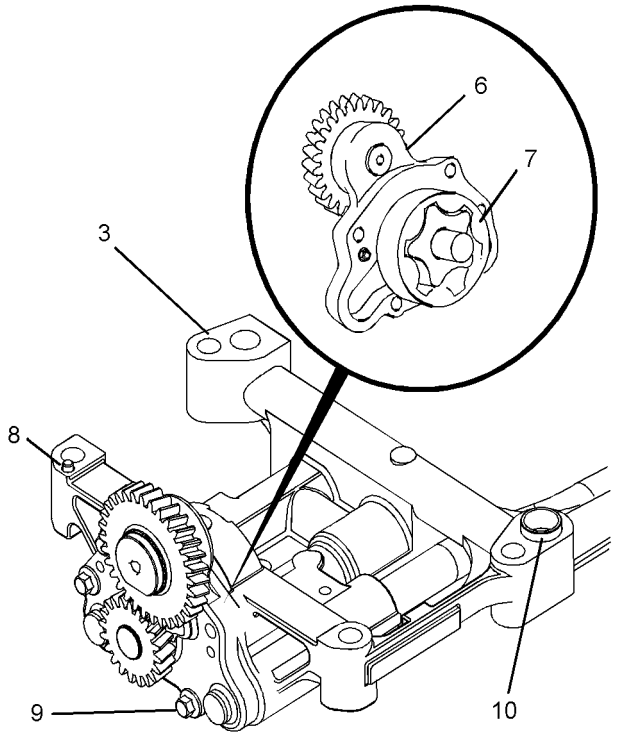


Illustration 50 g01343633

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).

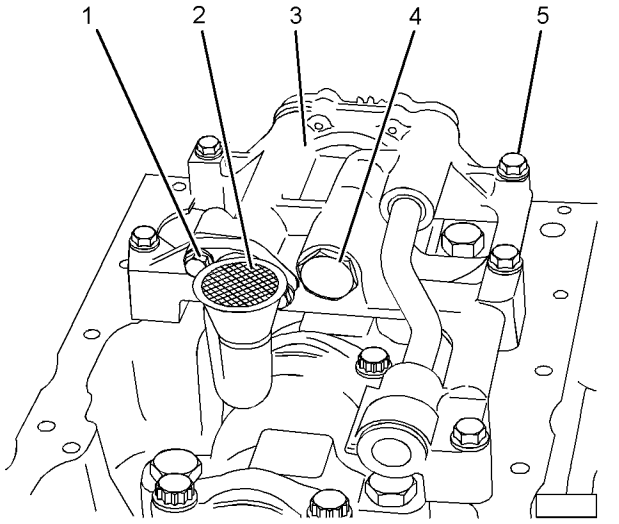


Illustration 51 g01343631

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 dowels (8) and (10) are correctly located in the housing of the 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 joint 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”.

i02628917

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.

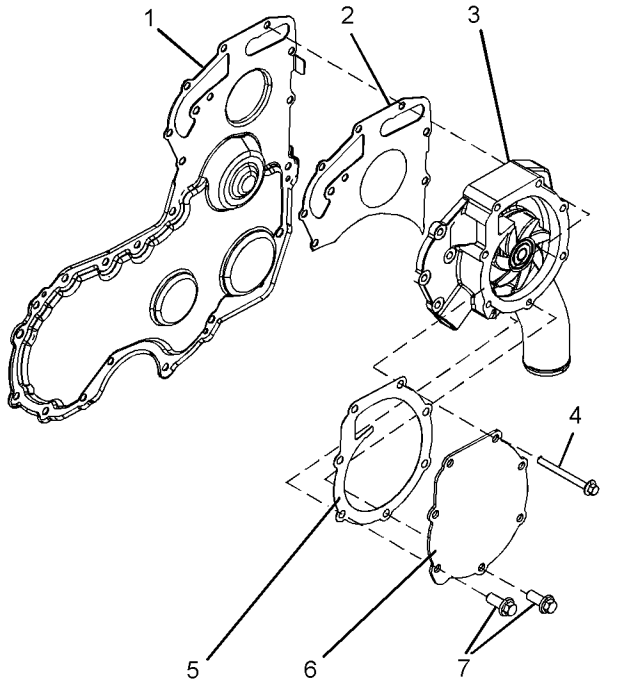


Illustration 52 g01263054

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 joint (2).

6. If necessary, remove the cover (6) from the water pump. Follow Steps 6.a through 6.c in order to remove the cover.

a. Remove bolts (7).

b. Remove cover (6).

c. Remove joint (5).

i02628916

Water Pump - Install

Installation Procedure

Table 18

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.

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

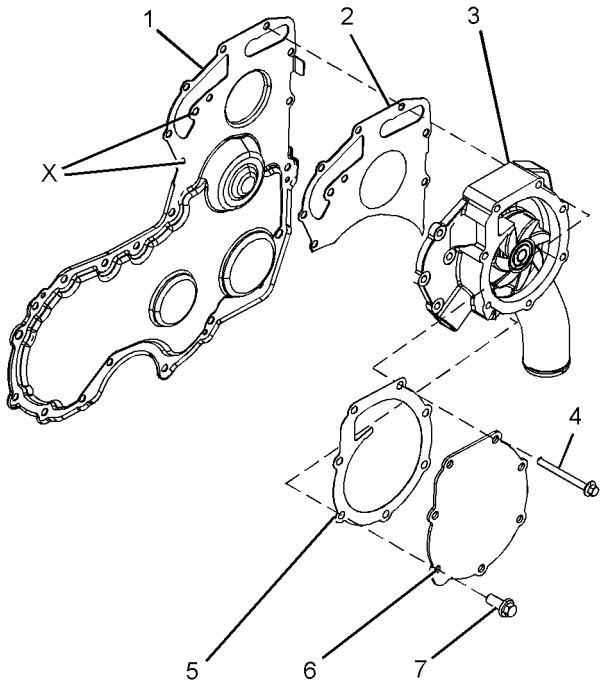


Illustration 53 g01269391

Typical example

2. If necessary, install cover (6) to water pump (3). Follow Steps 2.a through 2.d in order to install the cover.

a. Clean the mating surface of cover (6).

b. Position a new joint (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 mating surface of front cover (1).

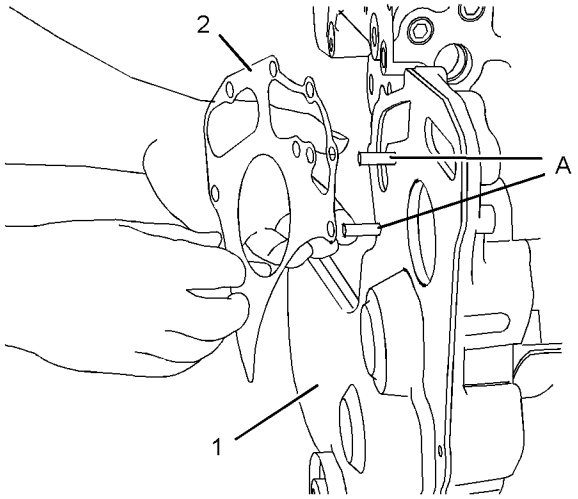


Illustration 54 g01269392

4. Install Tooling (A) in position (X).

5. Use Tooling (A) in order to align a new joint (2) to front cover (1). Install the joint 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 53. 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.

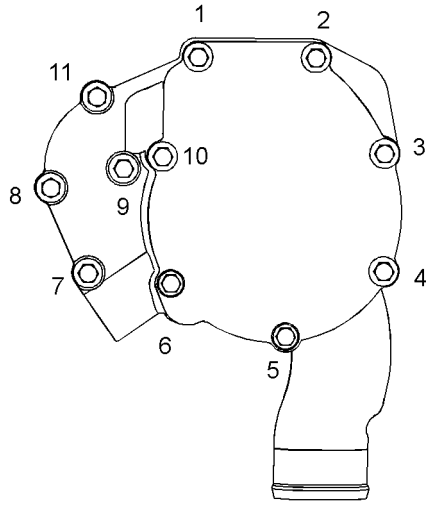


Illustration 55 g01269393

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 53. Tighten the bolts in the sequence that is shown in Illustration 55.

10. Install the hose to the water pump inlet. Tighten the hose clamps.

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”.

i02628918

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.

2. Loosen the hose clamps from the upper radiator hose and disconnect the upper radiator hose from water temperature regulator housing (2).

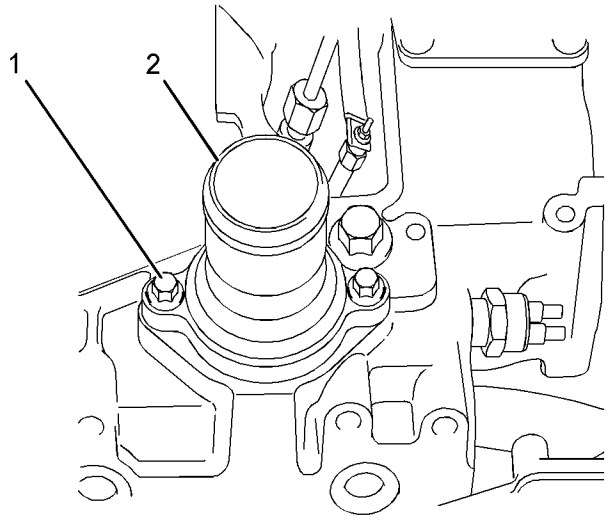


Illustration 56 g01343959
Typical example

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.

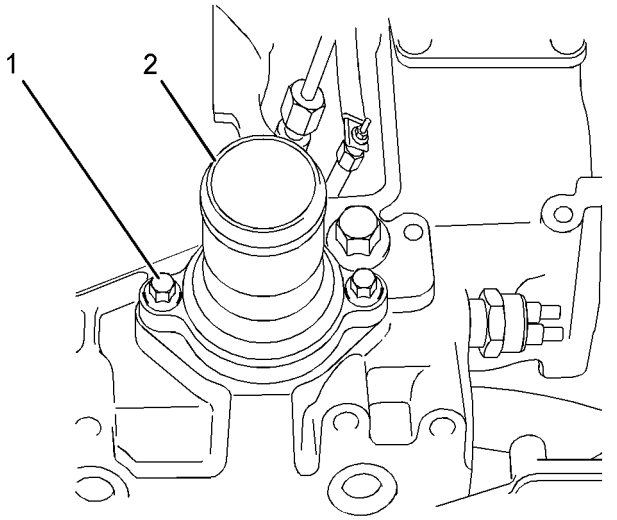


Illustration 57 g01343959
Typical example

5. Remove O-ring seal (3) from water temperature regulator housing (2).

Installation Procedure

Table 19

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.

1. Ensure that all components of water temperature regulator 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 are worn or damaged, the complete assembly must be replaced.

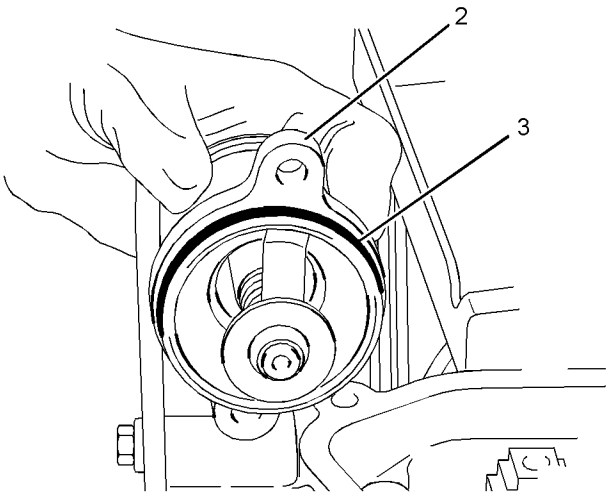


Illustration 58 g01343960
Typical example

2. If the original water temperature regulator housing is installed, position a new O-ring seal (3) into the groove in water temperature regulator housing (2).

A new water temperature regulator housing is supplied with a new O-ring seal.

3. Use Tooling (A) to lubricate the new O-ring seal.

4. Install water temperature regulator housing (2) to the cylinder head.

Note: Ensure the correct orientation of the water temperature regulator housing.

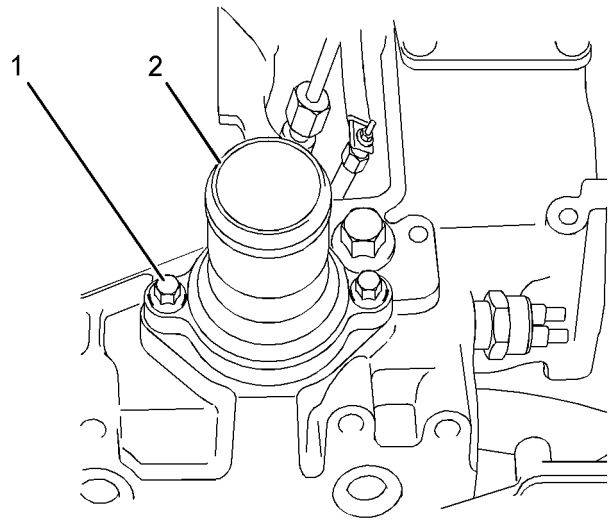


Illustration 59 g01343959
Typical example

5. Install bolts (1). Tighten the bolts to a torque of 22 N·m (16 lb ft).

6. Connect the upper radiator hose and tighten the hose clamps.

7. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, “Cooling System Coolant - Change” for the correct procedure.

i02628847

Flywheel - Remove

Removal Procedure

Table 20

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Guide Bolt (1/2 inch - 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.

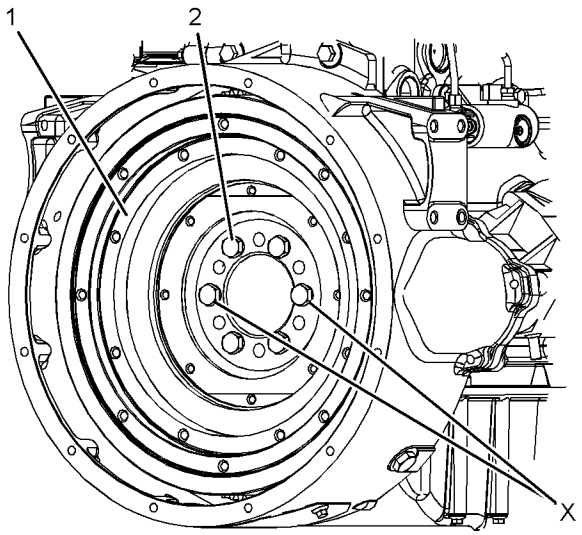


Illustration 60 g01245126
Typical example

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.

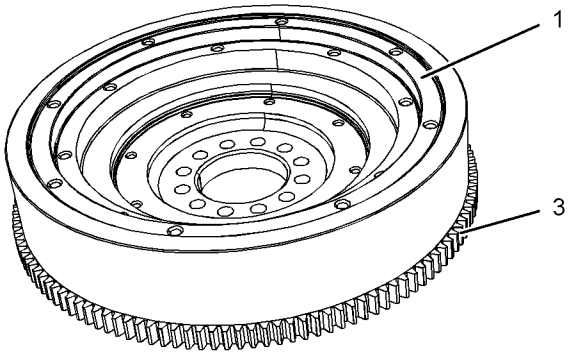


Illustration 61 g01245152
Typical example

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 Steps 7.a and 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).

i02628846

Flywheel - Install

Installation Procedure

Table 21

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Guide Bolt (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.

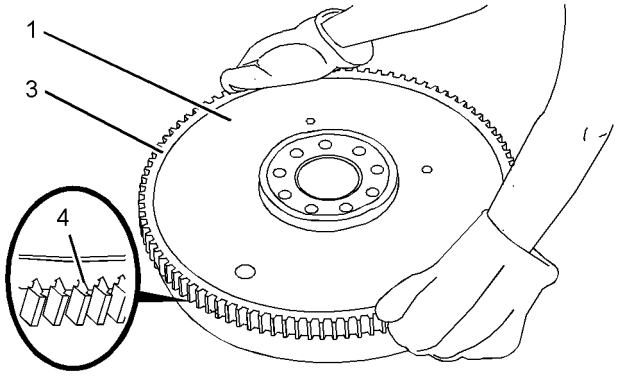


Illustration 62 g01343963
Typical example

⚠ WARNING

Always wear protective gloves when handling parts that have been heated.

1. If the flywheel ring gear was removed, follow Steps 1.a through 1.c in order to install a new ring gear to the flywheel.

   a. Identify the orientation of teeth (4) on the new ring gear (4).

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”.

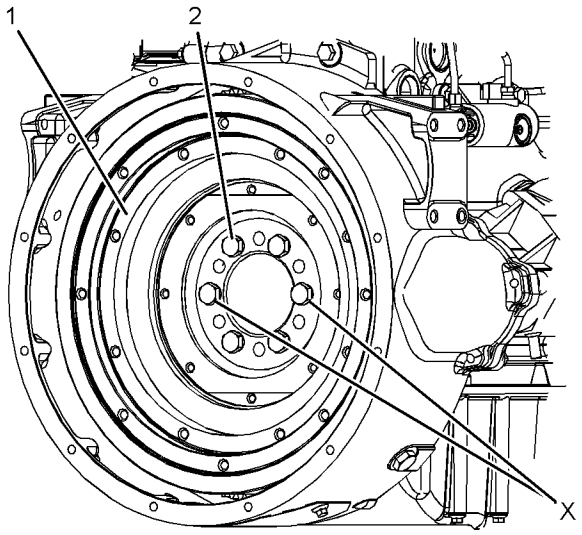


Illustration 63 g01245126
Typical example

3. Install a suitable lifting device to flywheel (1). The flywheel weighs 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 the 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 System Operation, Test and Adjusting, “Flywheel - Inspect” for further information.

End By:

a. Install the electric starting motor. Refer to Disassembly and Assembly, “Electric Starting Motor - Remove and Install”.

i02628827

Crankshaft Rear Seal - Remove

Removal Procedure

Table 22

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.

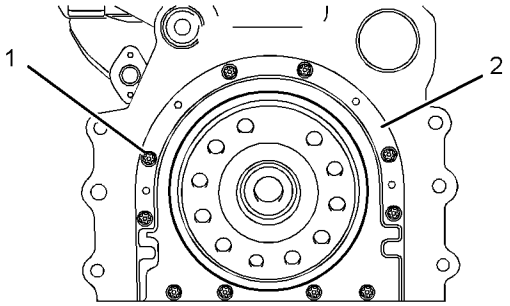


Illustration 64 g01269512
Typical example

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.

i02628824

Crankshaft Rear Seal - Install

Installation Procedure

Table 23

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.

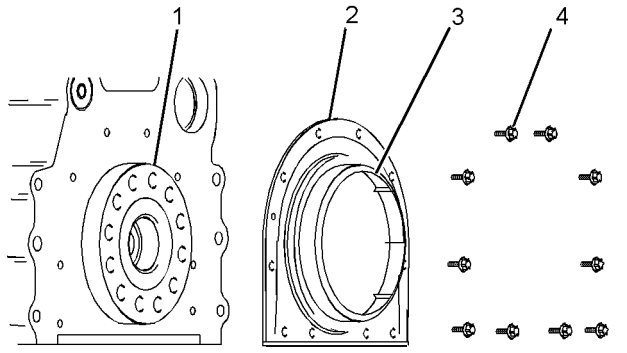


Illustration 65 g01258105

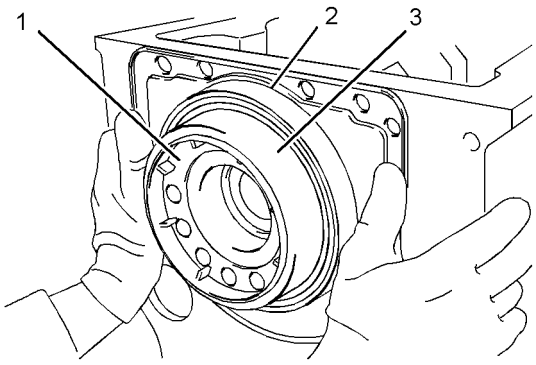


Illustration 66 g01255709
Typical example

1. Ensure that crankshaft flange (1) is clean, dry and free from damage. It is possible to reclaim a crankshaft flange that has a worn seal surface, or a damaged seal surface by installing a wear sleeve. Refer to Disassembly and Assembly, “Crankshaft Wear Sleeve (Rear) - Remove and Install” for more information.
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.

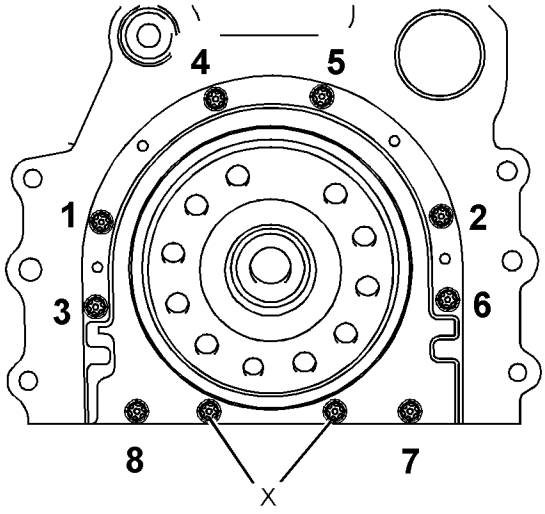


Illustration 67 g01258357

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 67.

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 67.

End By:

a. Install the flywheel. Refer to Disassembly and Assembly, “Flywheel - Install”.

i02628848

Flywheel Housing - Remove and Install

Removal Procedure

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.

1. 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).

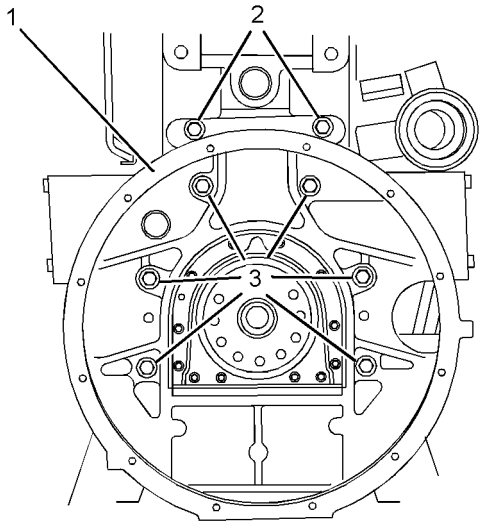


Illustration 68 g01244050

Typical example

2. Remove bolts (2) and bolts (3) from flywheel housing (1).

3. Use the lifting device in order to remove flywheel housing (1) from the cylinder block.

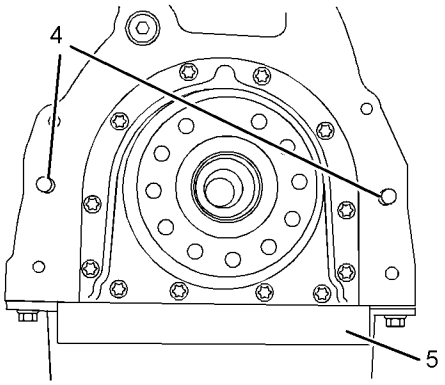


Illustration 69 g01244051
Typical example

4. If the engine has an aluminum oil pan, remove dust seal (5).

5. If necessary, remove dowels (4) from the cylinder block.

Installation Procedure

Table 24

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Guide Stud (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.

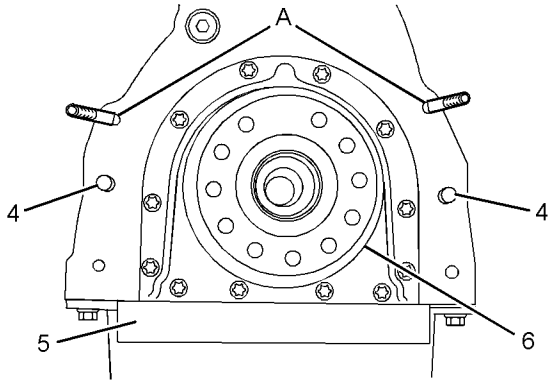


Illustration 70 g01244056
Typical example

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).

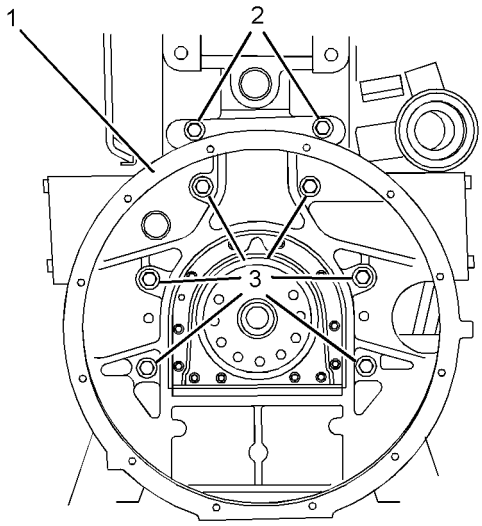


Illustration 71 g01244050
Typical example

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 the bolts (2) and bolts (3) finger tight.

9. Remove Tooling (A). Install the 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”.

i02674882

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.

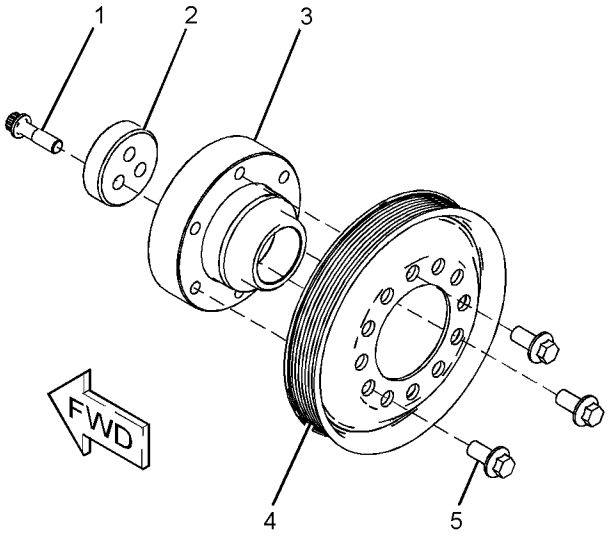


Illustration 72 g01249049

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 Steps 4.a through 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. It is possible to reclaim a crankshaft adapter with a worn seal surface by installing a wear sleeve. Refer to Disassembly and Assembly, “Crankshaft Wear Sleeve (Front) - Remove and Install”.

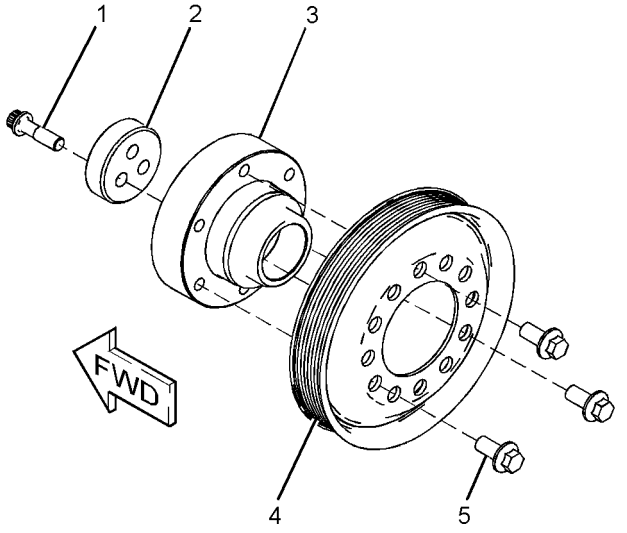


Illustration 73 g01367385

2. If necessary, follow Steps 2.a through 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 the crankshaft pulley to the crankshaft.

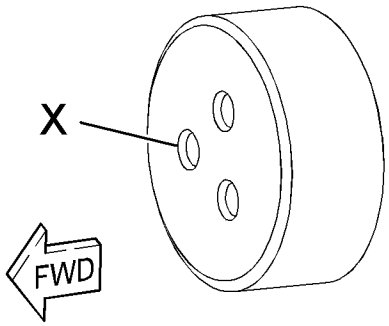


Illustration 74 g01367392

4. Align the holes in thrust block (2) with the holes in the crankshaft.

Note: Ensure chamfered holes (X) in thrust block (2). 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 evenly to a torque of 115 N·m (85 lb ft).

8. Repeat Step 7 one more times in order to ensure correct torque.

End By:

a. Install the alternator belt. Refer to Disassembly and Assembly, “Alternator Belt - Remove and Install”.

i02628822

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.

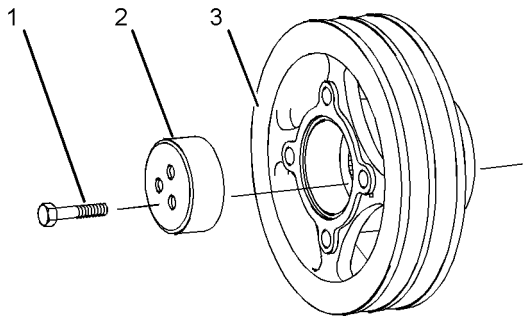


Illustration 75 g01255707

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

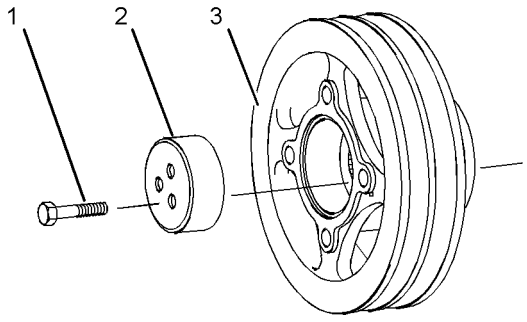


Illustration 76 g01255707

1. Ensure that the crankshaft pulley and the thrust block are clean and free from damage. Replace any components that are damaged. It is possible to reclaim a crankshaft pulley with a worn seal surface by installing a wear sleeve. Refer to Disassembly and Assembly, “Crankshaft Wear Sleeve (Front) - Remove and Install”.

2. Ensure that the front of the crankshaft is clean and free from damage. Install crankshaft pulley (3) to the crankshaft.

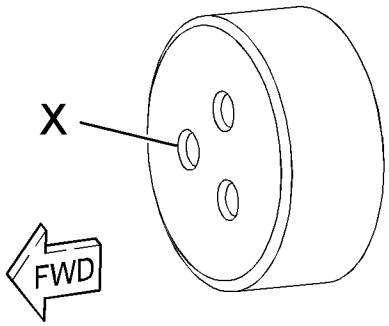


Illustration 77 g01367392

3. Align the holes in thrust block (2) with the holes in the crankshaft.

Note: Ensure chamfered holes (X) in thrust block (2). Face toward the front of the engine.

4. Install thrust block (2) to the assembly of 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 evenly to a torque of 115 N·m (85 lb ft).

7. Repeat Step 6 one more times in order to ensure correct torque.

End By:

a. Install the V-Belts. Refer to Disassembly and Assembly, “V-Belts - Remove and Install”.

i02628819

Crankshaft Front Seal - Remove and Install

Removal Procedure

Table 25

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.

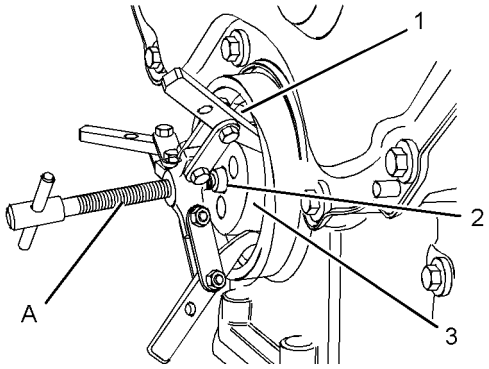


Illustration 78 g01266942

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 26

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
B	21825577	Threaded Bar	1
	21825580	Anchor Plate	1
	21825579	Sleeve	1
	21825578	Pressure Plate	1
	27610217	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.

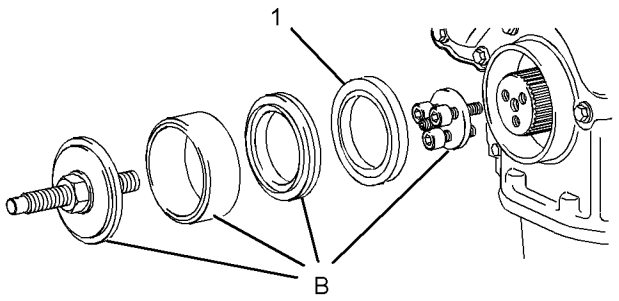


Illustration 79 g01266453
Typical example

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”.

i02628828

Crankshaft Wear Sleeve (Front) - Remove and Install

Removal Procedure

Start By:

a. Remove the crankshaft pulley. Refer to Disassembly and Assembly, “Crankshaft Pulley - Remove and Install”.

b. Remove the crankshaft front seal . Refer to Disassembly and Assembly, “Crankshaft Front Seal - Remove and Install”.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Wear sleeves are used to reclaim worn seal surfaces. Wear sleeves are not original equipment. A new crankshaft front seal must be installed when a new wear sleeve is installed.

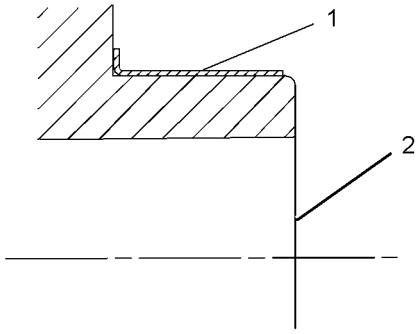


Illustration 80 g01269535
Sectional view of the crankshaft pulley and the wear sleeve

1. Use a sharp tool to score a deep line across wear sleeve (1).

Note: Take care to avoid damaging to the crankshaft pulley.

2. Insert a thin blade between wear sleeve (1) and crankshaft pulley (2) below the scored line. The wear sleeve will separate along the line.
3. Remove wear sleeve (1) from crankshaft pulley (2).

Installation Procedure

Table 27

Required Tools		
Tool	**Part Number**	**Part Description**
A	21820518	POWERPART Liquid Gasket

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the crankshaft pulley is thoroughly clean and dry. Remove any areas of raised damage.

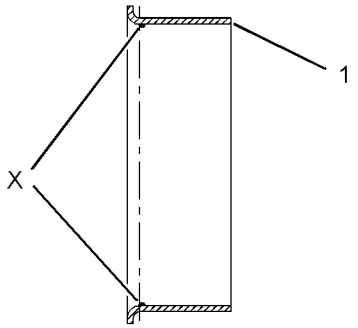


Illustration 81 g01269521

Sectional view of the wear sleeve

2. Apply a small continuous bead of Tooling (A) to the inner surface of wear sleeve (1) at position X. Apply the bead of Tooling (A) 5.00 mm (0.2 inch) from the flange end of the wear sleeve.

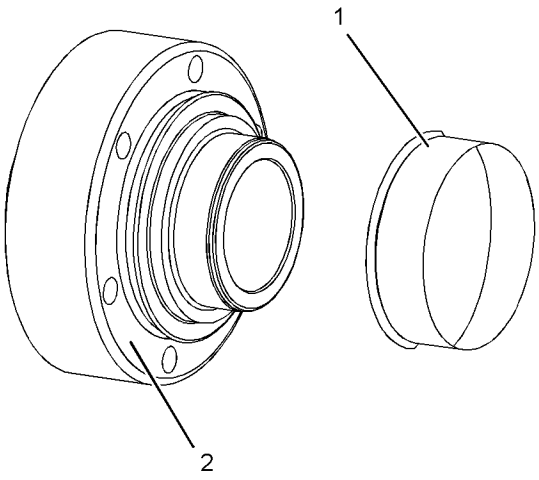


Illustration 82 g01258423

Typical example

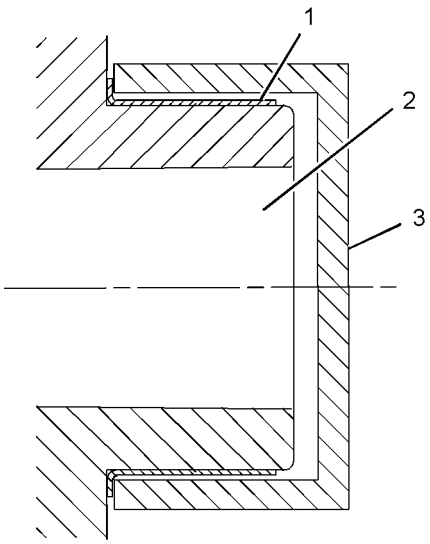


Illustration 83 g01258430

Sectional view of the crankshaft pulley, the wear sleeve and the installation tool

3. Align wear sleeve (1) with crankshaft pulley (2). Use installation tool (3) that is provided with the wear sleeve and use a suitable press in order to install wear sleeve (1) onto crankshaft pulley (2).

Note: Ensure that the wear sleeve is installed squarely against the shoulder of the crankshaft pulley.

4. Remove installation tool (3) from wear sleeve (1).

5. Ensure that wear sleeve (1) has no rough edges.

End By:

a. Install a new crankshaft front seal. Refer to Disassembly and Assembly, “Crankshaft Front Seal - Remove and Install”.

b. Install the crankshaft pulley. Refer to Disassembly and Assembly, “Crankshaft Pulley - Remove and Install”.

i02628849

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.

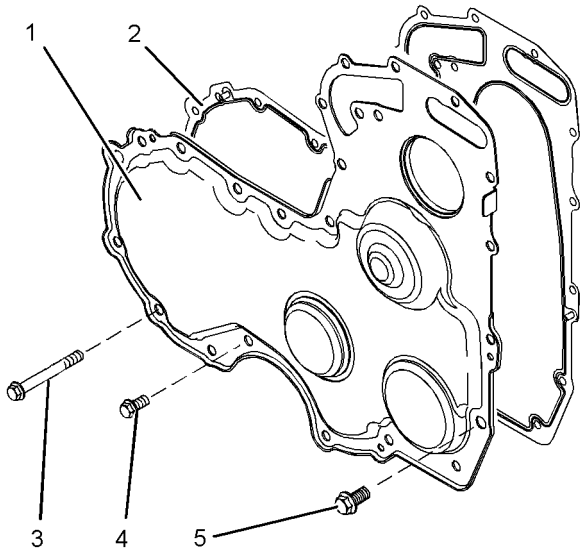


Illustration 84 g01258462
Typical example

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 joint (2) from front cover (1).

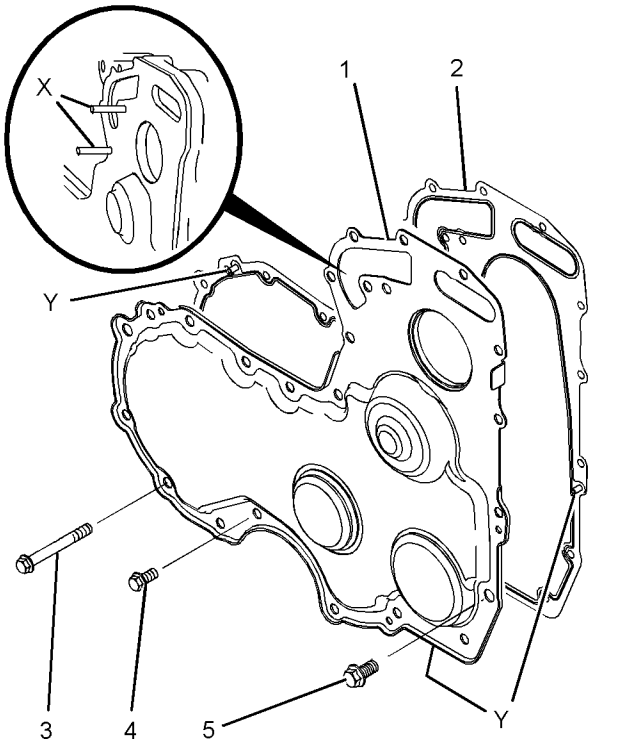
Installation Procedure

Table 28

Required Tools			
Tool	**Part Number**	**Part Name**	**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.



g01343967

Illustration 85

Typical example

1. Thoroughly clean the mating surface of the front housing.

2. If the original front cover is installed, follow Steps 2.a and 2.b in order to install the joint.

   a. Thoroughly clean the front cover.

   b. Install a new joint (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”.

i02628883

Gear Group (Front) - Remove and Install

Removal Procedure

Table 29

Required Tools			
Tool	**Part Number**	**Part Name**	**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

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.

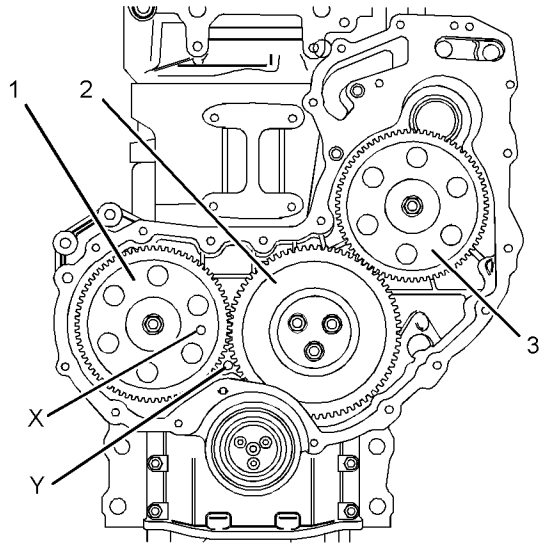
Contaminants may cause rapid wear and shortened component life.

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.

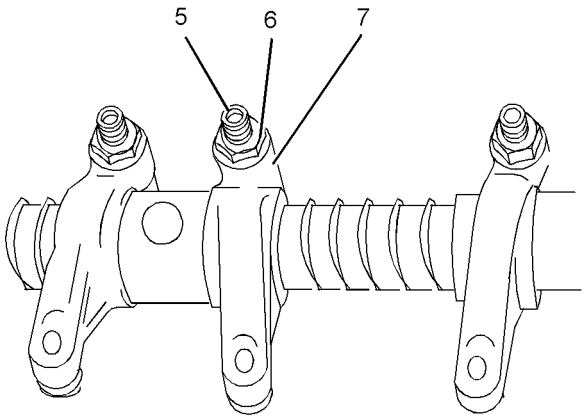
1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, “Finding Top Centre Position for No.1 Piston”.



g01247433
Illustration 86
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. Refer to Systems Operation, Testing and Adjusting, “Finding Top Centre Position for No.1 Piston”.

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

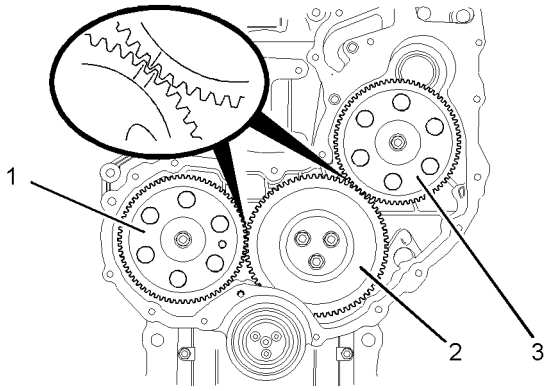


g01322693
Illustration 87
Typical example

3. Loosen nuts (6) on all rocker arms (7). Unscrew adjusters (5) on all rocker arms (7) 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.

4. Apply sufficient pressure to fuel injection pump gear (3) 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.



g01335384
Illustration 88
Typical example

5. Mark gears (1), (2) and (3) in order to show alignment. Refer to Illustration 88.

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

6. Remove fuel pump gear (3). 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 (2). Refer to Disassembly and Assembly, “Idler Gear - Remove and Install”.

Installation Procedure

Table 30

Required Tools			
Tool	**Part Number**	**Part Name**	**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 the Systems Operation, Testing and Adjusting, “Finding Top Center Position for No. 1 Piston”.

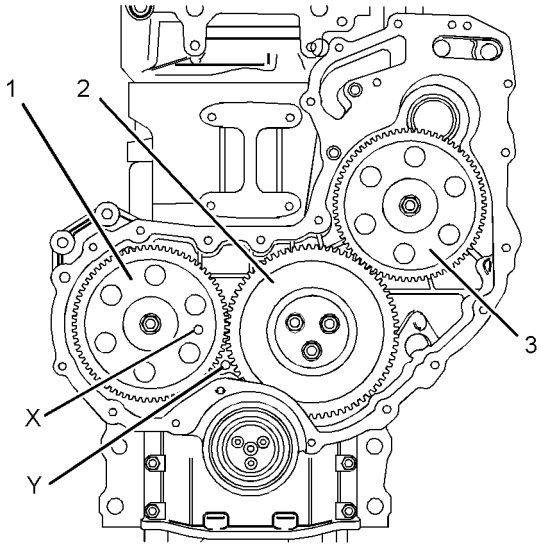


Illustration 89 g01247433
Typical example

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. Refer to Systems Operation, Testing and Adjusting, “Finding Top Centre Position for No.1 Piston”.

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.

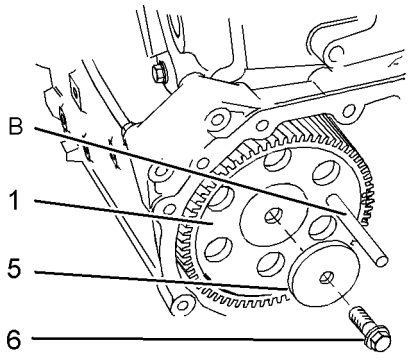


Illustration 90 g01269928
Typical example

4. Install camshaft gear (1). Loosely install bolt (6) and washer (5). 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.

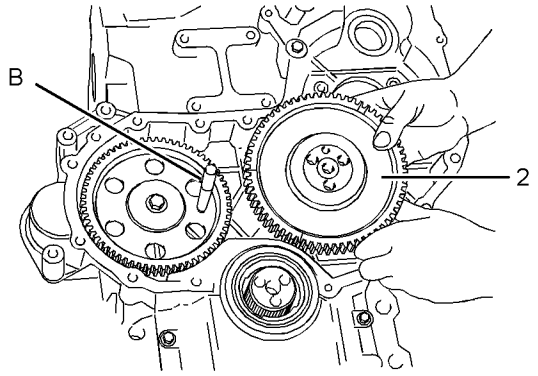


Illustration 91 g01269927
Typical example

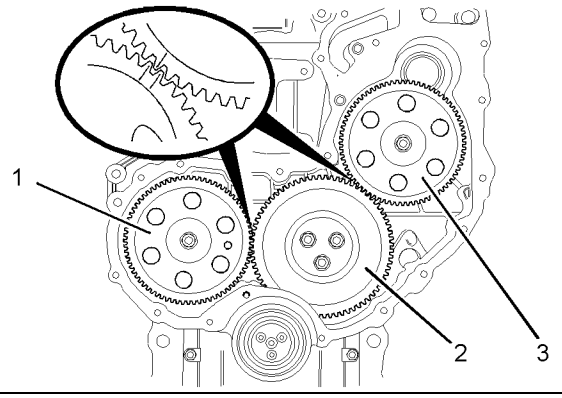


Illustration 92 g01335384
Alignment of timing marks

6. Install idler gear (2). Ensure that the timing marks on gears (1) and (2) are in alignment and that the mesh of the gears is correct. Refer to Disassembly and Assembly, “Idler Gear - Remove and Install”. Check the end play of the idler gear. Refer to Specifications, “Gear Group (Front)” and refer to Disassembly and Assembly, “Idler Gear - Remove and Install” for further information.

7. Remove Tooling (B) and (C). Tighten the bolt (6) 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 (3). Refer to Disassembly and Assembly, “Fuel Injection Pump Gear - Install” for the correct procedure. Ensure that timing marks on gears (2) and (3) are in alignment. See Illustration 92. Ensure that the mesh of the gears is correct.

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

11. Use Tooling (D) in order to measure the backlash for the gears (1), (2) and (3). 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”.

i02628889

Idler Gear - Remove

Removal Procedure (Standard Idler Gear)

Table 31

Required Tools			
Tool	**Part Number**	**Part Name**	**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 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.

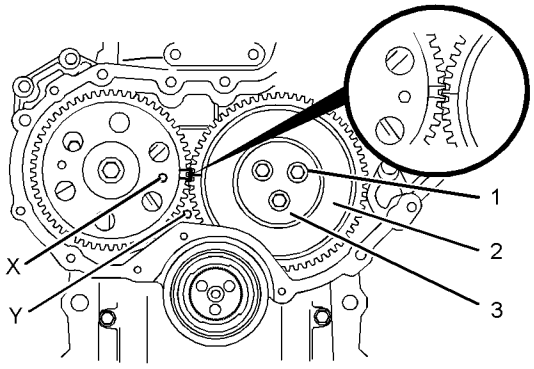


Illustration 93 g01343975
Alignment of timing marks

1. Ensure that Tooling (A) is installed into hole (X) in the camshaft gear. 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. Refer to Illustration 93.

2. 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.

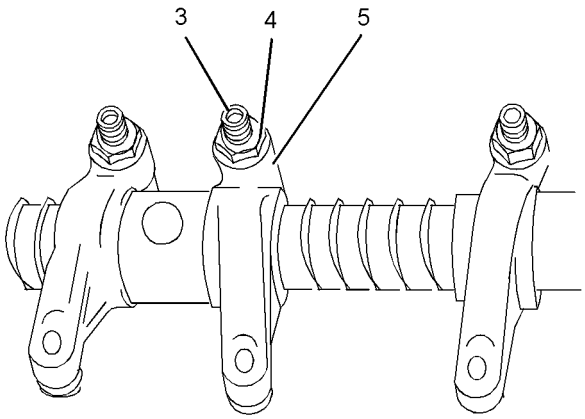


Illustration 94 g01348926
Typical example

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.

4. Mark plate (3) in order to show orientation. Refer to Illustration 93.

Note: Identification will ensure that the plate can be installed in the original orientation.

5. Remove bolts (1). Refer to Illustration 93.

6. Remove plate (3).

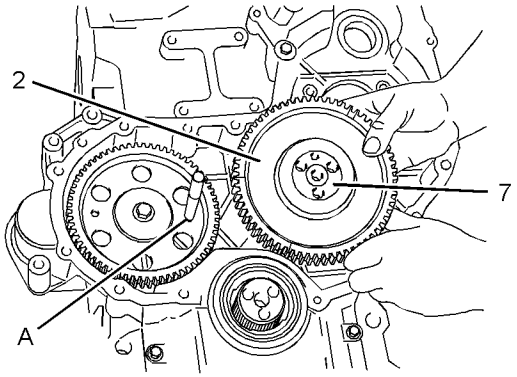


Illustration 95 g01269930
Typical example

7. Remove the assembly of idler gear (2) and hub (7) from the recess in the front housing.

Note: The idler gear must be tilted during removal.

8. Remove hub (7) from idler gear (2).

Removal Procedure (Heavy-Duty Idler Gear)

Table 32

Required Tools			
Tool	**Part Number**	**Part Name**	**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 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.

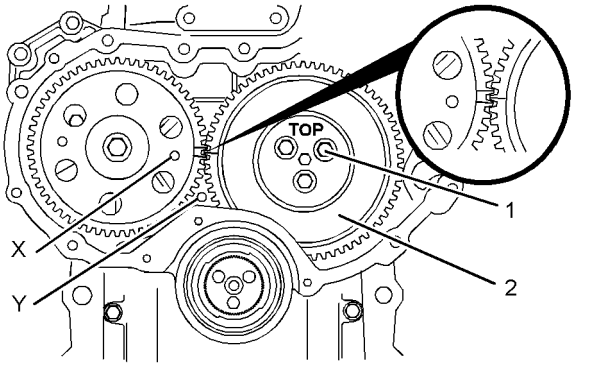


Illustration 96 g01343977
Alignment of timing marks

1. Ensure that Tooling (A) is installed into hole (X) in the camshaft gear. 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. Refer to Illustration 96.

2. 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.

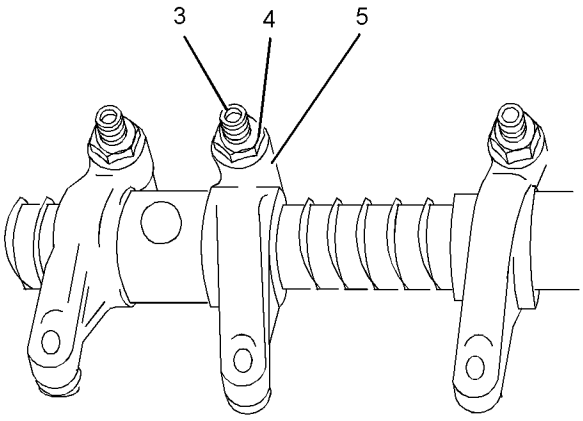


Illustration 97 g01348930
Typical example

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.

4. Remove bolts (1) from the assembly of heavy-duty idler gear (2). Refer to Illustration 96.

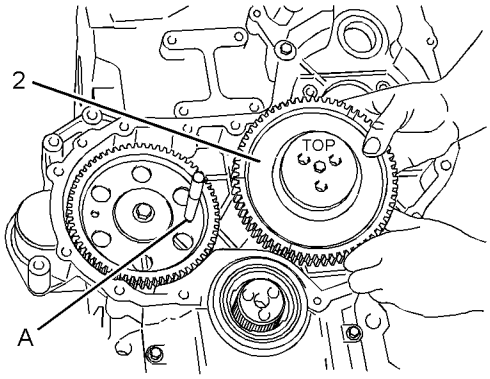


Illustration 98 g01269933
Typical example

5. Remove the assembly of idler gear (2) from the recess in the front housing.

Note: The idler gear must be tilted during removal.

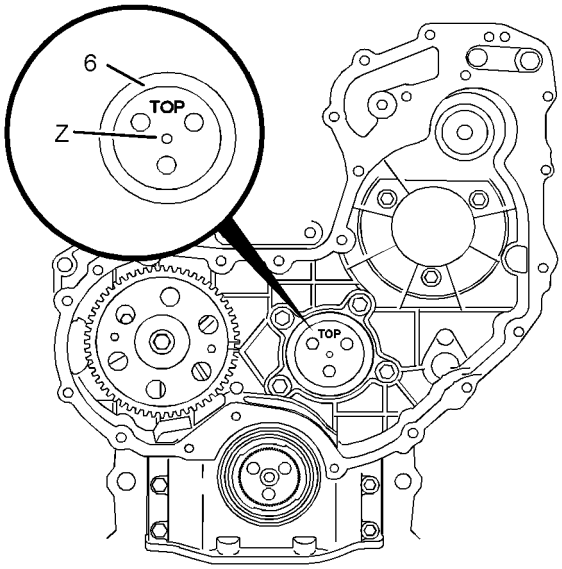


Illustration 99 g01348835
Typical example

6. If necessary, remove plate (6). Install Tooling (C) into threaded hole (Z) in order to remove plate (6).

i02628887

Idler Gear - Install

Installation Procedure (Standard Idler Gear)

Table 33

Required Tools			
Tool	**Part Number**	**Part Name**	**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 the Systems Operation, Testing and Adjusting, “Finding Top Center Postion for No. 1 Piston”.

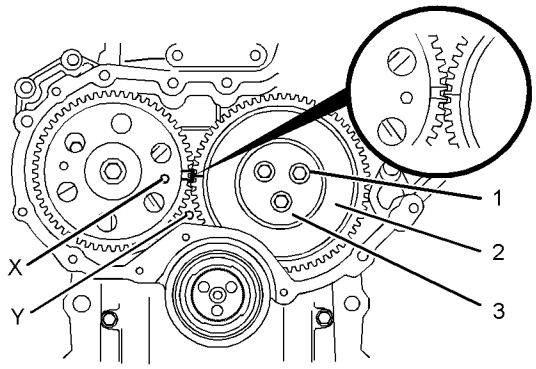


Illustration 100 g01343975
Alignment of timing marks

2. Ensure that Tooling (A) is installed into hole (X) in camshaft gear (1).

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. Refer to Systems Operation, Testing and Adjusting, “Finding Top Centre Position for No.1 Piston”.

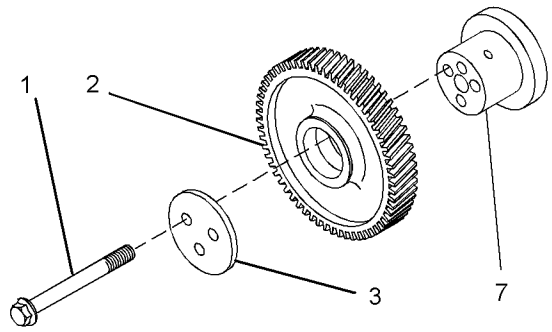


Illustration 101 g01269934

4. Clean idler gear (2) 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 (2). Ensure that the timing marks are toward the front of the idler gear.

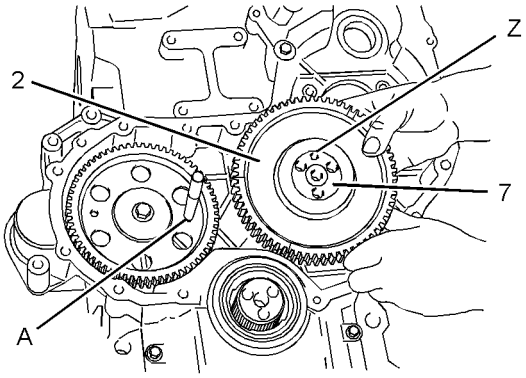


Illustration 102 g01269935
Typical example

7. Align the timing mark on idler gear (2) with the timing mark on the camshaft gear. Refer to the Illustration 100. Install the assembly of idler gear (2) 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 (3) and inspect the plate for wear or damage. If necessary, replace the plate.

9. Lubricate plate (3) 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 (3) are aligned with the holes in hub (7). Install plate (3) to hub (7).

10. Install bolts (1). Tighten bolts (1) to a torque of 44 N·m (32 lb ft).

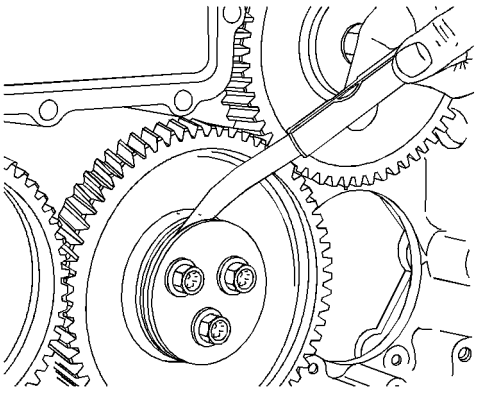


Illustration 103 g01269936
Checking end play by using a set of feeler gauge’s

11. Use a set of feeler gauge’s in order to check the end play for 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.

End By:

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, “Fuel 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”.

Installation Procedure (Heavy-Duty Idler Gear)

Table 34

Required Tools			
Tool	**Part Number**	**Part Name**	**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 Postion for No. 1 Piston”.

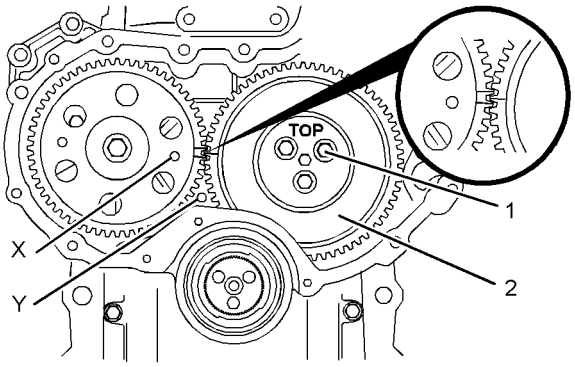


Illustration 104 g01343977
Alignment of timing marks

2. Ensure that Tooling (A) is installed into hole (X) in the camshaft gear.

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. Refer to Systems Operation, Testing and Adjusting, “Finding Top Centre Position for No.1 Piston”.

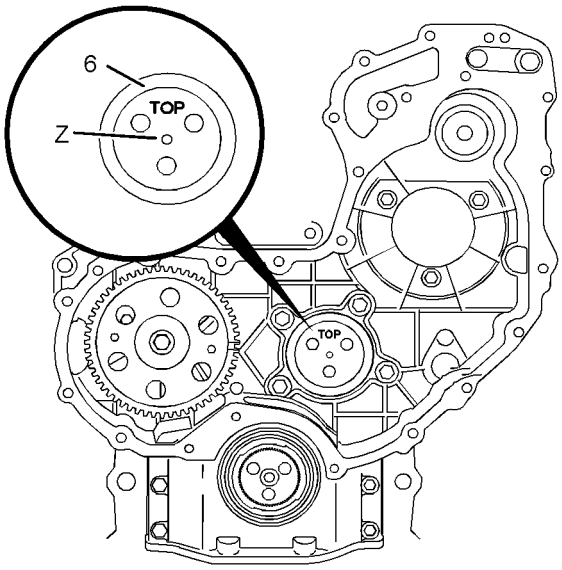


Illustration 105 g01348946
Typical example

4. Install plate (6) into the recess in the front housing.

Note: Ensure that the identification mark TOP is upward.

5. Clean the assembly of idler gear (2) 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 (2) with clean engine oil.

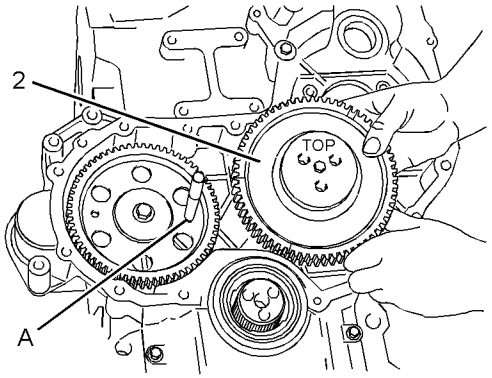


Illustration 106 g01269933

7. Align the timing mark on idler gear (2) with the timing mark on the camshaft gear. Refer to Illustration 104. Install the assembly of idler gear (2) 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 (1). Tighten bolts (1) to a torque of 44 N·m (32 lb ft).

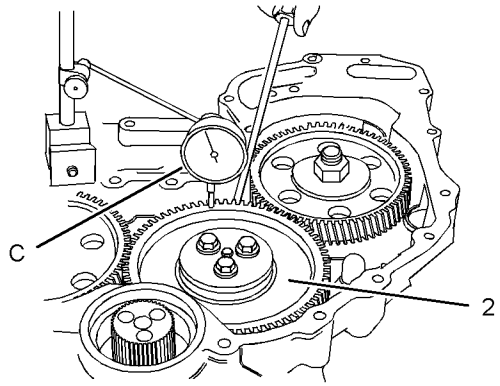


Illustration 107 g01269937

Checking end play by using a dial indicator group

9. Use Tooling (C) in order to check the end play of the idler 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 camshaft gear. Refer to Specifications, “Gear Group (Front)” for more information.

11. 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.

12. Lightly lubricate all of the gears with clean engine oil.

End By:

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, “Fuel 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”.

i02628886

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.

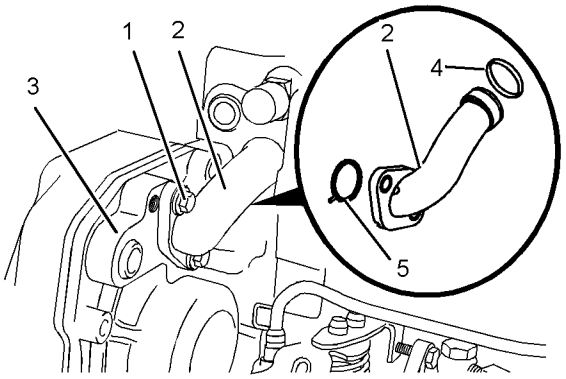


Illustration 108 g01337982
Typical example

2. Remove bolts (1) that secure bypass tube (2) to front housing (3). Note the position of any brackets that are secured by the bolts. Remove bypass tube (2). Remove O-ring seals (4) and (5) from bypass tube (2).

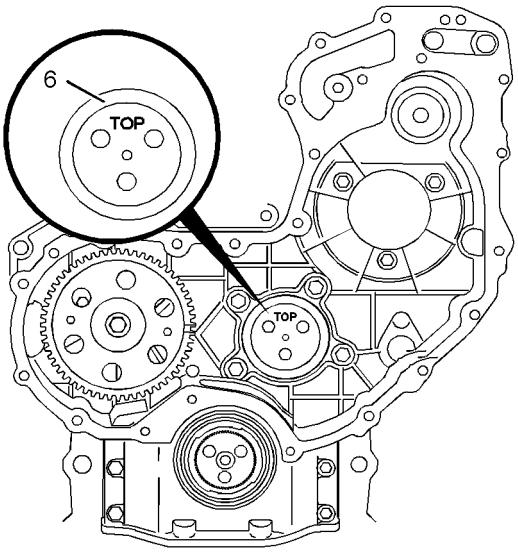


Illustration 109 g01350333

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.

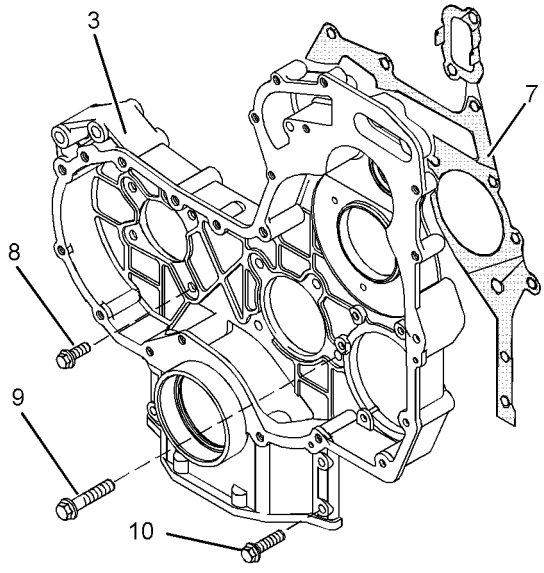


Illustration 110 g01350336
Typical example

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 joint (7).

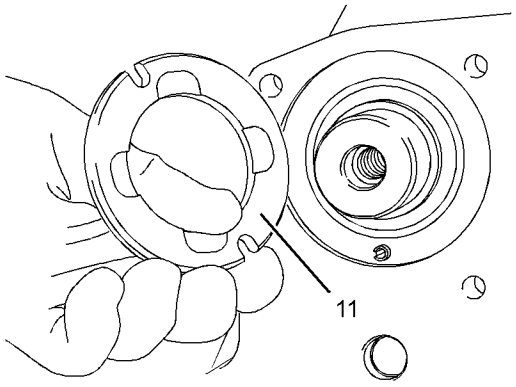


Illustration 111 g01350337
Typical example

7. Remove thrust washer (11) from the cylinder block.

i02628885

Housing (Front) - Install

Installation Procedure

Table 35

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 mating surfaces of the cylinder block.

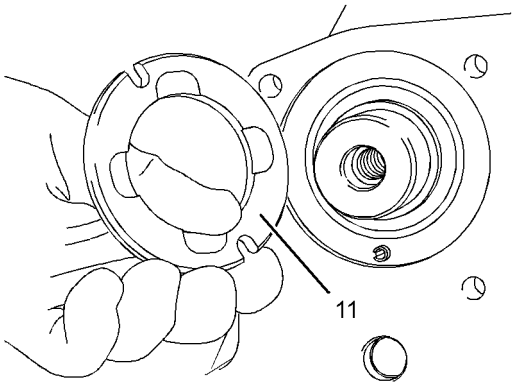


Illustration 112 g01350337
Typical example

4. Install thrust washer (11) into the recess in the cylinder block. Refer to Disassembly and Assembly, “Camshaft - Install” for more information.

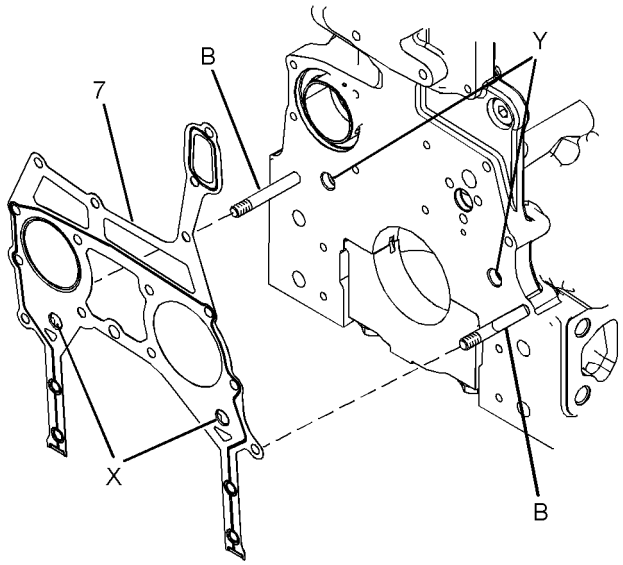


Illustration 113 g01350343
Typical example

5. Install Tooling (B) to the cylinder block. Refer to Illustration 113.

6. Install Tooling (C) to the cylinder block.

7. Align a new joint (7) with Tooling (B). Install the joint to the cylinder block.

Note: Ensure that tabs (X) on the joint are engaged in the holes (Y) in the cylinder block.

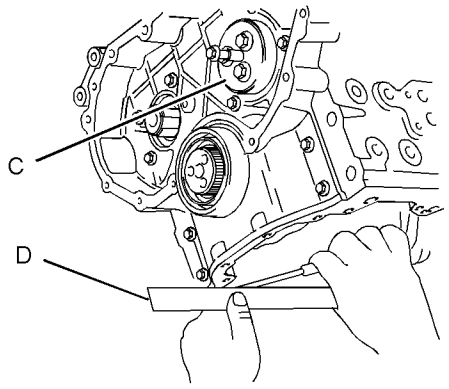


Illustration 114 g01269947

Typical example

8. Install the front housing over Tooling (B) and over Tooling (C) onto the cylinder block.

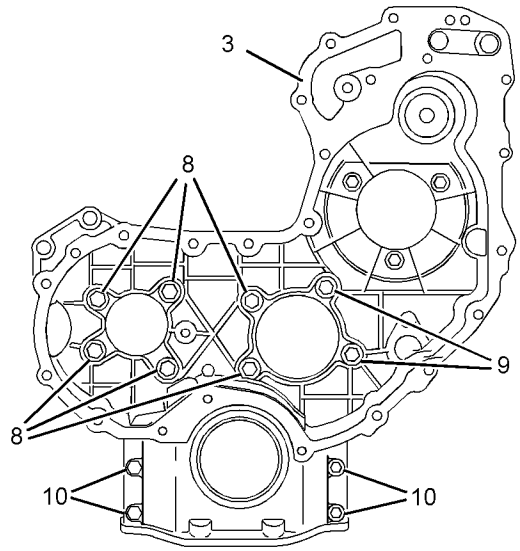


Illustration 115 g01350344

(8) M8 by 20 mm
(9) M8 by 35 mm
(10) M8 by 25 mm

9. Install bolts (10) to front housing (3) finger tight.

10. Remove Tooling (B).

11. Loosely install bolts (8) and (9). Refer to Illustration 115 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 a Tooling (D) and a feeler gauge in order to check the alignment between the front housing and the cylinder block. Refer to Illustration 114. Refer to Specifications, “Front Housing and Covers” for further information.

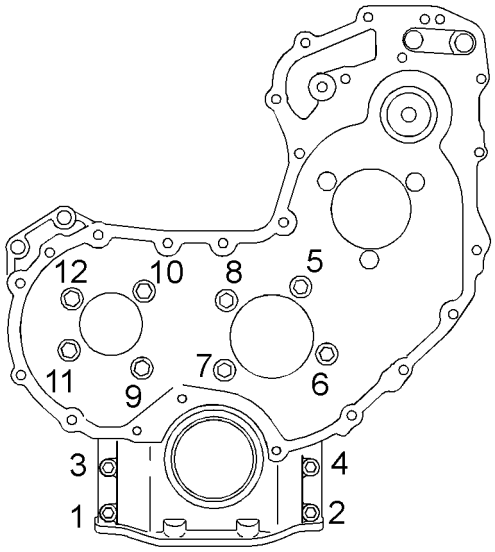


Illustration 116 g01269949

Tightening sequence for the front housing

13. Tighten bolts (8), (9) and (10) to a torque of 28 N·m (20 lb ft). Tighten the bolts in the sequence that is shown in Illustration 116.

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”.

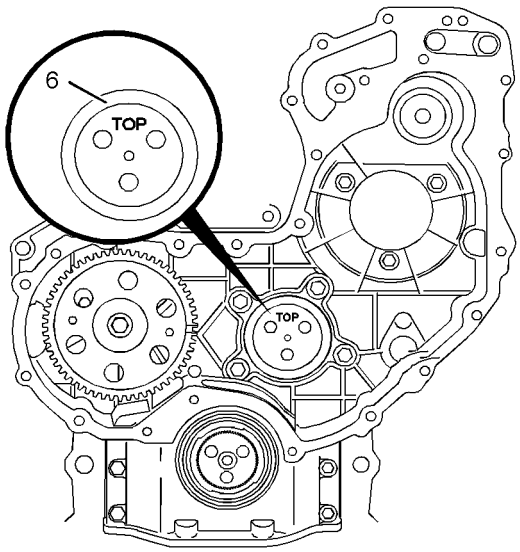


Illustration 117 g01350333

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.

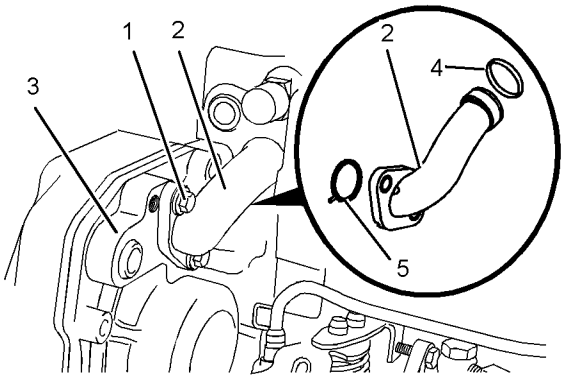


Illustration 118 g01337982

Typical example

17. Install new O-ring seals (4) and (5) to bypass tube (2). Use Tooling (E) in order to lubricate O-ring seal (5). Install bypass tube (2) to the cylinder head. Install bolts (1). Ensure that any brackets that are secured by the bolts are installed in the correct location. Tighten the bolts to a torque of 22 N·m (16 lb ft).

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) - 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”.

i02628800

Accessory Drive - Remove and Install

Removal Procedure

Table 36

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.

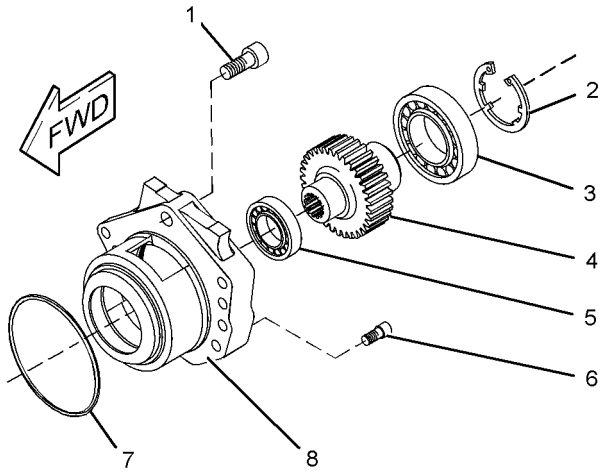


Illustration 119 g01269954

Typical example

1. Remove allen head screw (1) from accessory drive housing (8). Remove allen head screws (6) from accessory drive housing (8).

2. Remove accessory drive housing (8) from the front housing.

3. If necessary, follow Steps 3.a through 3.c in order to disassemble the accessory drive.

   a. Remove circlip (2) from accessory drive housing (8).

   b. Place accessory drive housing (8) onto a suitable support. Press the assembly of gear (4) and bearings (3) and (5) out of accessory drive housing (8). Use a Tooling (A) in order to remove bearings (3) and (5) from gear (4).

   c. Remove O-ring seal (7) from accessory drive housing (8).

Installation Procedure

Table 37

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
B	21820603	POWERPART Retainer	-
C	21820221	POWERPART Rubber Grease	1
D	21820117	POWERPART Threadlock and Nutlock	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

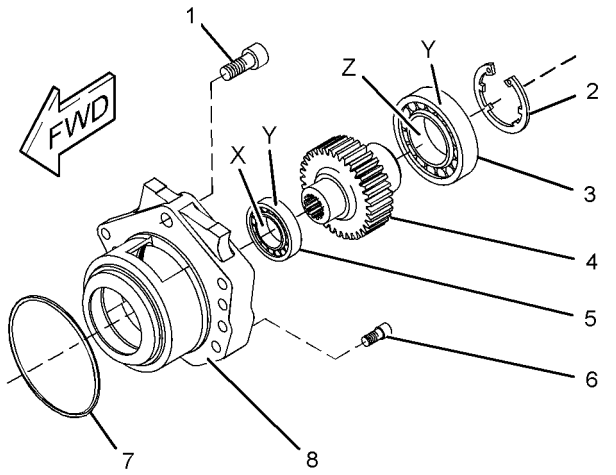


Illustration 120 g01264852
Typical example

1. If necessary, follow Steps 1.a through 1.e in order to assemble the accessory drive.

   a. Inspect the condition of the teeth and the splines of gear (4) for wear or damage. Inspect bearings (3) and (5), circlip (2), and the front housing for wear or damage. Replace any components that are worn or damaged.

   b. Apply a small continuous bead of Tooling (B) to inner surface (X) of bearing (5). Place the gear shaft on a suitable support. Press on the inner race of bearing (5) until the bearing (5) is against the shoulder of gear (4). Remove any excess sealant.

   c. Apply a small continuous bead of Tooling (B) to inner surface (Z) of bearing (3). Place the inner race of bearing (3) onto a suitable support. Press the shaft of gear (4) into bearing (3) until the shoulder of the gear is against the bearing. Remove any excess sealant.

   d. Apply a small continuous bead of Tooling (B) to the outer surface (Y) of bearings (3) and (5). Place accessory drive housing (8) on a suitable support. Press the assembly of the gear into the accessory drive housing. Ensure that bearing (5) is against the front face of the recess in accessory drive housing (8). Remove any excess sealant.

   e. Install circlip (2) into the groove in accessory drive housing (8). Ensure that circlip (2) is correctly positioned in the groove.

2. Lightly lubricate a new O-ring seal (7) with Tooling (C). Install the O-ring seal into the groove in accessory drive housing (8).

3. Inspect the bore in the front housing for damage. If necessary, replace the front housing. Refer to Disassembly and Assembly, “Housing (Front) - Remove” and Disassembly and Assembly, “Housing (Front) - Install”.

4. Lightly lubricate bearing (3), bearing (5), and gear (4) 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.

5. Apply Tooling (D) to allen head screws (1) and (6). Install allen head screws (1) and (6) to accessory drive housing (8).

6. Tighten the allen head screws to a torque of 22 N·m (16 lb ft).

7. Ensure that there is tactile backlash between the idler gear and the accessory drive gear.

i02628816

Crankcase Breather - Remove and Install (Turbocharged Engines with Unfiltered Breather)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

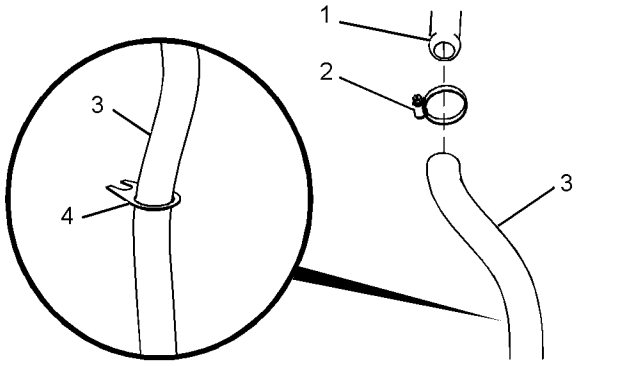


Illustration 121 g01343996
Typical example

1. Loosen clamp (2) and remove hose (3) from breather tube (1). Withdraw hose (3) from clip (4) and remove the hose.

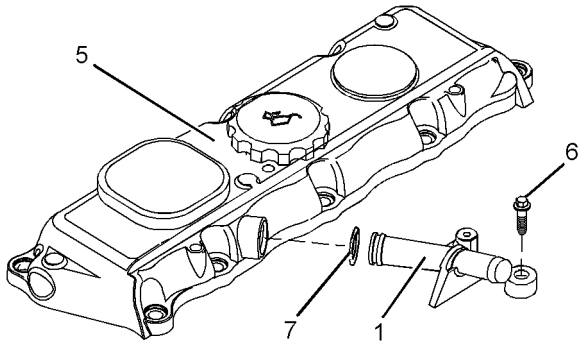


Illustration 122 g01346677

2. Remove bolt (6) and remove breather tube (1) from valve mechanism cover (5).

3. Remove O-ring seal (7) from breather tube(1).

Disassembly Procedure

⚠ WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

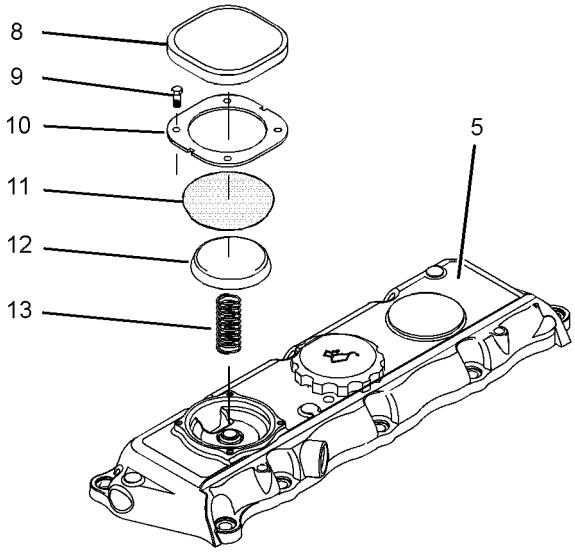


Illustration 123 g01347094

1. Remove plastic cover (8) from valve mechanism cover (5).

2. Remove screws (9). Remove plate (10).

3. Remove assembly of diaphragm (11) and the cap (12). Remove spring (13).

Assembly Procedure

Table 38

Required Tools			
Tool	**Part Number**	**Part Name**	**Qty**
A	27610296	Torque Wrench	1

⚠ WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

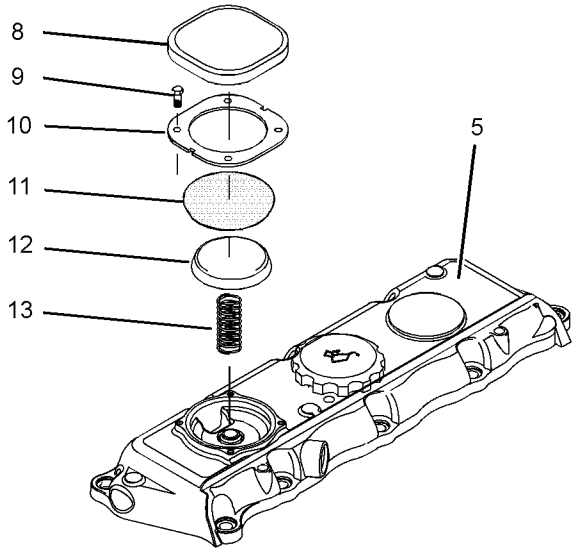


Illustration 124 g01347094

1. Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.

2. Install spring (13). Install assembly of diaphragm (11) and cap (12).

3. Position plate (10) on valve mechanism cover (5) and install screws (9).

4. Use Tooling (A) to tighten screws (9) to a torque of 1.3 N·m (12 lb in).

5. Install plastic cover (8) to valve mechanism cover (5).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

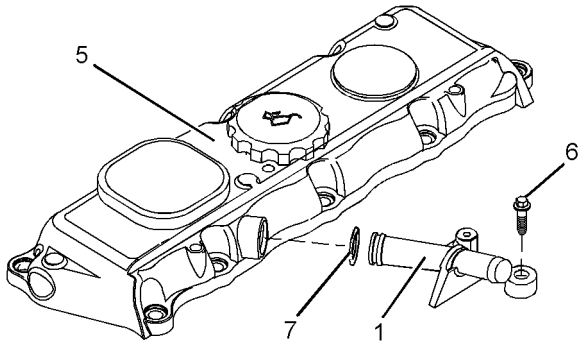


Illustration 125 g01346677

1. Install a new O-ring seal (7) to breather tube(1).

2. Install breather tube (1) to valve mechanism cover (5). Install bolt (6) and tighten the bolt to a torque of 9 N·m (80 lb in).

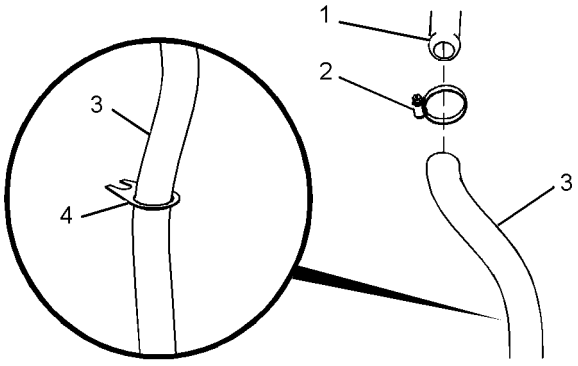


Illustration 126 g01343996
Typical example

3. Connect hose (3) to breather tube (1). Tighten clamp (2). Install hose (3) into clip (4).

i02628815

Crankcase Breather - Remove and Install (Turbocharged Engines with 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.

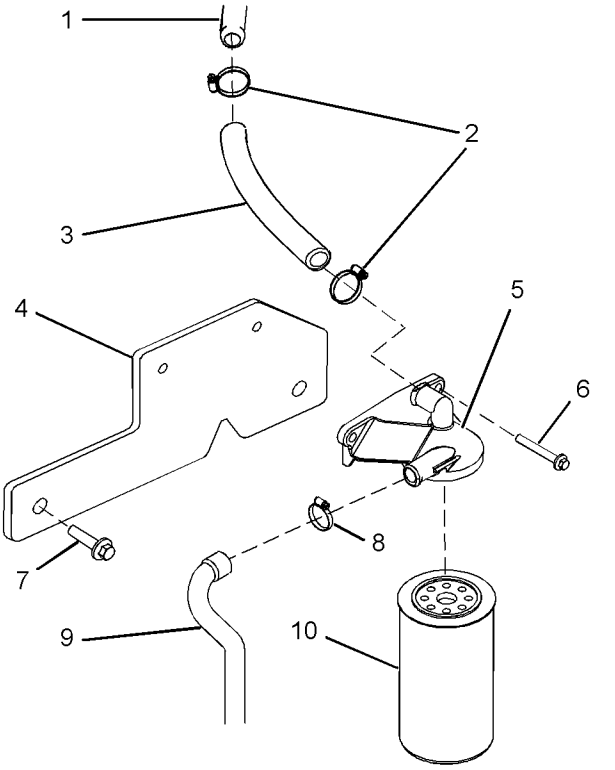


Illustration 127 g01368198
Typical example

1. Remove canister (10). Refer to Operation and Maintenance Manual, “Crankcase Breather (Canister) - Replace”.
2. Release spring clamps (8) and remove hose (9).
3. Release spring clamps (2) in order to remove hose (3). Remove the hose from breather tube (1) and from filter base (5).
4. Remove bolts (6) and remove filter base (5).
5. If necessary, remove bolts (7) and remove bracket (4) from cylinder head.

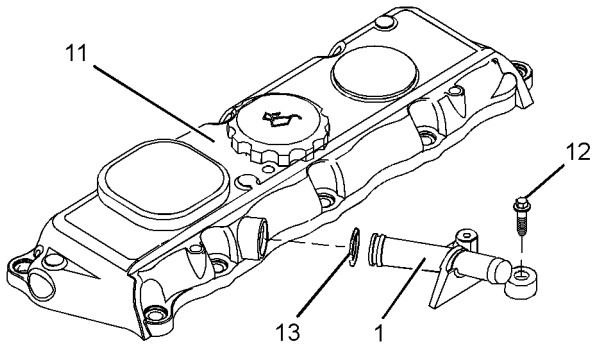


Illustration 128 g01368677

6. Remove bolt (12) and remove breather tube (1) from valve mechanism cover (11).
7. Remove O-ring seal (13) from breather tube (1).

Disassembly Procedure

⚠ WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

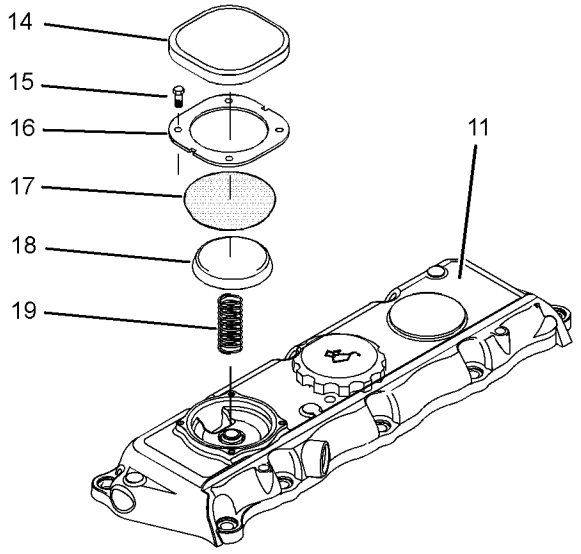


Illustration 129 g01368678

1. Remove plastic cover (14) from valve mechanism cover (11).
2. Remove screws (15). Remove plate (16).
3. Remove assembly of diaphragm (17) and the cap (18). Remove spring (19).

Assembly Procedure

Table 39

Required Tools			
Tool	**Part Number**	**Part Name**	**Qty**
A	27610296	Torque Wrench	1

⚠ WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

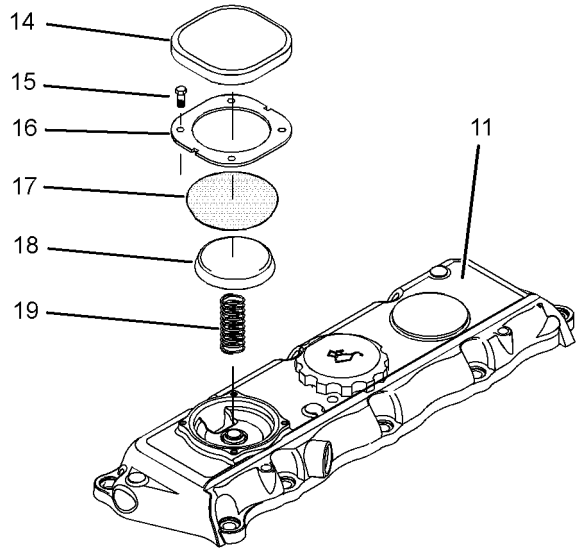


Illustration 130 g01368678

1. Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.
2. Install spring (19). Install assembly of diaphragm (17) and cap (18).
3. Position plate (16) on valve mechanism cover (11) and install screws (15).
4. Use Tooling (A) to tighten screws (15) to a torque of 1.3 N·m (12 lb in).
5. Install plastic cover (14) to valve mechanism cover (11).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

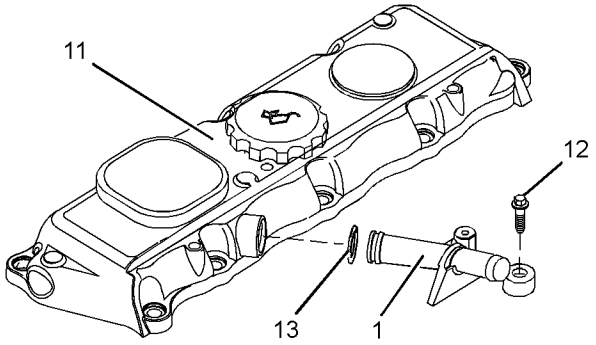


Illustration 131 g01368677

1. Install a new O-ring seal (13) to breather tube (1).
2. Install breather tube (1) to valve mechanism cover (11). Install bolt (12) and tighten the bolt to a torque of 9 N·m (80 lb in).

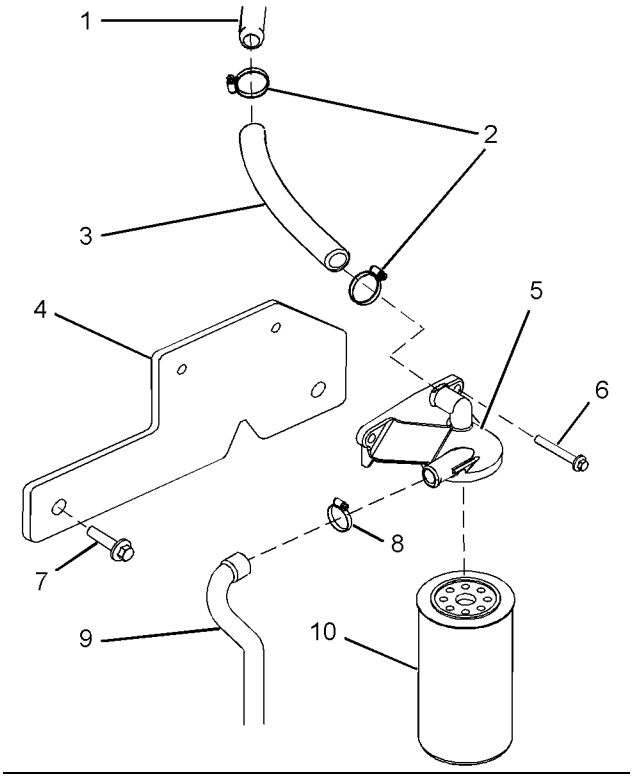


Illustration 132 g01368198
Typical example

3. If necessary, install bracket (4). Position bracket (4) onto cylinder head and install bolts (7). Tighten the bolts to a torque of 22 N·m (16 lb ft).
4. Install bolts (6) to filter base (5).
5. Install the assembly of the filter base to the engine.
6. Tighten bolts (6) to a torque of 22 N·m (16 lb ft).
7. 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.

8. Install spring clamp (8) to hose (9). Install hose (9) to filter base (5).
9. Install a new canister (10) to filter base (5). Refer to Operation and Maintenance Manual, “Crankcase Breather (Canister) - Replace”.

i02681626

Crankcase Breather - Remove and Install (Naturally Aspirated Engines)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

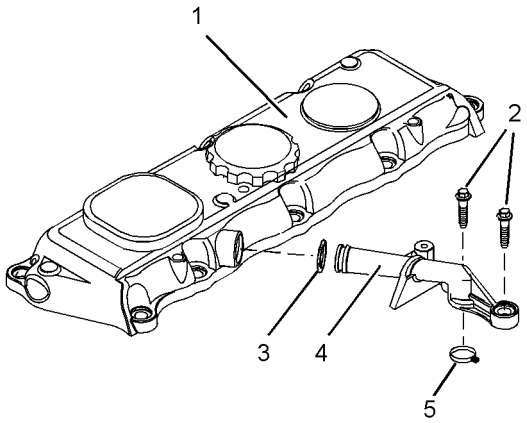


Illustration 133 g01368193
Typical example

1. Remove bolts (2) and remove breather tube (4) from valve mechanism cover (1).
2. Remove O-ring seal (3) and seal (5) from breather tube(4).

Disassembly Procedure

⚠ WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

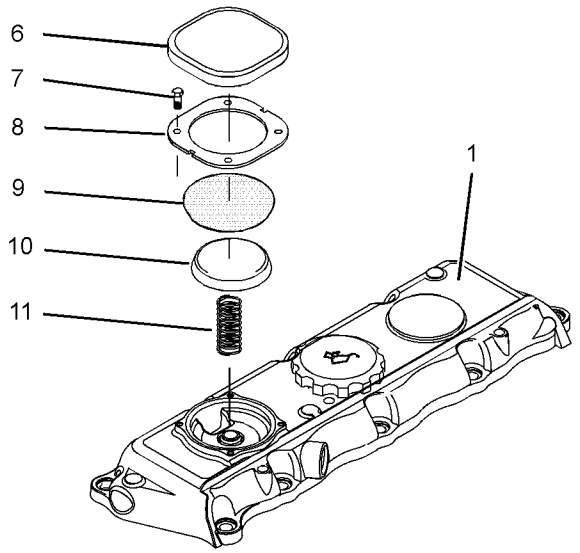


Illustration 134 g01347463
Typical example

1. Remove plastic cover (6) from valve mechanism cover (1).
2. Remove screws (7). Remove plate (8).
3. Remove assembly of diaphragm (9) and the cap (10). Remove spring (11).

Assembly Procedure

Table 40

Required Tools			
Tool	**Part Number**	**Part Name**	**Qty**
A	27610296	Torque Wrench	1

⚠ WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

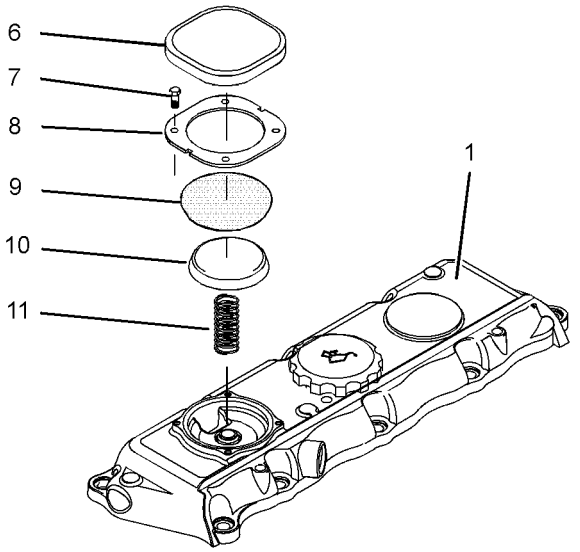


Illustration 135 g01347463
Typical example

1. Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.
2. Install spring (11). Install assembly of diaphragm (10) and cap (9).
3. Position plate (8) on valve mechanism cover (1) and install screws (7).
4. Use Tooling (A) to tighten screws (7) to a torque of 1.3 N·m (12 lb in).
5. Install plastic cover (6) to valve mechanism cover (1).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

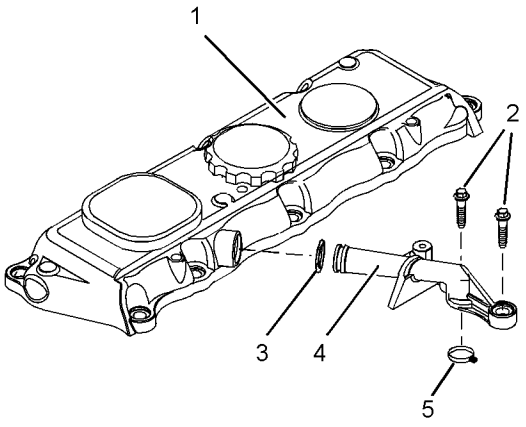


Illustration 136 g01368193
Typical example

1. Install new O-ring seals (3) and (5) to breather tube(4).

2. Install breather tube (4) to valve mechanism cover (1). Install bolts (2) and tighten the bolt to a torque of 9 N·m (80 lb in).

i02628915

Valve Mechanism Cover - 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. If the engine is equipped with a cover for the fuel injectors, remove the cover for the fuel injectors. Refer to Disassembly and Assembly, “Fuel Injector Cover - Remove and Install”.

2. If the engine is equipped with a heat shield, remove the heat shield.

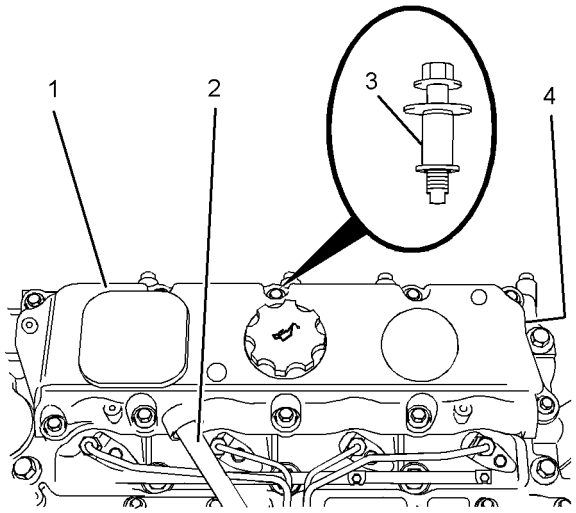


Illustration 137 g01368184
Typical example

3. Remove breather tube (2) from valve mechanism cover (1). Refer to Disassembly and Assembly, “Crankcase Breather - Remove and Install”.

4. Loosen captive bolts (3). Remove valve mechanism cover (1).

5. Remove captive bolts (3) and remove joint (4) (not shown) from valve mechanism cover (1).

Installation Procedure

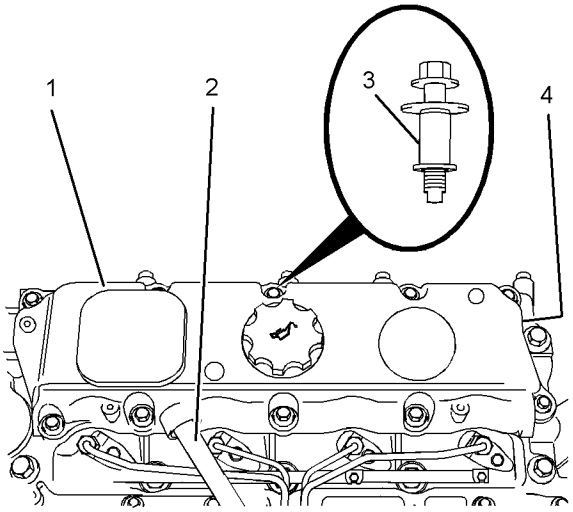


Illustration 138 g01368184
Typical example

1. Thoroughly clean valve mechanism cover (1). Ensure that the groove for the joint in the valve mechanism cover is clean and dry. Ensure that the mating surface on the cylinder head is clean and dry.
2. Check the condition of captive bolts (3). If necessary, replace the captive bolts.
3. Install a new joint (4) to valve mechanism cover (1). Ensure that the joint is seated correctly in the groove in the valve mechanism cover.
4. Install captive bolts (3) to valve mechanism cover (1).
5. Position valve mechanism cover (1) onto the cylinder head.

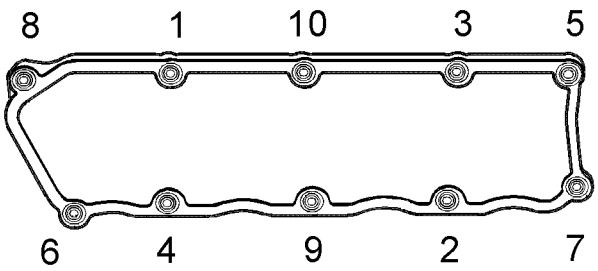


Illustration 139 g01344009
Sequence for tightening the isolating bolts

6. Tighten the captive bolts for the valve mechanism cover in the sequence that is shown in Illustration 139. Tighten the captive bolts to a torque of 9 N·m (80 lb in).
7. Install breather tube (3) to valve mechanism cover (1). Refer to Disassembly and Assembly, “Crankcase Breather - Remove and Install”.
8. If the engine is equipped with a heat shield, install the heat shield.
9. If the engine is equipped with a cover for the fuel injectors, install the cover for the fuel injectors. Refer to Disassembly and Assembly, “Fuel Injector Cover - Remove and Install”.

i02628906

Rocker Shaft and Pushrod - Remove

Removal Procedure

Table 41

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	E10 Torx Socket	1
B	27610227	Rocker Assembly Tool	4

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.

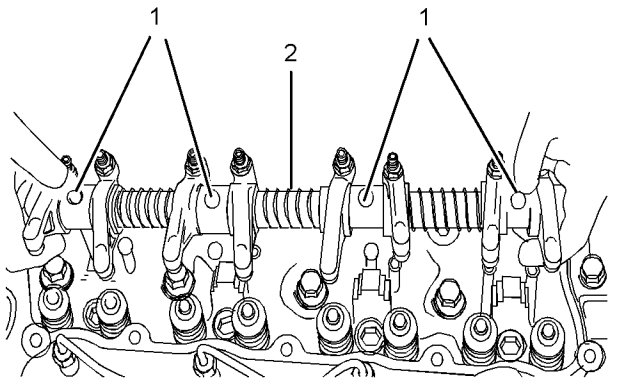


Illustration 140 g01323013
Typical example

1. Use Tooling (A) 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. If the rocker shaft will not be disassembled, install Tooling (B) between each pair of rocker arms.

4. Remove rocker shaft assembly (2) from the cylinder head.

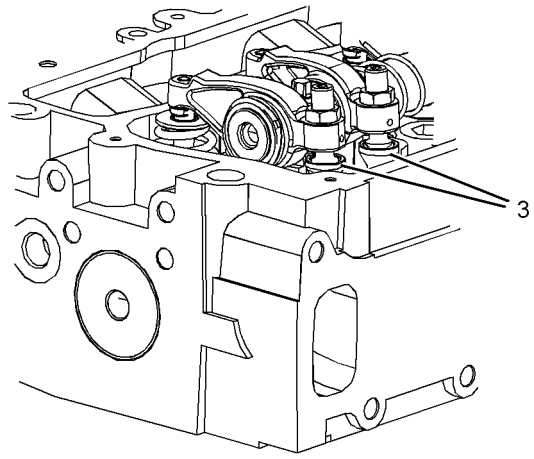


Illustration 141 g01359104
Typical example

5. Place an identification 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.

i02628903

Rocker Shaft - Disassemble

Disassembly Procedure

Table 42

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Circlip Pliers	1

Start By:

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

⚠ 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. 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.

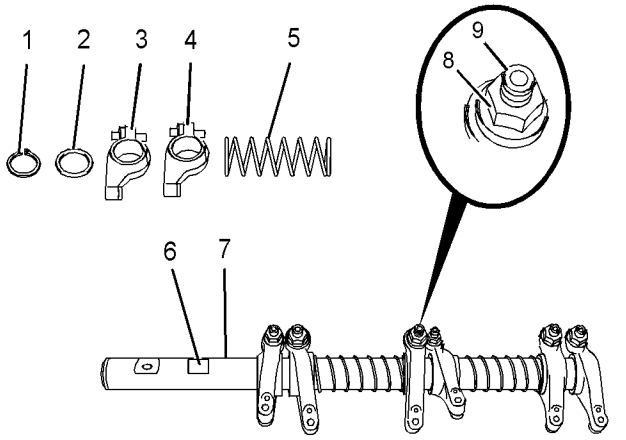


Illustration 142 g01350909

Typical example

2. Use Tooling (A) to remove circlip (1) and remove washer (2) from both ends of the rocker shaft assembly.

Note: The rocker shaft (7) is not symmetrical as there is a machined flat (6) toward one end of the shaft.

3. Remove rocker arm assembly (3) for the inlet valve from rocker shaft (7). Remove rocker arm assembly (4) for the exhaust valve from rocker shaft (7).

4. Remove spring (5) from rocker shaft (7).

5. Repeat Step3 and Step4 in order to completely disassemble the rocker shaft assembly.

6. If necessary, remove nuts (8) and adjusters (9) 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.

i02628901

Rocker Shaft - Assemble

Assembly Procedure

Table 43

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Circlip Pliers	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. Refer to Specifications, “Rocker Shaft” for more information. If necessary, replace any components that are worn or damaged.

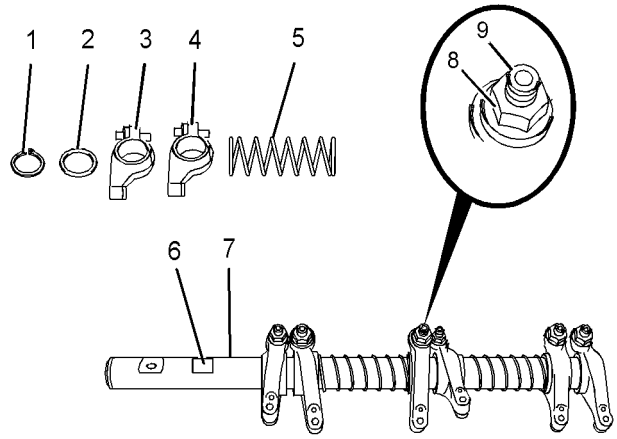


Illustration 143 g01350909

Typical example

2. If necessary, install adjusters (9) and nuts (8) to rocker arm assemblies (3) and (4). If the original adjusters are reused, ensure that the adjusters are installed in the original positions.

3. Use Tooling (A) to install circlip (1) and washer (2) to the front end of rocker shaft (7).

4. Lubricate the bores of rocker arm assemblies (3) and (4) and rocker shaft (7) with clean engine oil.

5. 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 (7).

⚠ 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.

6. Install spring (5) to rocker shaft (7).

7. Repeat Steps 5 to 6 in order to assemble the remaining components to rocker shaft (7).

8. Install washer (2) to rocker shaft (7). Use Tooling (A) to install circlip (1).

End By:

a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, “Rocker Shaft and Pushrod - Install”.

i02628904

Rocker Shaft and Pushrod - Install

Installation Procedure

Table 44

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	E10 Torx Socket	1
B	27610227	Rocker Assembly Tool	4

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the pushrods. Inspect the pushrods for wear or damage. Replace any pushrods that are worn or damaged.

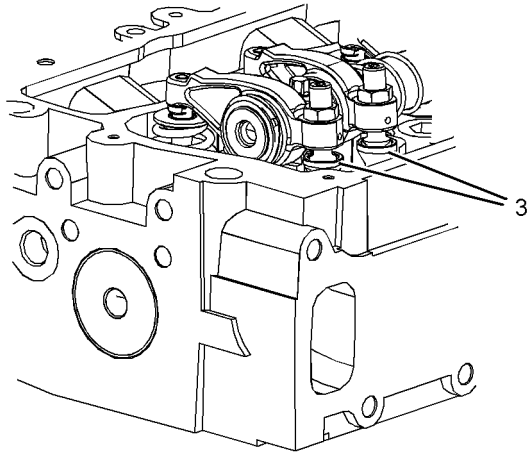


Illustration 144 g01359104
Typical example

2. 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.

3. Ensure that the rocker shaft assembly is clean and free from wear or damage.

4. If the rocker shaft assembly was disassembled, install Tooling (B) between each pair of rocker arms.

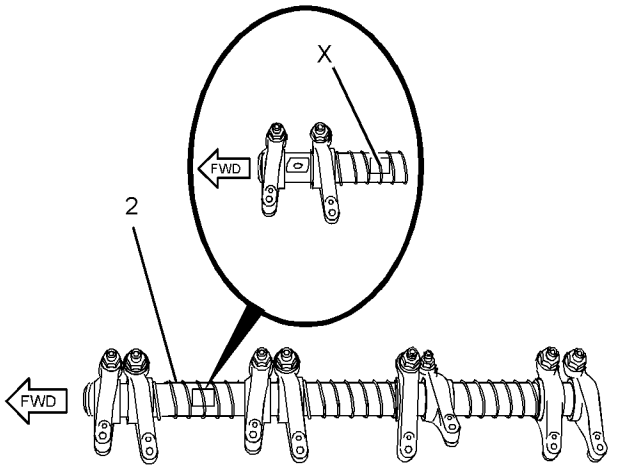


Illustration 145 g01323445
Typical example

5. Ensure that the machined flat (X) is facing upward, and facing the front end of the engine.

6. Position rocker shaft assembly (2) onto the cylinder head.

Note: Ensure that adjustment screws are properly seated in the ends of pushrods (3).

7. Install torx screws (1) to the rocker shaft assembly finger tight.

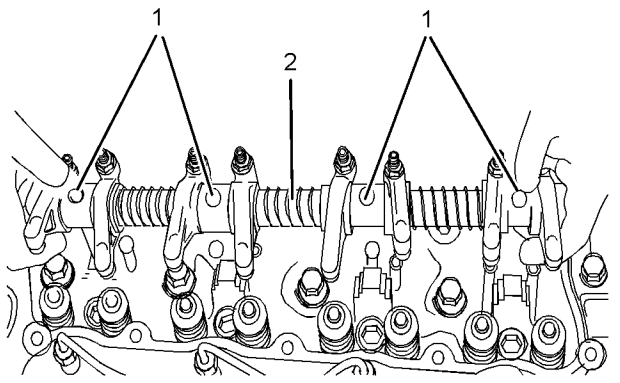


Illustration 146 g01323447
Typical example

8. Use Tooling (A) to progressively tighten torx screws (1). Begin at the center of the rocker shaft assembly and work toward the ends.

Note: To avoid distortion of the rocker shaft assembly, each torx screw should be tightened by a quarter of a turn at one time. Repeat the procedure until all torx screws are tightened.

Tighten torx screws (1) to a torque of 35 N·m (26 lb ft).

9. Check the valve lash. Refer to Systems Operation, Testing and Adjusting, “Engine Valve Lash - Inspect/Adjust”. 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”.

i02628830

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 injectors. Refer to Disassembly and Assembly, “Injector - Remove”.

c. Remove the rocker shaft assembly and the pushrods. Refer to this Disassembly and Assembly Manual, “Rocker Shaft and Pushrod - Remove”.

d. 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 fuel filter base are mounted on the cylinder head, remove the fuel priming pump and the fuel filter base. Refer to Disassembly and Assembly, "Fuel Priming Pump and Fuel Filter Base - 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.

4. Disconnect the upper radiator hose from the water temperature regulator housing.

5. If necessary, remove the air hose from the inlet connection.

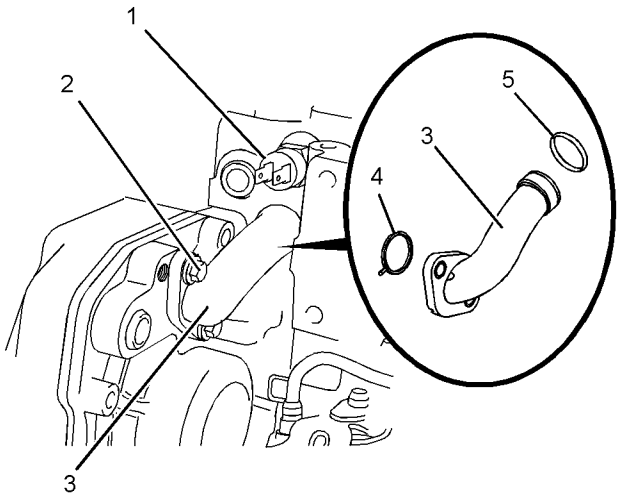


Illustration 147 g01344073

6. Disconnect the harness assembly from sensor (1).

7. Remove the bolts (2). Remove the bypass tube (3) from the cylinder head. Remove O-ring seals (4) and (5).

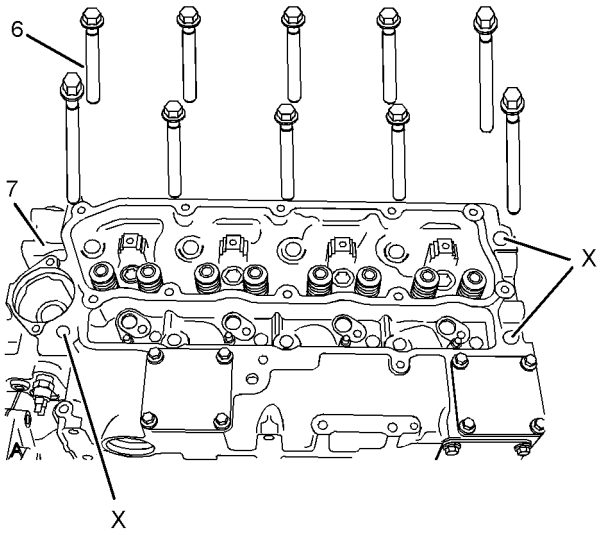


Illustration 148 g01323622
Typical example

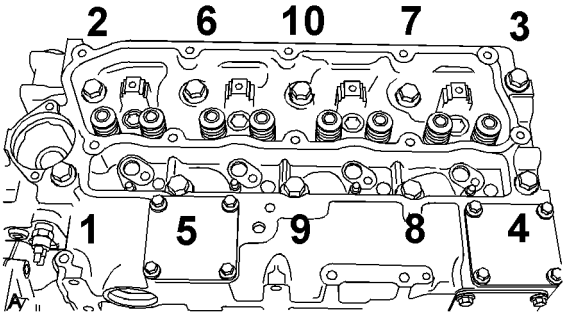


Illustration 149 g01352264
Sequence for tightening the bolts for the cylinder head

8. Gradually loosen bolts (6) in the reverse numerical order to the sequence that is shown in Illustration 149.

Note: Follow the correct sequence in order to help prevent distortion of the cylinder head.

9. Remove bolts (6) from cylinder head (7).

Note: The bolts are two different lengths. Note the positions of the different bolts.

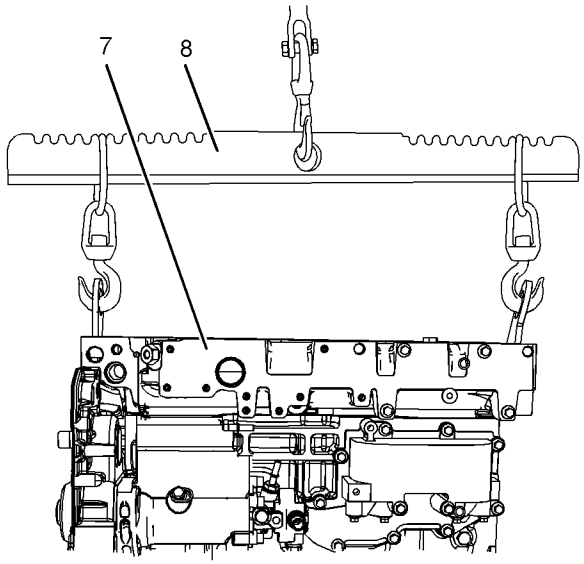


Illustration 150 g01323631
Typical example

10. Attach a suitable lifting device (8) to cylinder head (7). Support the weight of the cylinder head. The weight of the cylinder head is approximately 56 kg (124 lb).

Note: It is advisable to use a spreader bar during the lifting operation in order to distribute the weight of the cylinder head .

11. Use lifting device (8) to carefully lift cylinder head (7) 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.

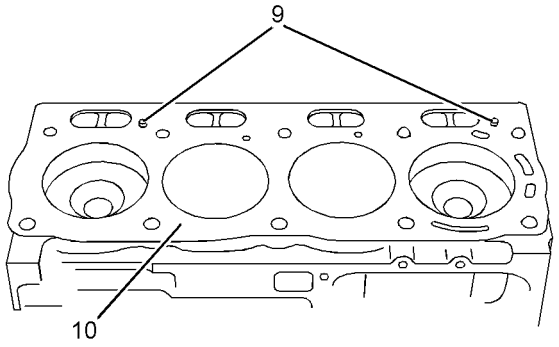


Illustration 151 g01323639
Typical example

12. Remove cylinder head gasket (10).

13. Note the position of dowels (9) in the cylinder block. Do not remove the dowels unless the dowels are damaged.

14. If necessary, remove the sensor from cylinder head.

15. If necessary, remove the water temperature regulator from the cylinder head. Refer to Disassembly and Assembly, “Water Temperature Regulator - Remove and Install”.

i02628829

Cylinder Head - Install

Installation Procedure

Table 45

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Bolt (M16 by 115mm)	2
B	-	Straight Edge	1
C	21825607	Degree Wheel	1
D	21820221	POWERPART Rubber Grease	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the mating surfaces of the cylinder head and the cylinder block. Do not damage the mating 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 mating surface of the cylinder head for distortion. Refer to Specifications, “Cylinder Head” for more information.

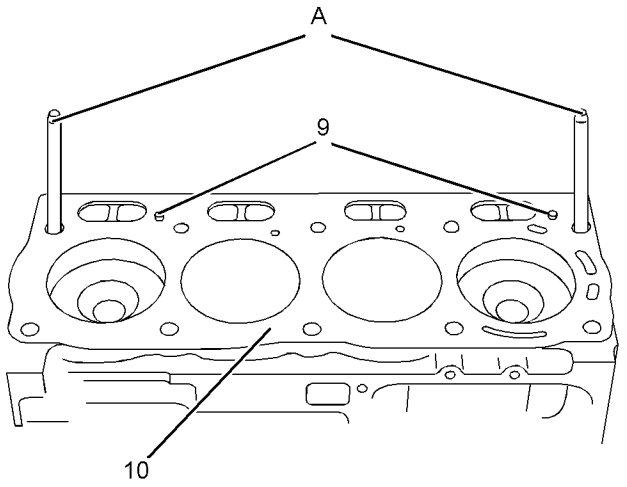


Illustration 152 g01324063
Typical example

3. Inspect dowels (9) for damage. If necessary, replace the dowels in the cylinder block.

4. Install Tooling (A) to the cylinder block. Refer to Illustration 152.

5. Align cylinder head gasket (10) with Tooling (A) and with dowels (9). Install the cylinder head gasket onto the cylinder block.

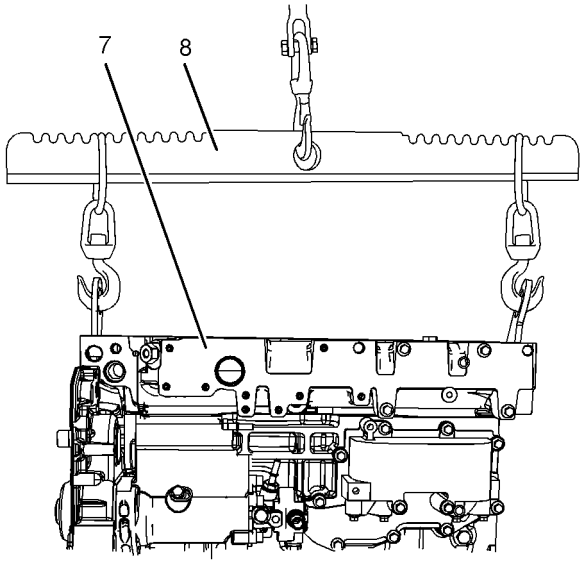


Illustration 153 g01323631
Typical example

6. Use a suitable lifting device (8) to lift the cylinder head. The weight of the cylinder head is approximately 56 kg (124 lb).

Note: It is advisable to use a spreader bar during the lifting operation in order to distribute the weight of the cylinder head.

7. Use Tooling (A) to align cylinder head (7) with the cylinder block. Install the cylinder head to the cylinder block.

Note: Ensure that the cylinder head is correctly positioned onto dowels (9).

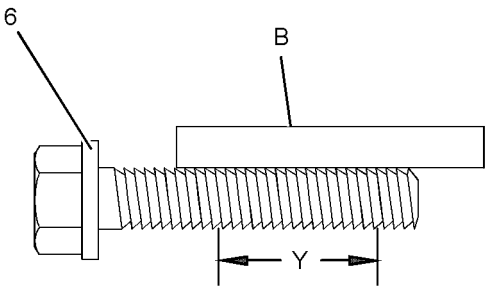


Illustration 154 g01324064

8. Clean bolts (6). Follow Steps 8.a and 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 154. 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 (6) with clean engine oil.

10. Remove Tooling (A).

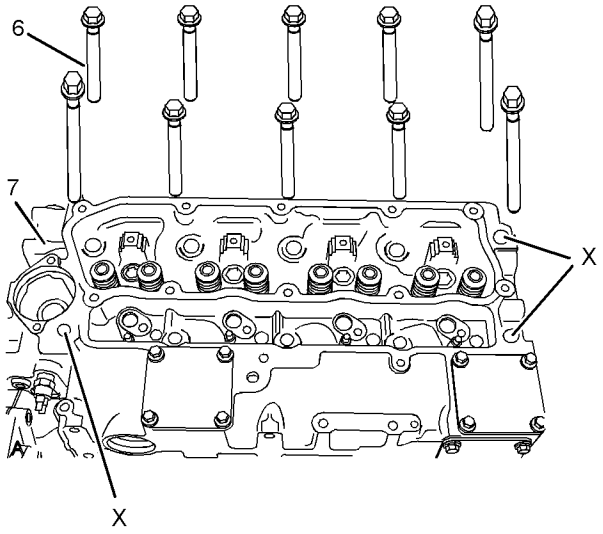


Illustration 155 g01323622

11. Install bolts (6) to cylinder head (7).

Note: There are two different lengths of bolts (6) for cylinder head (7). Install longer bolts in position (X) in the cylinder head.

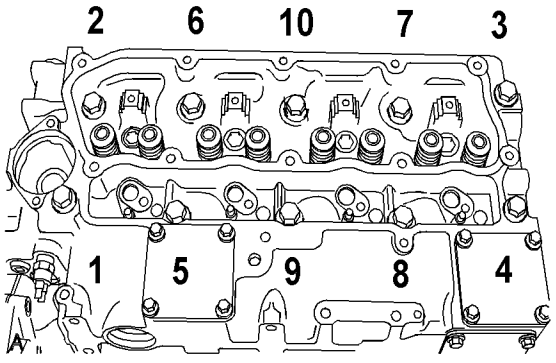


Illustration 156 g01352300

Sequence for tightening the bolts for cylinder head

12. Tighten bolts (6) to a torque of 50 N·m (37 lb ft) in the sequence that is shown in Illustration 156.

13. Tighten bolts (6) to a torque of 100 N·m (74 lb ft) in the sequence that is shown in Illustration 156.

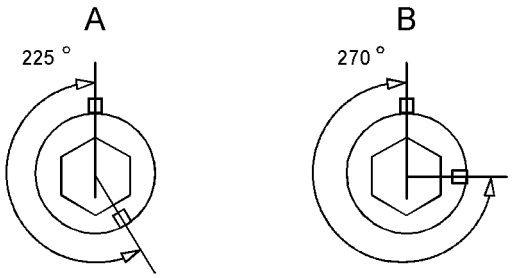


Illustration 157 g01352369

(A) Short bolts

(B) Long bolts

14. Use Tooling (C) to turn bolts (6) through an additional angle in the sequence that is shown in Illustration 156.

Turn the long bolts through 270 degrees.

Turn the short bolts through 225 degrees.

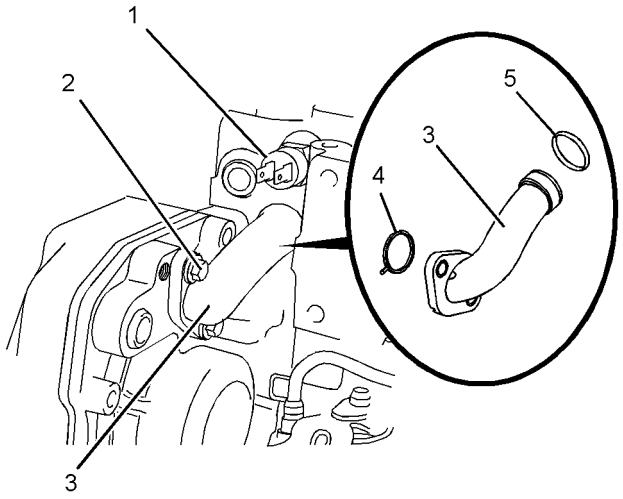


Illustration 158 g01344073

15. Install new O-ring seals (4) and (5) to bypass tube (3). Use Tooling (D) in order to lubricate the O-ring seal (5). Install the bypass tube to the cylinder head. Install bolts (2). Ensure that any brackets that are secured by the bolts are installed in the correct position. Tighten the bolts to a torque of 22 N·m (16 lb ft).

16. Connect the harness assembly to sensor (1).

17. If the alternator bracket is mounted on the cylinder head, Install the alternator. Refer to Disassembly and Assembly, “ Alternator - Remove”.

18. Install the injectors. Refer to Disassembly and Assembly, “Injector - Install”.

19. Install the glow plugs. Refer to Disassembly and Assembly, “Glow Plugs - Remove and Install”.

20. If the fuel priming pump and the fuel filter base are mounted on the cylinder head, install the fuel priming pump and the fuel filter base. Refer to Disassembly and Assembly, “Fuel Priming Pump and Fuel Filter Base - Remove and Install”.

21. Install the exhaust manifold. Refer to Disassembly and Assembly, “Exhaust Manifold - Remove and Install”.

22. If necessary, install the air hose to the inlet connection.

23. If necessary, install the water temperature regulator housing to the cylinder head. Refer to Disassembly and Assembly, “Water Temperature Regulator Housing - Remove and Install”.

24. Connect the upper radiator hose to the water temperature regulator housing .

25. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, “Cooling System Coolant - Change” for the correct filling procedure.

26. If necessary, fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, “Engine Oil Level - Check”.

i02628895

Lifter Group - Remove and Install

Removal Procedure

Table 46

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”.

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 lifters (1).

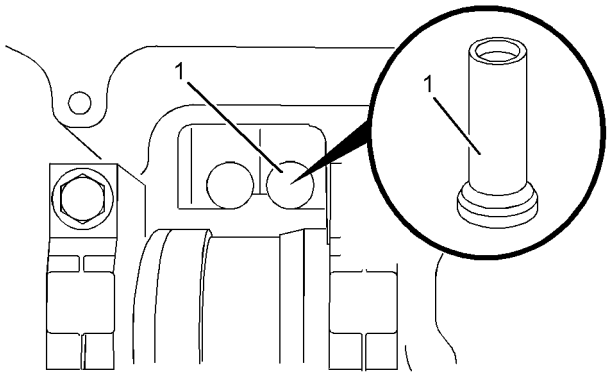


Illustration 159 g01340518
Typical example

2. Use Tooling (B) in order to remove lifters (1).

Note: Make a temporary identification mark on each lifter in order to identify the correct location.

3. Repeat Steps 1 and 2 in order to remove the remaining lifters.

Installation Procedure

Table 47

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 Steps 1.a through 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.

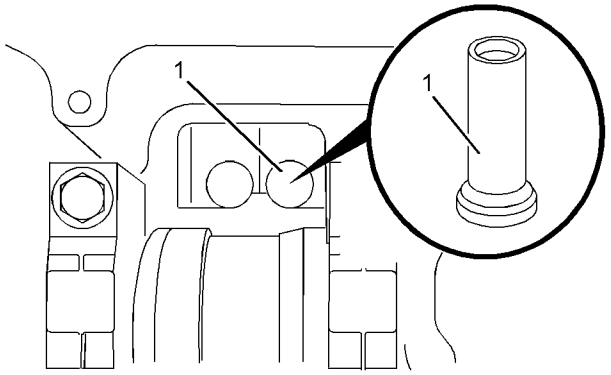


Illustration 160 g01340518
Typical example

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 Steps 1 and 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 - Install”.

i02628809

Camshaft - Remove and Install

Removal Procedure

Start By:

a. Remove the rockershaft 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.

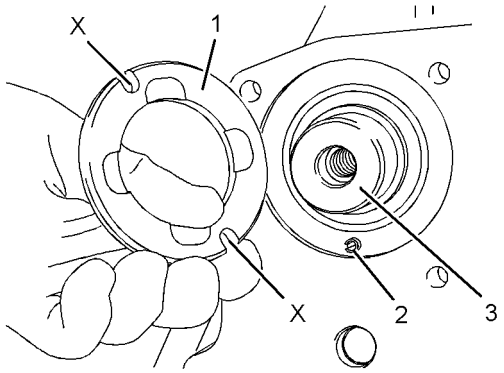


Illustration 161 g01266056
Typical example

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).

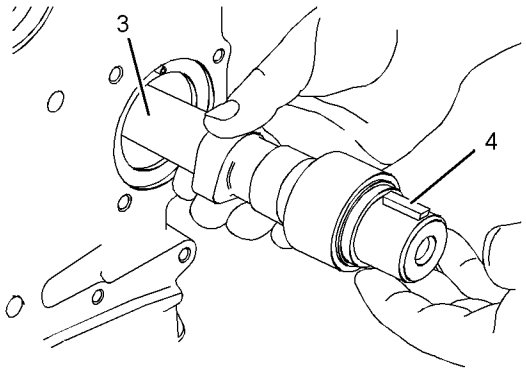


Illustration 162 g01266057

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 Bearing - 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”.

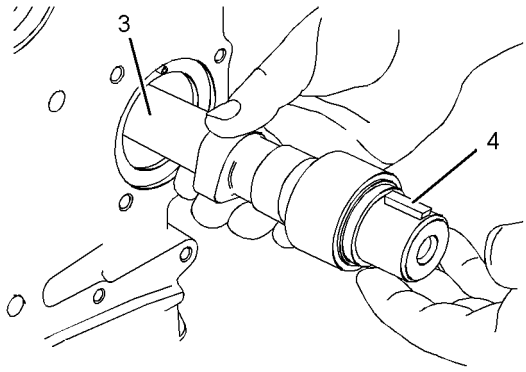


Illustration 163 g01266057

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.

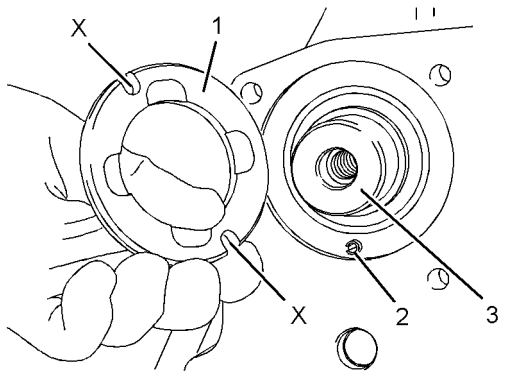


Illustration 164 g01266056
Typical example

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 rockershaft and pushrods. Refer to Disassembly and Assembly, “Rocker shaft and Pushrod - Install”.

i02628811

Camshaft Gear - Remove and Install

Removal Procedure

Table 48

Required Tools			
Tool	Part Number	Part Name	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

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”.

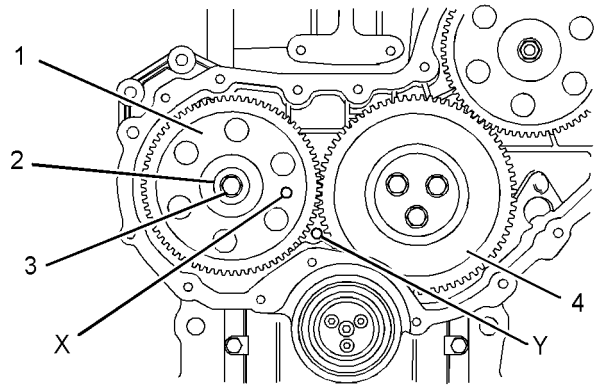


Illustration 165 g01255712
Typical example

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.

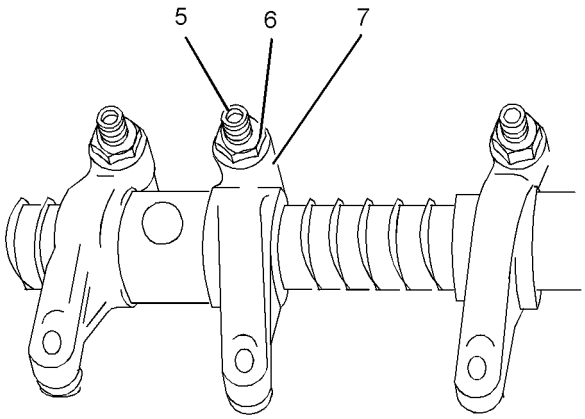


Illustration 166 g01350327
Typical example

4. Loosen nuts (6) on ALL rocker arms (7). Unscrew adjusters (5) on all rocker arms (7) 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.

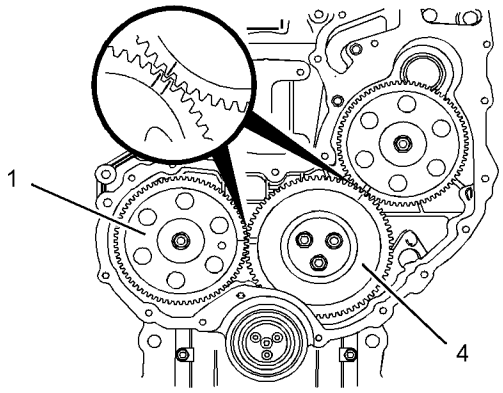


Illustration 167 g01344527
Alignment of timing marks

5. Mark gears (1) and (4) in order to show alignment. Refer to Illustration 167.

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

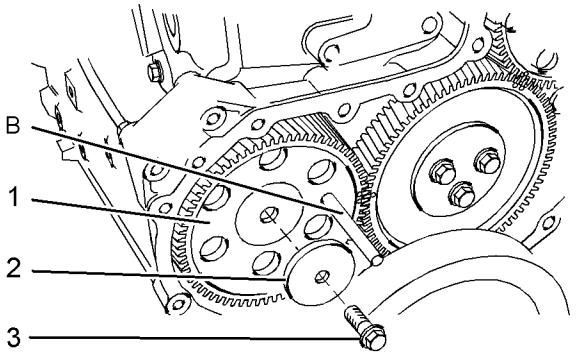


Illustration 168 g01340554
Typical example

6. Remove Tooling (B) and Tooling (C). Remove bolt (3) and washer (2) 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 49

Required Tools			
Tool	Part Number	Part Name	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 the Systems Operation, Testing and Adjusting, “Finding Top Center Position for No. 1 Piston”.

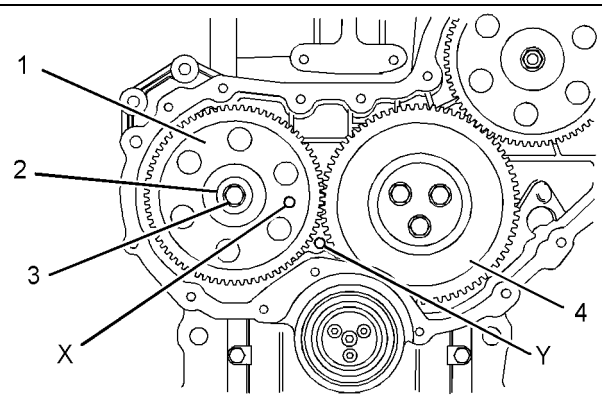


Illustration 169 g01255712
Typical example

2. Install Tooling (C) into hole (Y) in the cylinder block. Use Tooling (C) in order to lock the crankshaft in the correct position. Refer to Systems Operation, Testing and Adjusting, “Finding Top Centre Position for No.1 Piston”.

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.

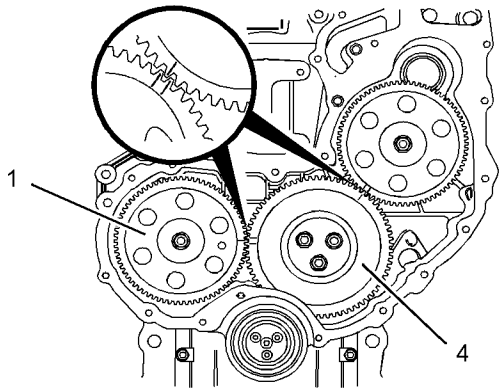


Illustration 170 g01344527

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 gears (1) and (8) are in alignment and that the mesh of the gears is correct. Refer to Illustration 170.

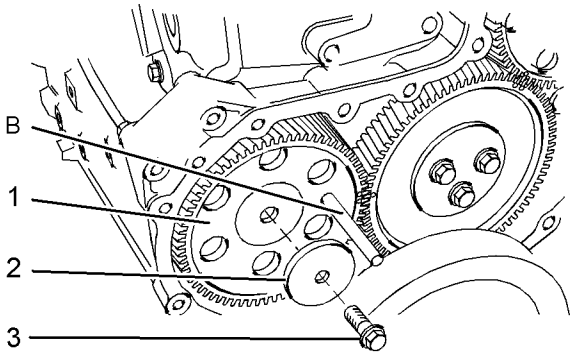


Illustration 171 g01340554

Typical example

6. Install Tooling (B) through hole (X) in the camshaft gear into the front housing. Install washer (2) and bolt (3) to camshaft gear (1).

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

8. Tighten bolt (3) to a torque of 95 N·m (70 lb ft).

9. Use Tooling (D) to check the backlash for gears (1) and (8). Ensure that the backlash for the gears is within specified values. Refer to the Specifications, “Gear Group (Front)” for further information.

10. Use Tooling (D) to check the end play for camshaft gear (1). Ensure that the end play is within specified values. Refer to the Specifications, “Camshaft” for further information.

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

12. 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”.

i02628810

Camshaft Bearings - Remove and Install

Removal Procedure

Table 50

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	27610275	Bearing Puller Group	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.

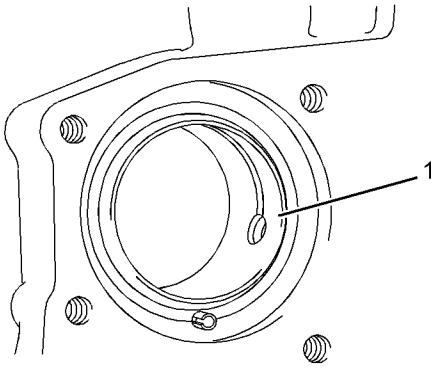


Illustration 172 g01270437

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 51

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	27610271	Bearing Puller Group	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.

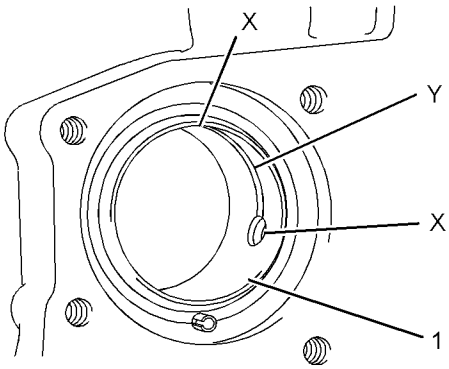


Illustration 173 g01266512

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”.

i02628836

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.

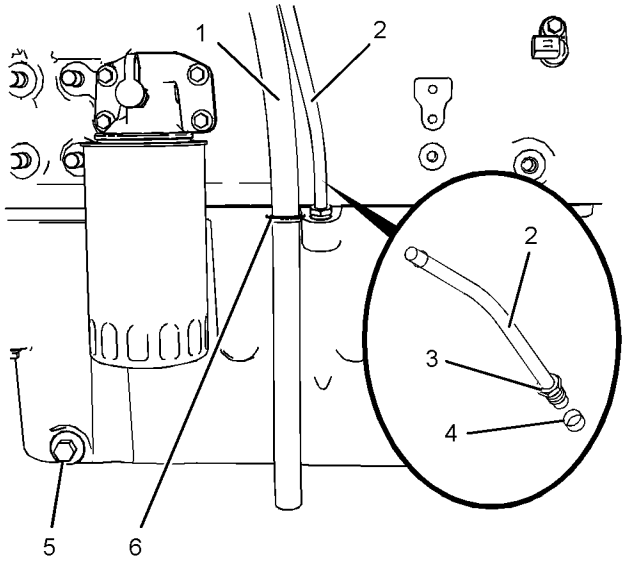


Illustration 174 g01344541
Typical example

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.

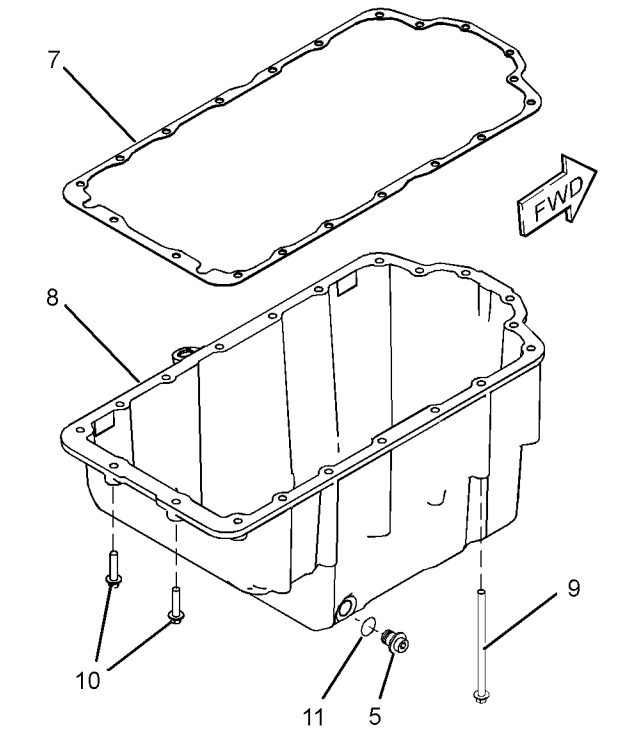


Illustration 175 g01251767
Typical example

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 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 the bolt that secures the clip and remove the clip.

6. Remove bolts (9) and (10).

7. Remove engine oil pan (8) and remove joint (7) from the cylinder block.

Installation Procedure

Table 52

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Guide Stud (M8 by 100 mm)	4
B	21826038	POWERPART Silicon Rubber Sealant	-
C	21820117	POWERPART Threadlock and Nutlock	-

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the mating surface of the cylinder block is clean and free from damage.

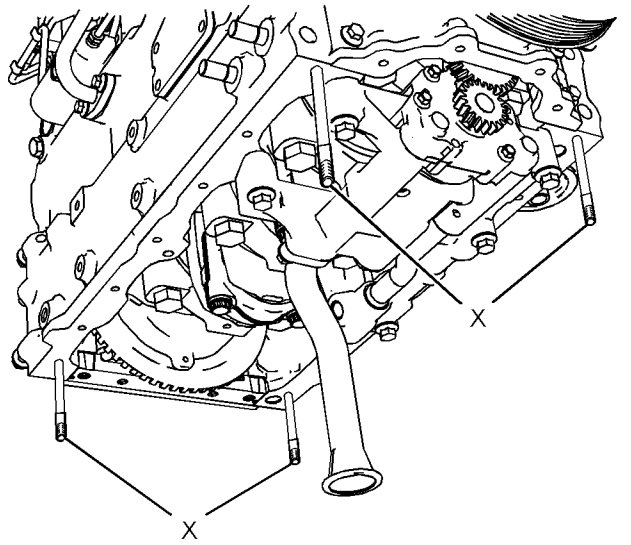


Illustration 176 g01251768
Typical example

2. Install Tooling (A) to positions (X) in the cylinder block.

3. Ensure that the engine oil pan is clean and free from damage.

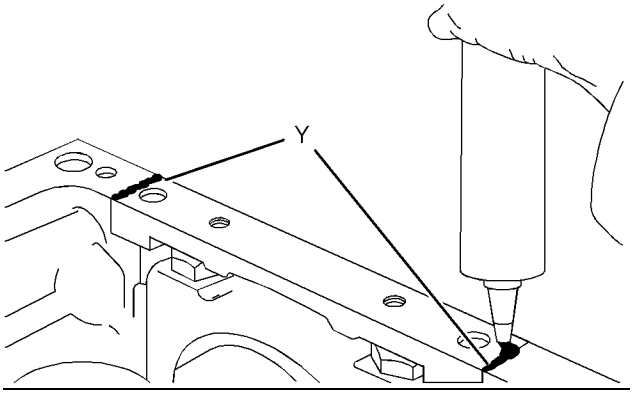


Illustration 177 g01251763
Typical example

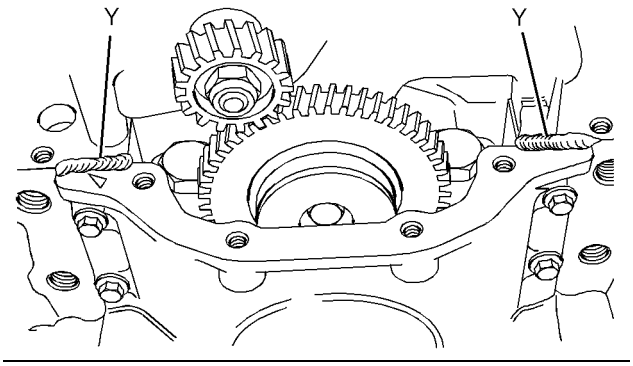


Illustration 178 g01251766
Typical example

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.

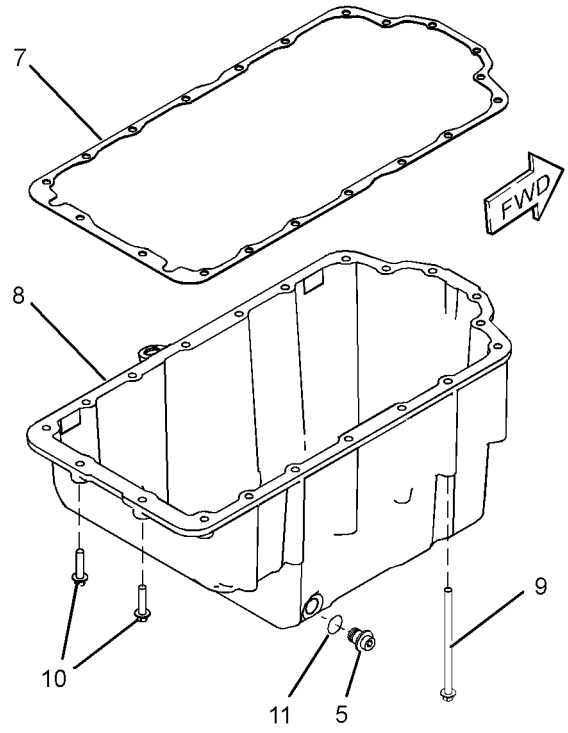


Illustration 179 g01251767
Typical example

5. Position a new joint (7) onto engine oil pan (8).

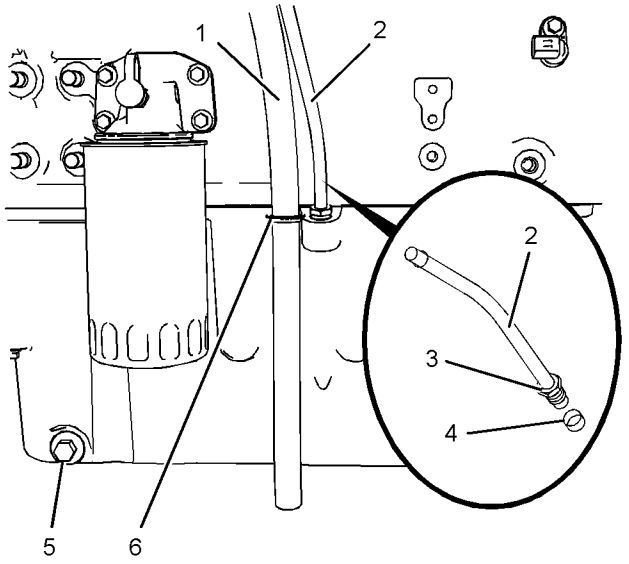


Illustration 180
g01344541
Typical example

6. Align the assembly of the engine oil pan with Tooling (A). Install the assembly of the engine oil pan to the cylinder block.

7. Install bolts (9) finger tight. Install clip (6) in the correct position.

8. Remove Tooling (A).

9. Apply Tooling (C) to bolts (10). Install bolts (10) and the remaining bolts (9).

10. Tighten bolts (9) and (10) to a torque of 22 N·m (16 lb ft).

11. Install a new O-ring seal (11) to drain plug (5). Install the drain plug to engine oil pan (8). Tighten the oil drain plug to a torque of 34 N·m (25 lb ft).

12. If necessary, follow Steps 12.a through 12.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.

13. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, “Engine Oil and Filter - Change” for the procedure.

i02628835

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. Ensure that the engine lubricating oil is drained. Refer to Operation and Maintenance Manual, “Engine Oil and Filter - Change” for the correct 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. The engine should be mounted in a suitable stand and placed in the inverted position.

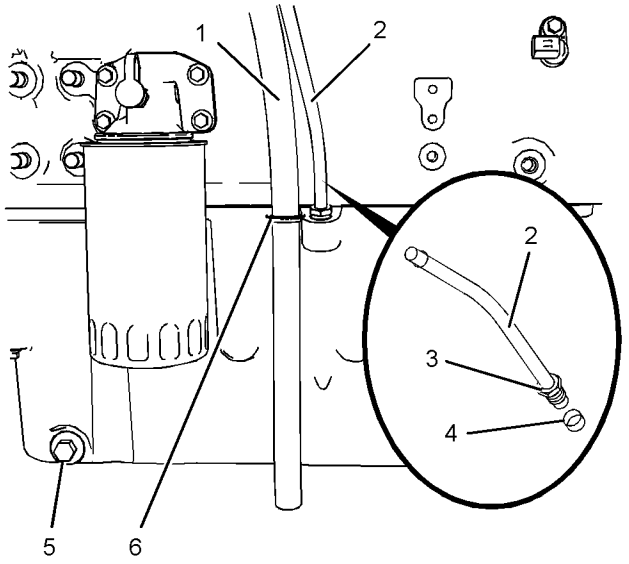


Illustration 181 g01344541

Typical example

2. 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.

3. Remove the assembly of the dipstick tube. Loosen nut (3) and remove tube assembly (2). Remove seal (4) from the tube assembly.

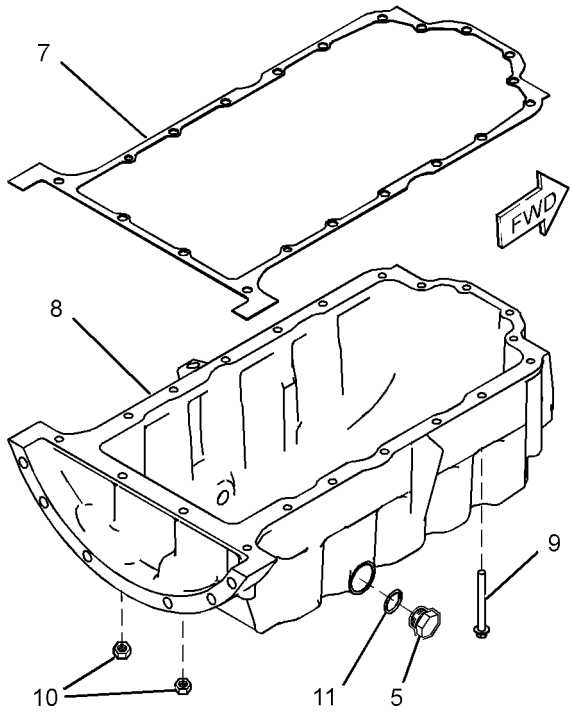


Illustration 182 g01251978

Typical example

4. Mark the position of clip (6). Refer to Illustration 181. Loosen the bolt that secures the clip and remove the clip.

5. Remove nuts (10) and bolts (9).

Note: The bolts are different lengths. Note the position of the different bolts.

6. 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).

7. Use the lifting device to remove engine oil pan (8) from the cylinder block.

8. Remove joint (7) from the cylinder block.

9. If necessary, remove drain plug (5). Remove O-ring seal (11) from oil drain plug (5).

Installation Procedure

Table 53

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 mating surface 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.

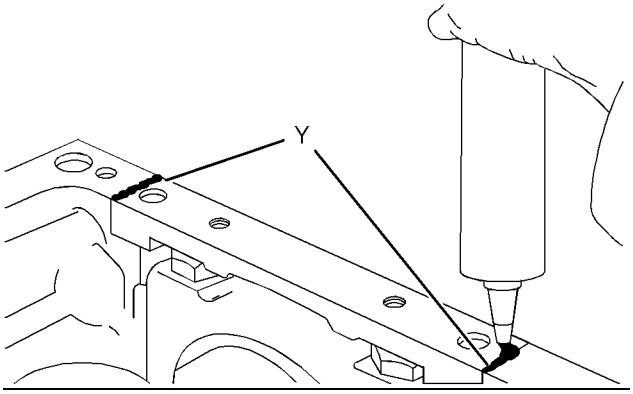


Illustration 183 g01251763
Typical example

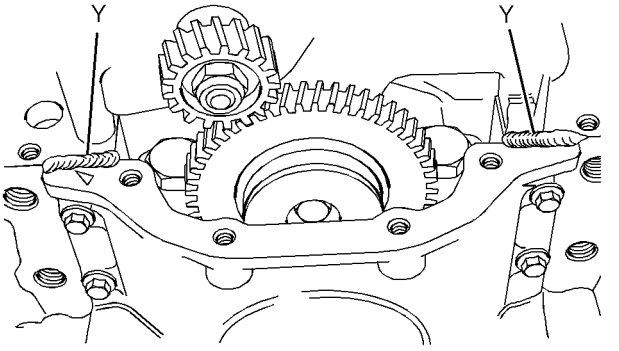


Illustration 184 g01251766
Typical example

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.

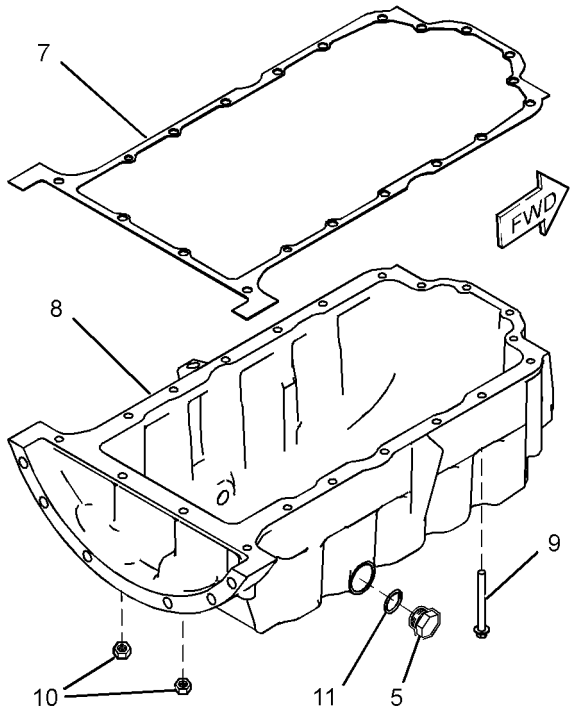


Illustration 185 g01251978
Typical example

4. Align a new joint (7) with the studs in the cylinder block. Install the joint 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 the clip (6).

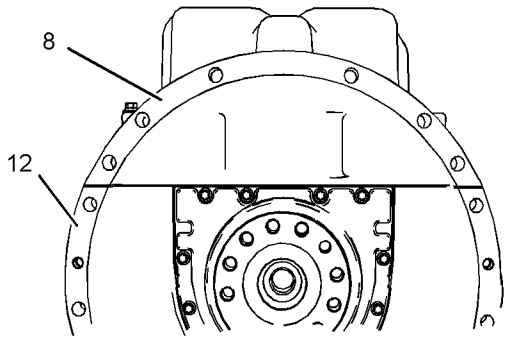


Illustration 186 g01251982
Typical example

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.

9. Tighten bolts (9) and nuts (10) to a torque of 22 N·m (16 lb ft).

10. If necessary, install a new O-ring seal (11) 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).

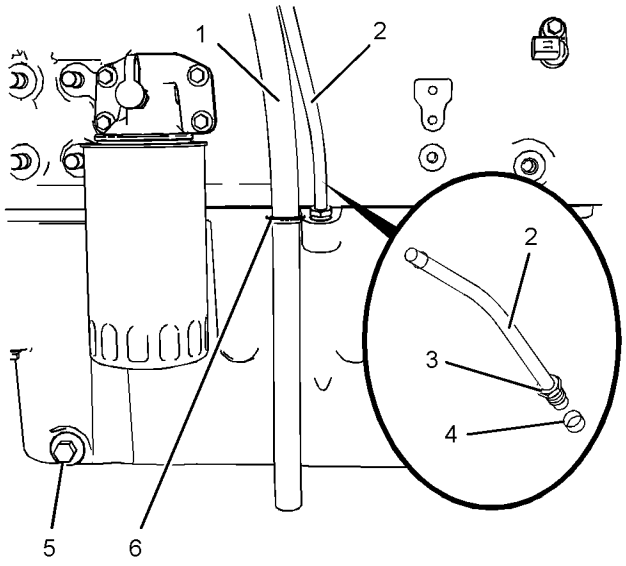


Illustration 187 g01344541
Typical example

11. Follow Steps 11.a through 11.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.

i02628808

Balancer - Remove

Removal Procedure

Table 54

Required Tools			
Tool	**Part Number**	**Part Name**	**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.

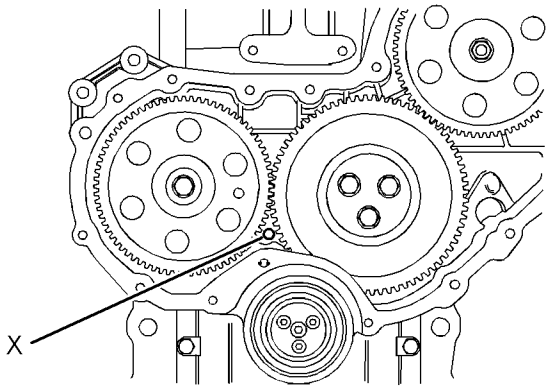


Illustration 188 g01259627
Typical example

2. Install Tooling (B) through hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

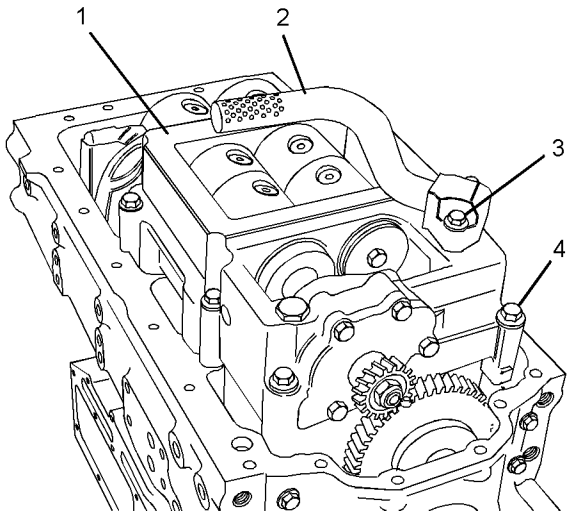


Illustration 189 g01259635
Typical example

3. Remove bolts (3) and suction pipe (2).

4. Remove the joint from the suction pipe.

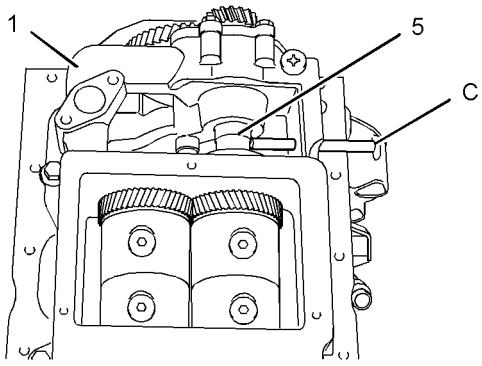


Illustration 190 g01252310
Typical example

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.

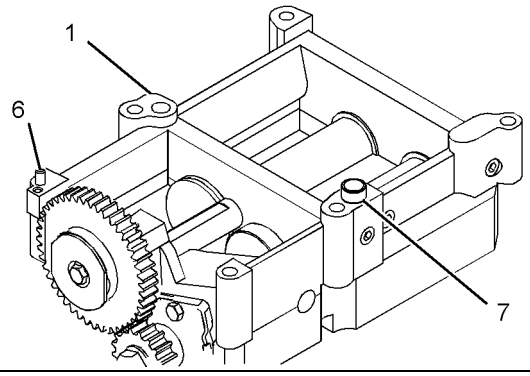


Illustration 191 g01259636

8. Do not remove dowels (6) and (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”.

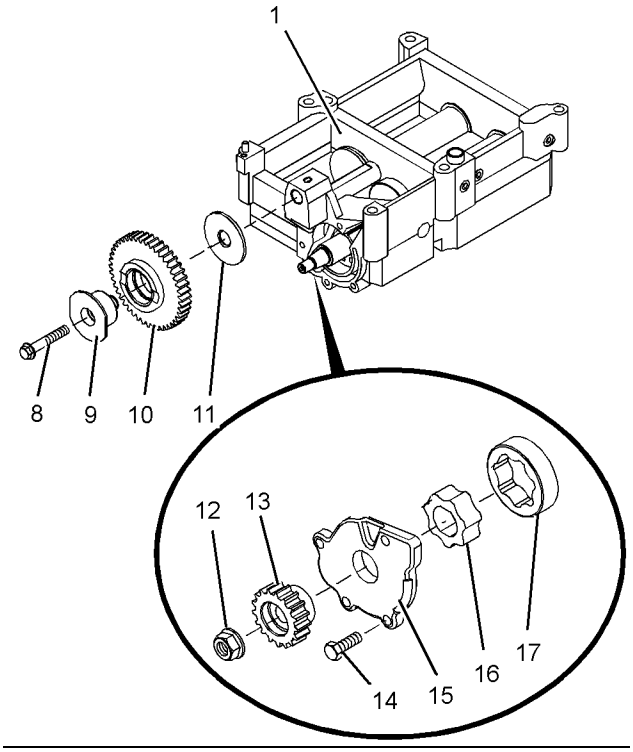


Illustration 192 g01344542

2. Remove bolt (8) and hub (9). Remove idler gear (10) and thrust washer (11).

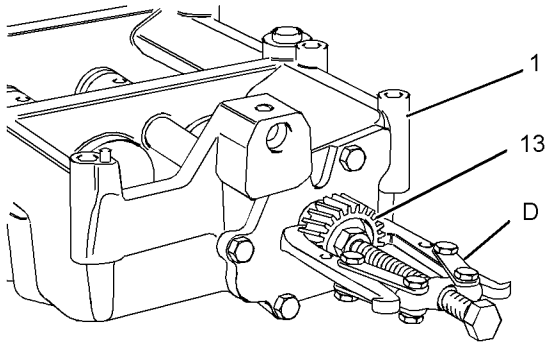


Illustration 193 g01259631

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.

i02628805

Balancer - Install

Assembly Procedure

Table 55

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.

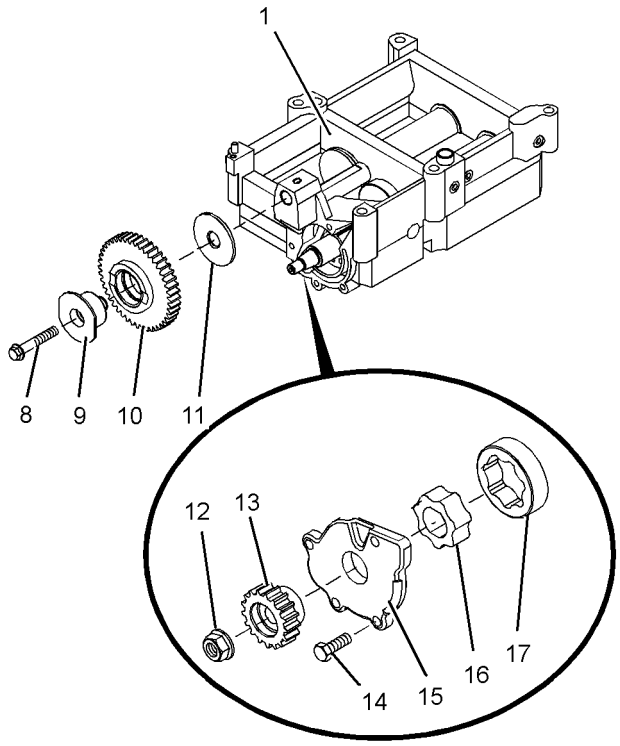


Illustration 194 g01344542
Typical example

2. Install inner rotor (16) and 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 56

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

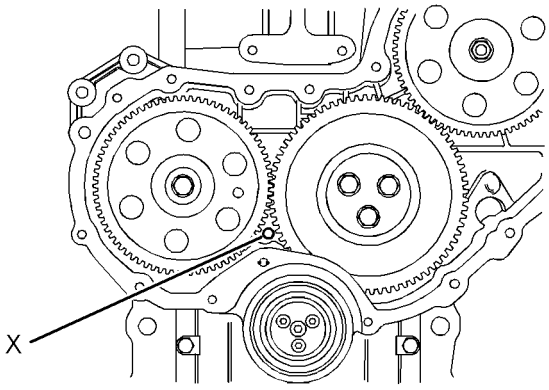


Illustration 195 g01259627

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 mating surfaces of the cylinder block.

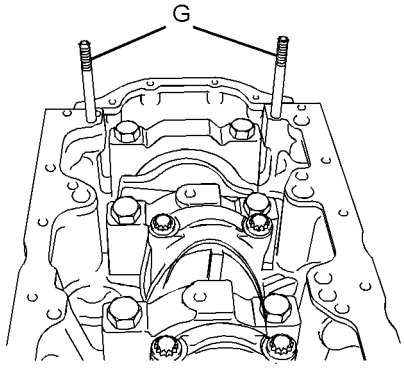


Illustration 196 g01252312

3. Install Tooling (G) to the cylinder block.

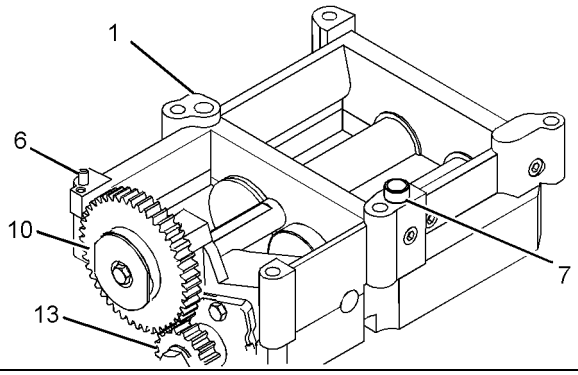


Illustration 197 g01260306

4. Ensure that dowels (6) and (7) are seated in the housing of balancer (1).

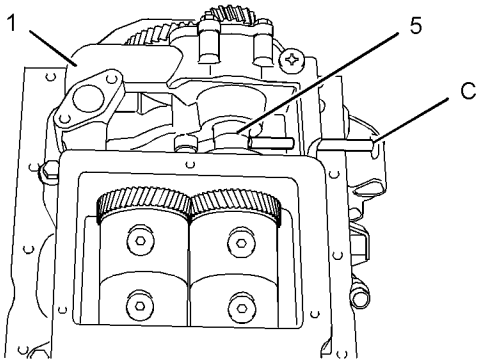


Illustration 198 g01252310

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.

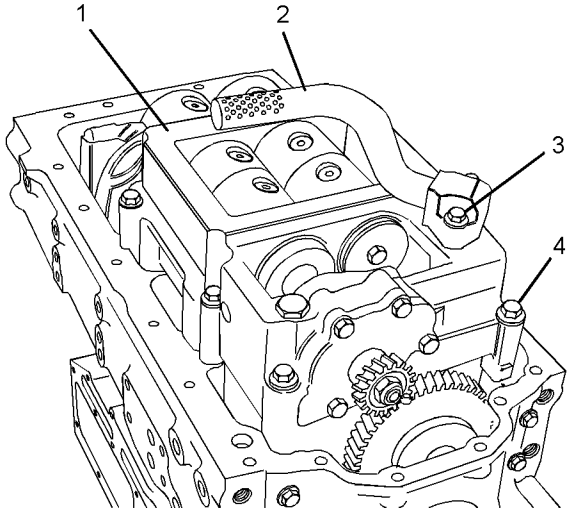


Illustration 199 g01259635

8. Install bolts (4) to balancer (1) finger tight.

9. Remove the Tooling (G) and install the remaining bolts (4). Tighten the bolts to a torque of 54 N·m (40 lb ft).

10. Remove the Tooling (B) and (C).

11. Install suction pipe (2) and a new joint 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 197. 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”.

i02628896

Piston Cooling Jets - 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

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 piston cooling jet.

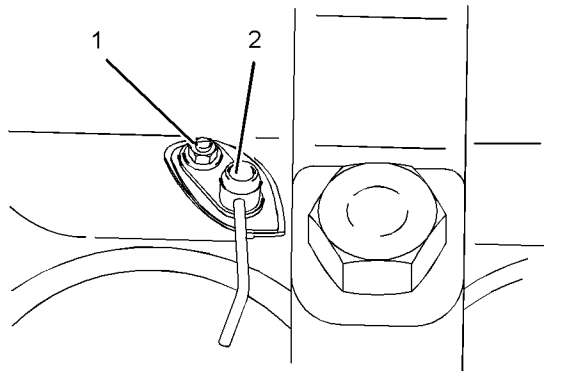


Illustration 200 g01265615

Typical example

2. Remove bolt (1) and piston cooling jet (2) from the cylinder block.

3. Repeat Steps 1 and 2 for the remaining piston cooling jets.

Installation Procedure

Table 58

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

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.

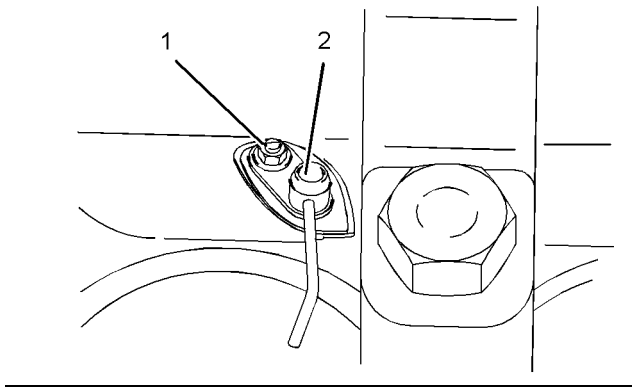


Illustration 201 g01265615

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 Steps 2 through 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”.

i02628900

Pistons and Connecting Rods - Remove

Removal Procedure

Table 59

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

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”.

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.

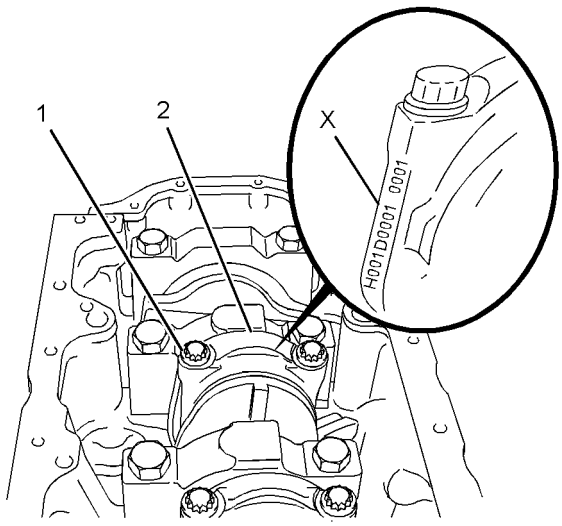


Illustration 202 g01344569

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.

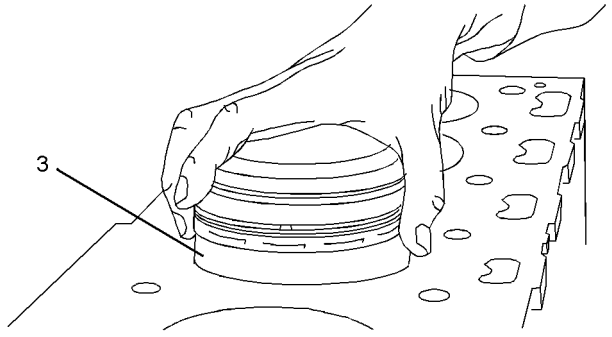


Illustration 203 g01244066
Typical example

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 Steps 1 through 5 for the remaining pistons and connecting rods.

i02628898

Pistons and Connecting Rods - Disassemble

Disassembly Procedure

Table 60

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.

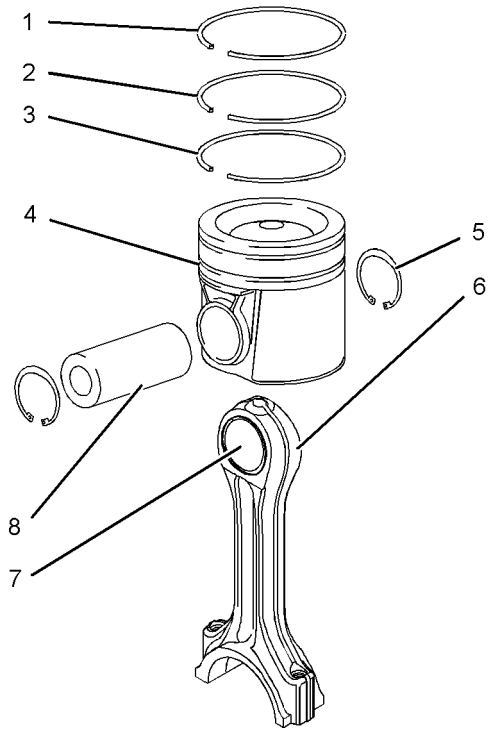


Illustration 204 g01244067

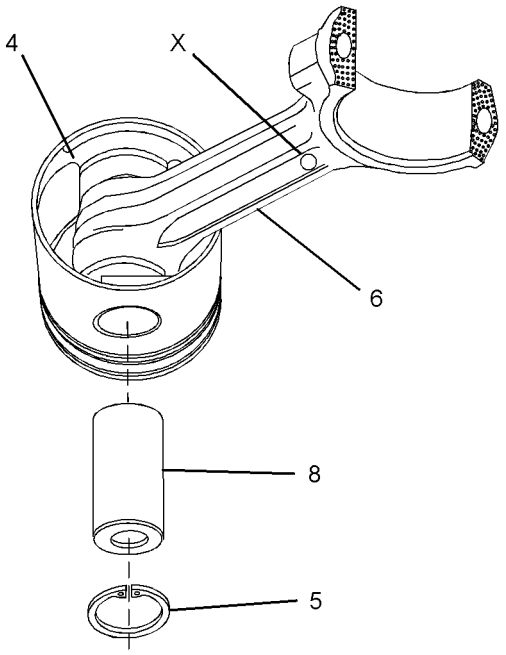


Illustration 205 g01253091
Typical example

2. Place the piston and connecting rod assembly on a suitable surface with the connecting rod upward. Use Tooling (A) in order to remove retaining rings(5).

Note: The 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).

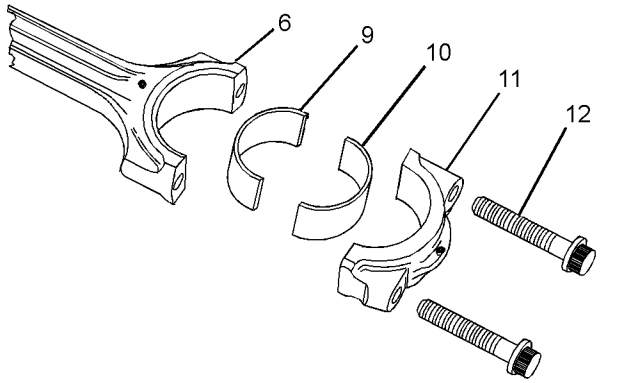


Illustration 206 g01244068

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 bearing shells 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 Rod”.

8. Repeat Steps 1 through 7 in order to disassemble the remaining pistons and connecting rods.

i02628897

Pistons and Connecting Rods - Assemble

Assembly Procedure

Table 61

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.

2. If the original piston is assembled, follow Steps 2.a through 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.

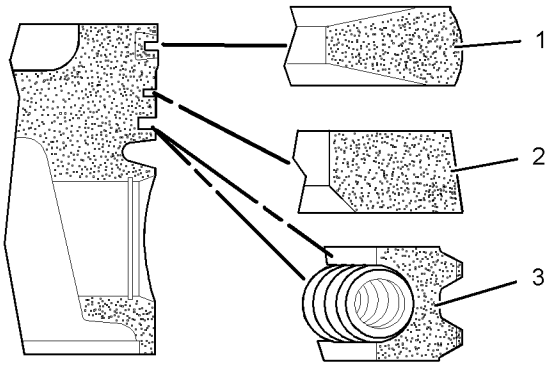


Illustration 207 g01155119

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 Rod” for further information.

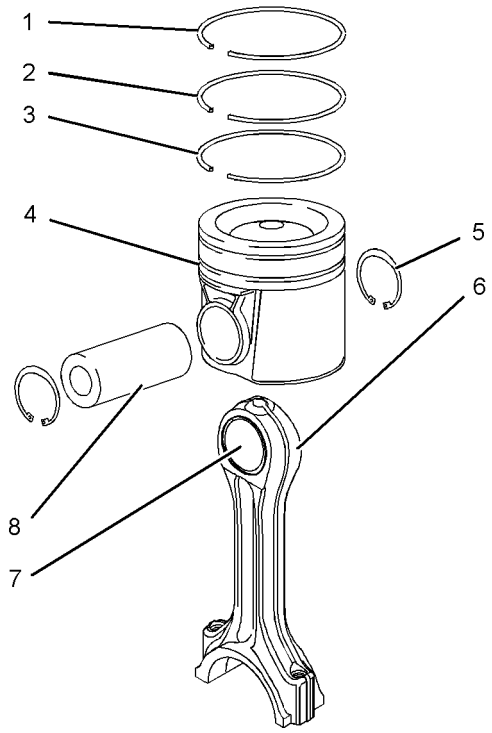


Illustration 208 g01244067

4. Lubricate bush (7) and lubricate the bore for the piston pin in piston (4) with clean engine oil.

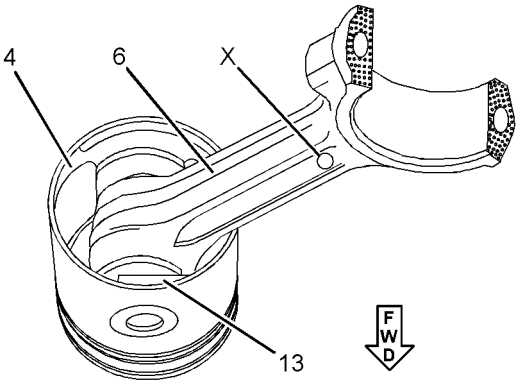


Illustration 209 g01244172

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 209.

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 retaining rings (5) to the piston pin bore in piston (4).

Note: Ensure that the retaining rings are seated in the grooves in the piston.

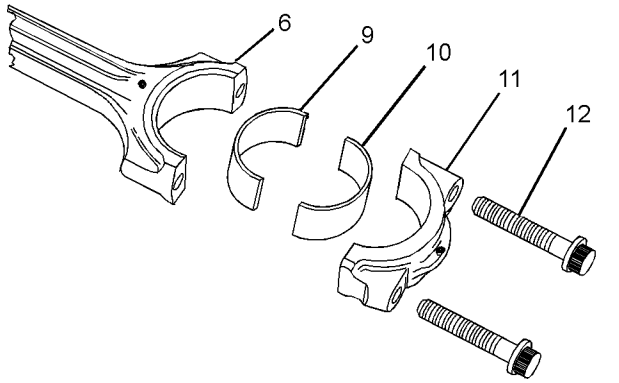


Illustration 210 g01244068

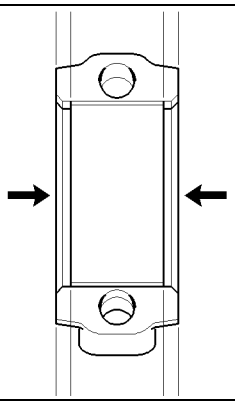


Illustration 211 g01001160

Aligning the connecting rod bearing in the center of the connecting rod

Note: New connecting rod bearings are supplied with an alignment tool. If new connecting rod bearings are installed, use the tool to align the bearing in the connecting rod.

7. Install the upper half of connecting rod bearing (9) to connecting rod (6). Ensure that the bearing is centralized in the connecting rod. Refer to Illustration 211.

8. Install the lower half of connecting rod bearing (10) to connecting rod cap (11). Ensure that the bearing is centralized in the connecting rod cap. Refer to Illustration 211.

9. Repeat Steps 2 through 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. Refer to Disassembly and Assembly, “Piston and Connecting Rods - Install”.

End By:

a. Install the pistons and the connecting rods. Refer to Disassembly and Assembly, “Piston and Connecting Rods - Install”.

i02628899

Pistons and Connecting Rods - Install

Installation Procedure

Table 62

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

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.

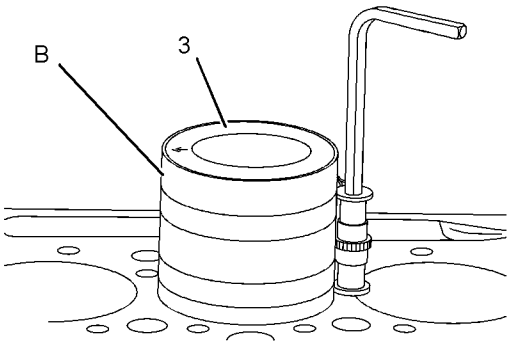


Illustration 212 g01253096
Typical example

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.

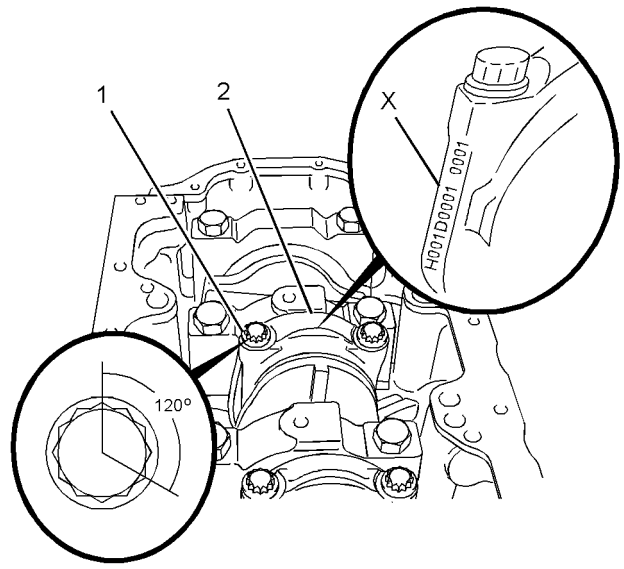


Illustration 213 g01344572
Typical example

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 Steps 2 through 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 - Install”.

c. Install the cylinder head. Refer to Disassembly and Assembly, “Cylinder Head - Install”.

i02628814

Connecting Rod Bearings - Remove (Connecting rods in position)

Removal Procedure

Table 63

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

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.

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.

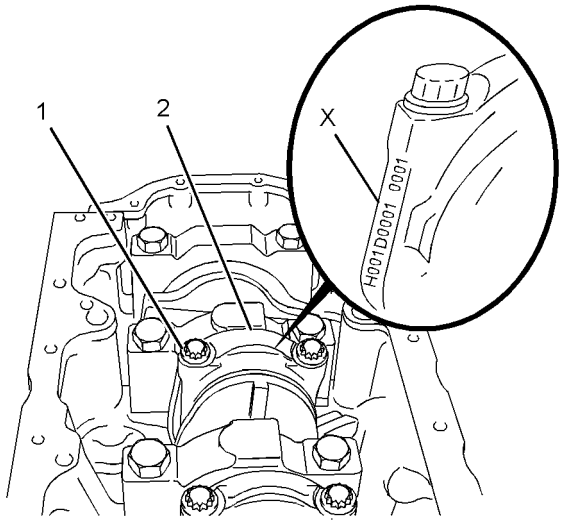


Illustration 214 g01344569

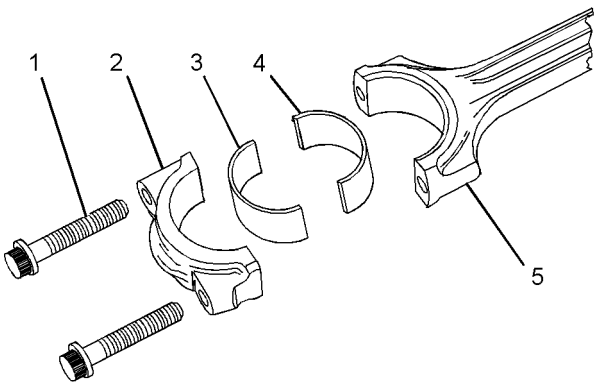


Illustration 215 g01253101

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”.

i02744541

Connecting Rod Bearings - Install (Connecting rods in position)

Installation Procedure

Table 64

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

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.

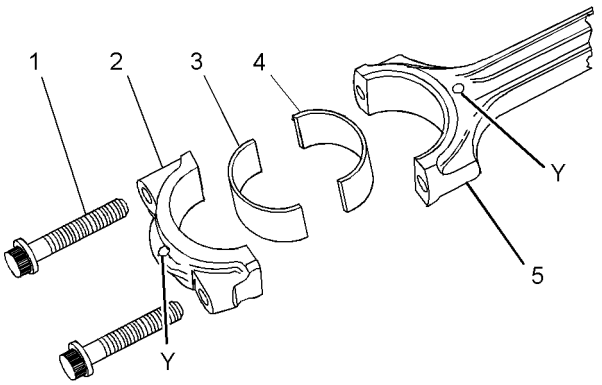


Illustration 216 g01260354

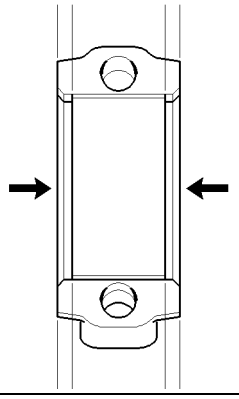


Illustration 217 g01001160

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 217.

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 mating 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 217.

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 mating 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.

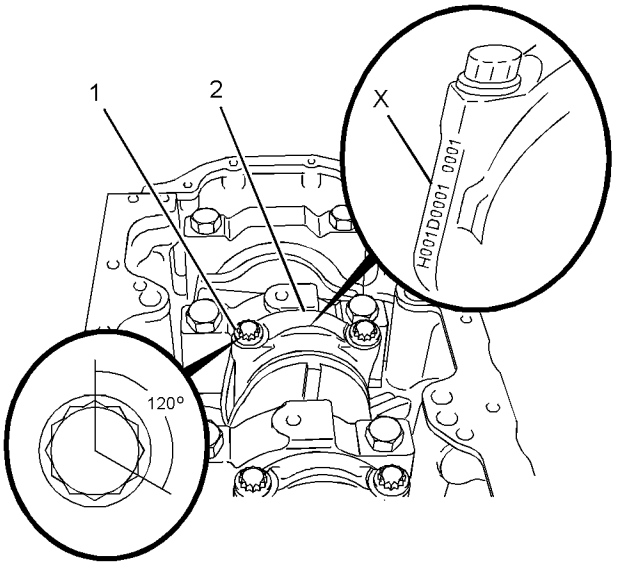


Illustration 218 g01344572

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 216.

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 Steps 2 through 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 - Remove and 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 - Install”.

i02628821

Crankshaft Main Bearings - Remove and Install (Crankshaft in position)

Removal Procedure

Table 65

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

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 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.

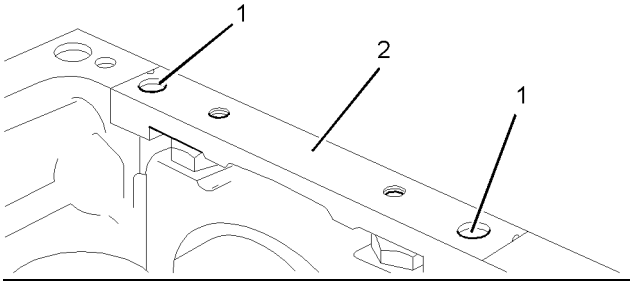


Illustration 219 g01253717
Typical example

1. Remove allen head screws (1). Remove bridge piece (2).

2. Ensure that the main bearing cap is marked for the correct location and orientation.

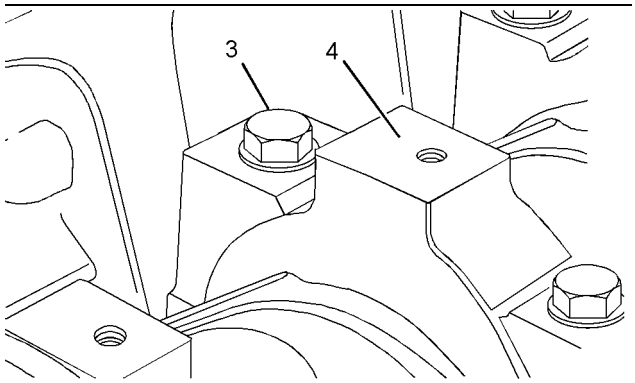


Illustration 220 g01253719
Typical example

3. Remove bolts (3). Remove main bearing cap (4) from the cylinder block.

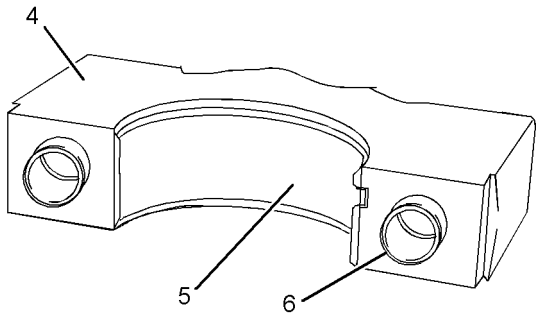


Illustration 221 g01253146
Typical example

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.

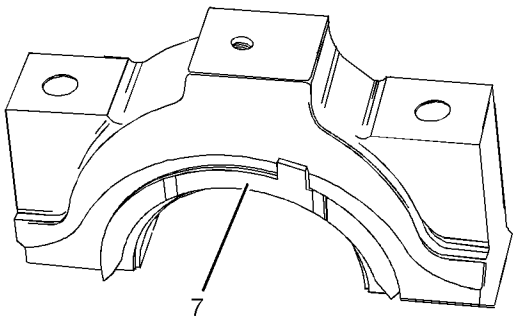


Illustration 222 g01253137
Typical example

5. For number three main bearing cap, remove thrust washers (7).

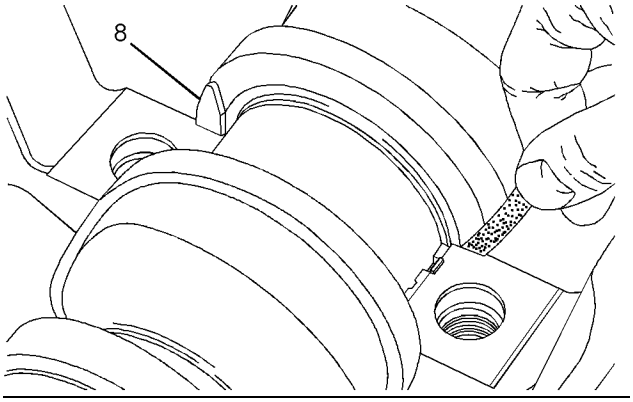


Illustration 223 g01253142
Typical example

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.

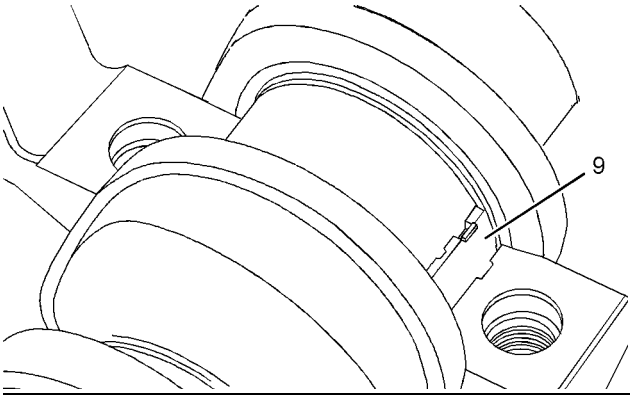


Illustration 224 g01253145

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. The upper main bearing has a groove and two oil holes.

Installation Procedure

Table 66

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	-

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.

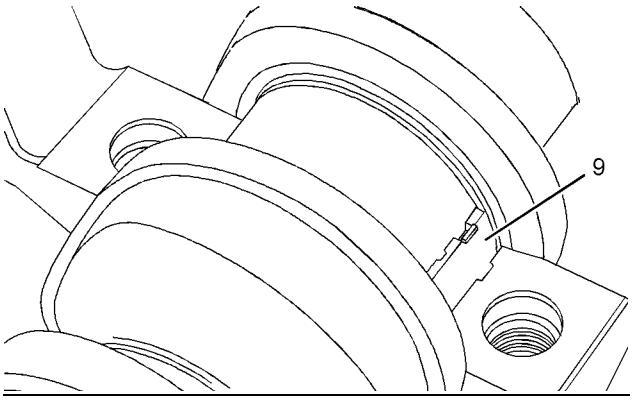


Illustration 225 g01253145
Typical example

3. Lubricate the crankshaft journal and the upper main bearing (9) with clean engine oil. Slide the 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: The upper main bearing has a groove and two oil holes.

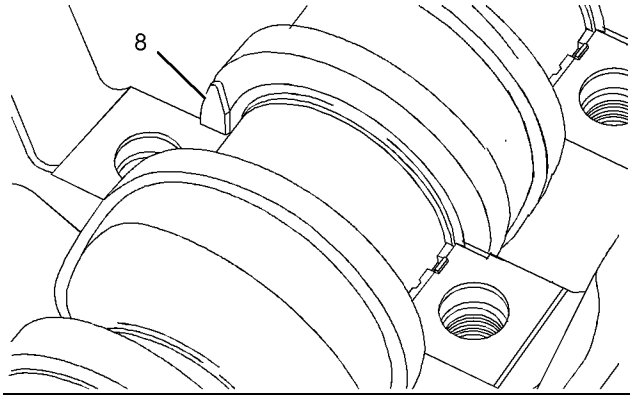


Illustration 226 g01261200
Typical example

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.

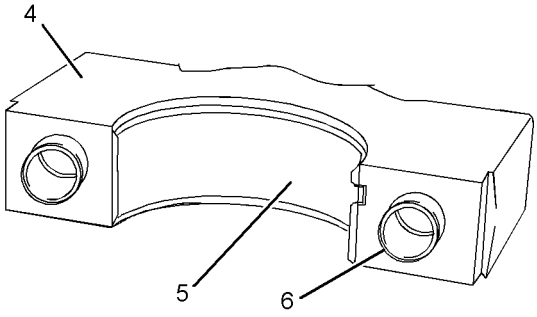


Illustration 227 g01253146
Typical example

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.

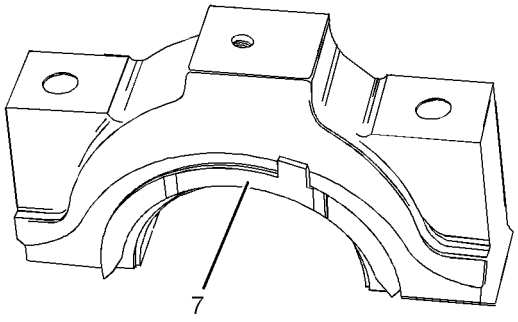


Illustration 228 g01253137
Typical example

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.

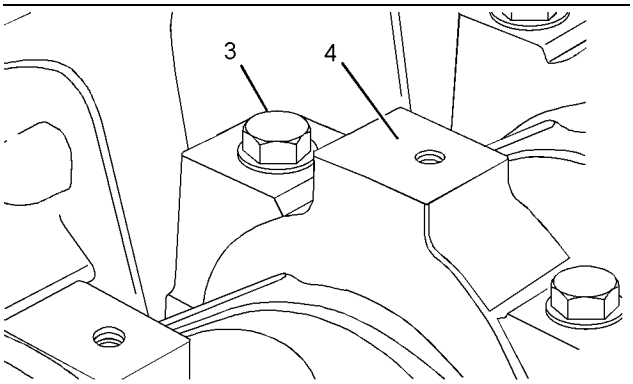


Illustration 229 g01253719
Typical example

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).

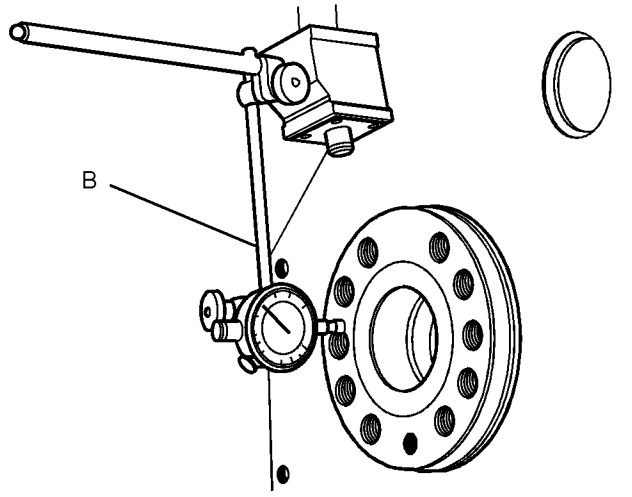


Illustration 230 g01253186
Typical example

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 mm (0.007 inch) to 0.41 mm (0.016 inch).

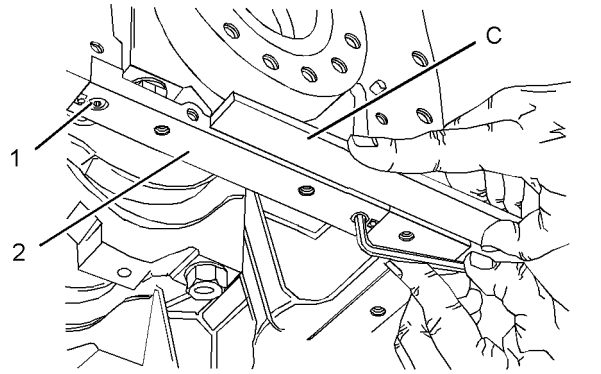


Illustration 231 g01253836
Typical example

12. Follow Steps 12.a through 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”.

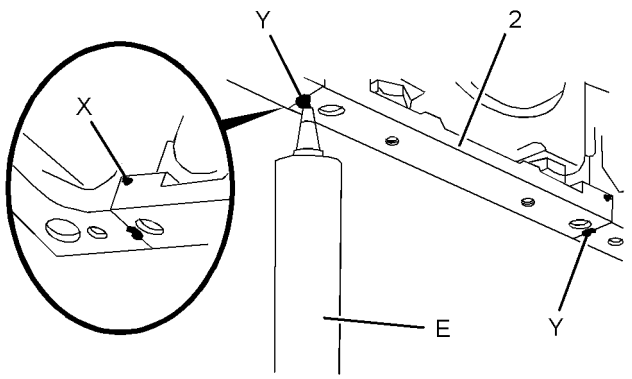


Illustration 232 g01344584
Typical example

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 joint 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 - Install”.

i02628818

Crankshaft - Remove

Removal Procedure

Table 67

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”.

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.

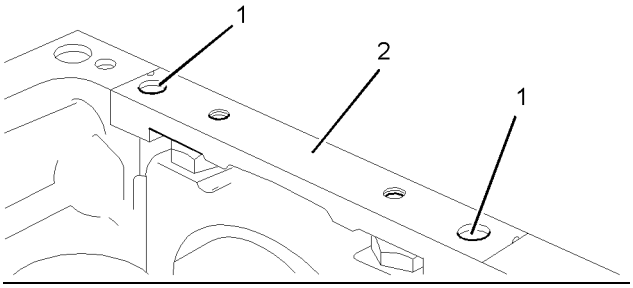
NOTICE
Keep all parts clean from contaminants.

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”.



g01253717

Illustration 233

Typical example

3. Remove allen head screws (1). Remove bridge piece (2).

4. Ensure that the bearing caps are marked for the location and orientation.

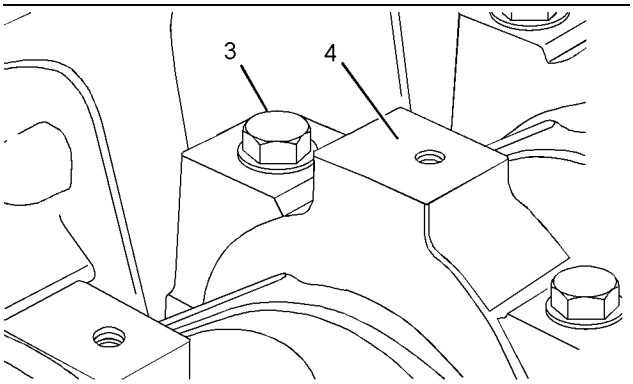


Illustration 234 g01253719
Typical example

5. Remove bolts (3) and bearing caps (4) from the cylinder block.

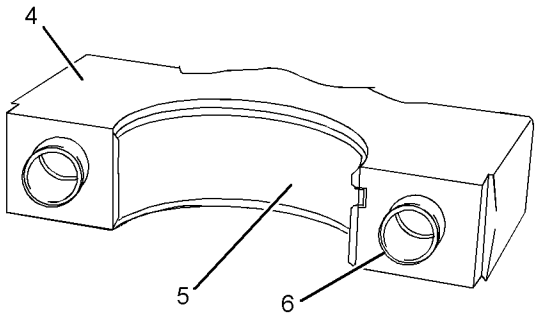


Illustration 235 g01253146
Typical example

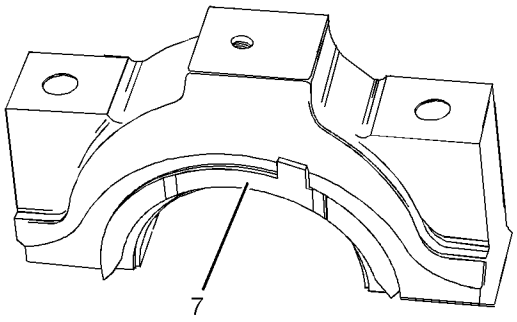


Illustration 236 g01253137
Typical example

6. Remove lower bearings (5) from bearing caps (4). Take care not to displace dowels (6). For number three bearing cap, remove thrust washers (7). Keep the lower bearing and the thrust washers with the respective bearing caps.

Note: The lower bearings are plain bearings that have no oil holes. The dowels may remain in the bearing cap or in the cylinder block.

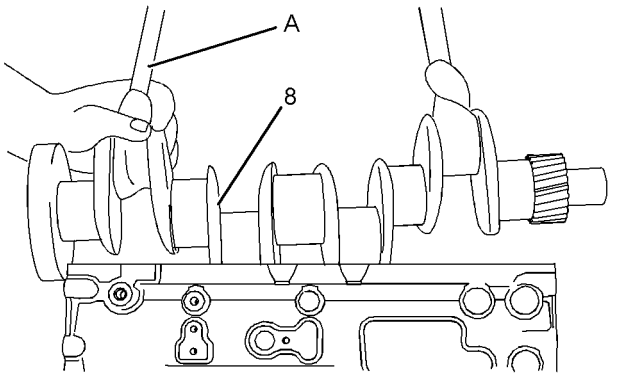


Illustration 237 g01254099
Typical example

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.

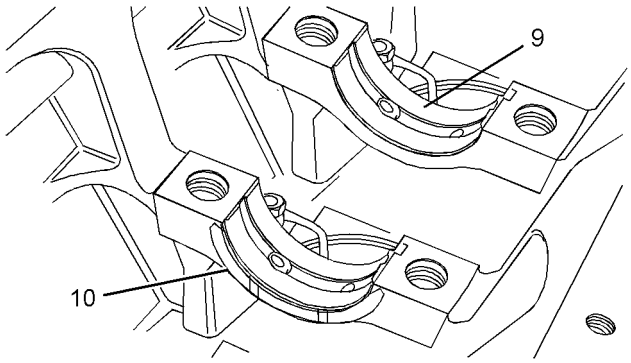


Illustration 238 g01254104
Typical example

8. Remove upper bearings (9) from the cylinder block. Keep the upper bearings with the respective bearing caps.

Note: The upper bearings have a groove and two oil holes.

9. Remove thrust washers (10) from number three bearing in the cylinder block.

10. If necessary, remove the crankshaft gear. Refer to Disassembly and Assembly, “Crankshaft Gear - Remove and Install”.

i02628817

Crankshaft - Install

Installation Procedure

Table 68

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.

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”.

Note: The engine should be mounted on a suitable stand and placed in the inverted position.

3. 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.

4. 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.

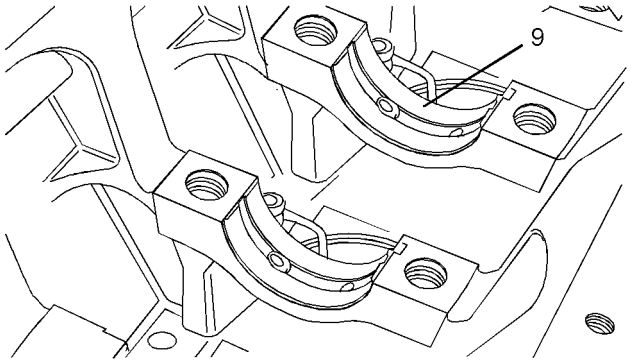


Illustration 239 g01253240
Typical example

5. 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: The upper bearings have a groove and two oil holes.

6. Lubricate upper bearings (9) with clean engine oil.

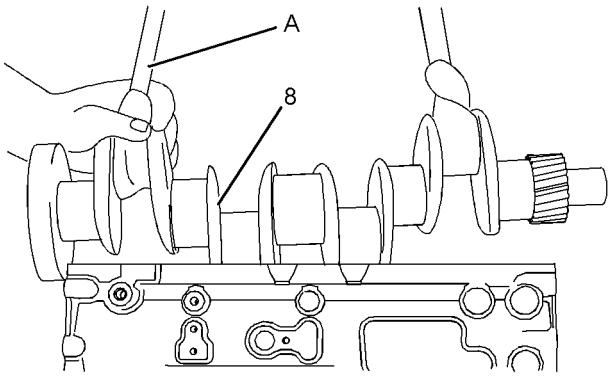


Illustration 240 g01254099
Typical example

7. 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.

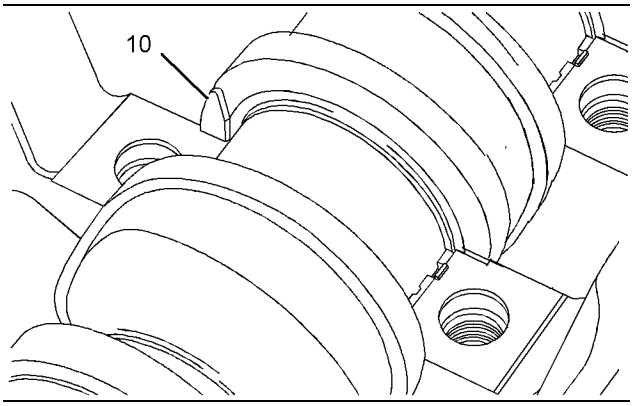


Illustration 241 g01254100

Typical example

8. 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.

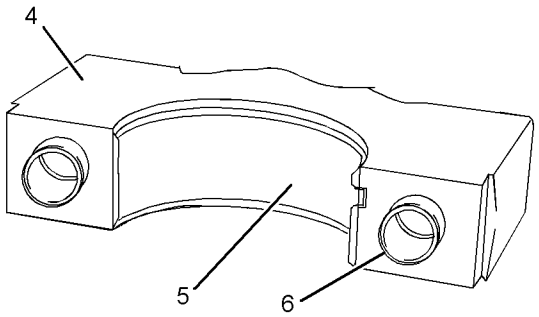


Illustration 242 g01253146

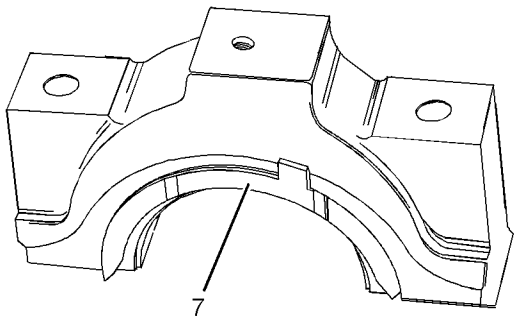


Illustration 243 g01253137

9. 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.

10. 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.

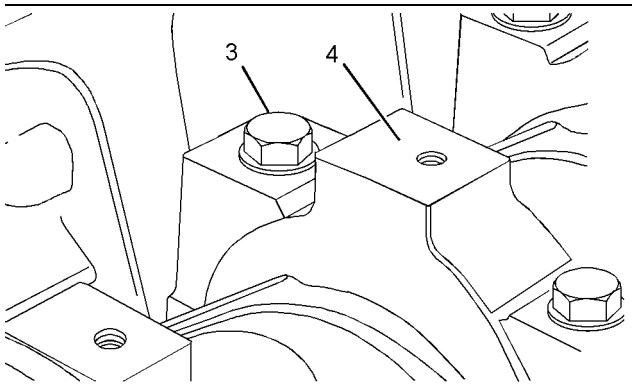


Illustration 244 g01253719

11. Lubricate the threads of bolts (3) with clean engine oil. Lubricate the underside of the heads of the bolts with clean engine oil.

12. 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.

13. Tighten bolts (3) to a torque of 245 N·m (180 lb ft).

14. Rotate the crankshaft in order to ensure that there is no binding.

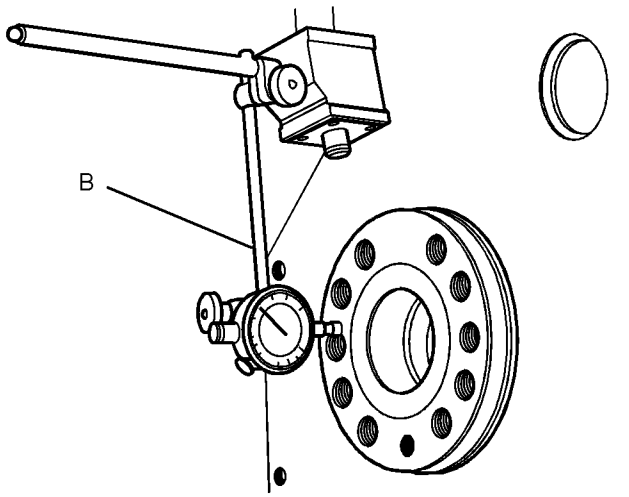


Illustration 245 g01253186
Typical example

15. 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 mm (0.007 inch) to 0.41 mm (0.016 inch).

16. If the piston and connecting rods have been removed , install the piston and connecting rods. Refer to Disassembly and Assembly, “Piston and Connecting Rods - Install”.

If the piston and connecting rods have not been removed , install the connecting rod caps. Refer to Disassembly and Assembly, “Connecting Rod Bearings - Install”.

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.

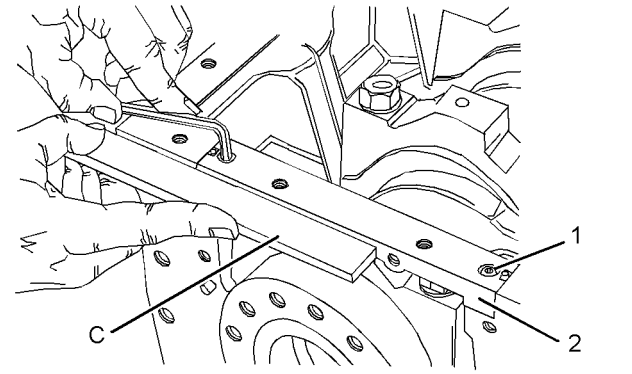


Illustration 246 g01254102
Typical example

18. Follow Steps 18.a through 18.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”.

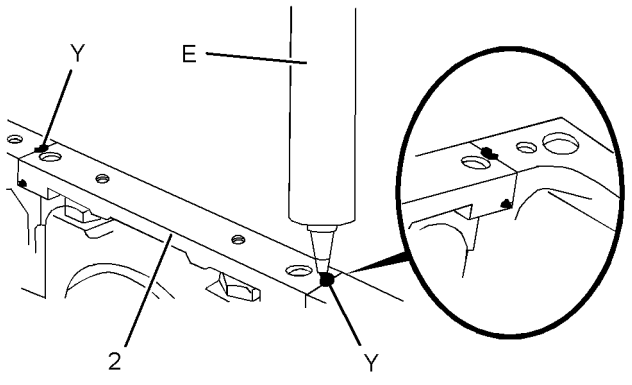


Illustration 247 g01344593
Typical example

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 joint face of the bridge piece and the cylinder block are left free of sealant.

End By:

a. 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 - Install”.

b. Install the front housing. Refer to Disassembly and Assembly, “Housing (Front) - Install”.

c. If necessary, install the cylinder head. Refer to Disassembly and Assembly, “Cylinder Head - Install”.

d. Install the rockershaft and pushrods. Refer to Disassembly and Assembly, “Rockershaft and Push Rods - Install”.

i02628820

Crankshaft Gear - Remove and Install

Removal Procedure

Table 69

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”.

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.

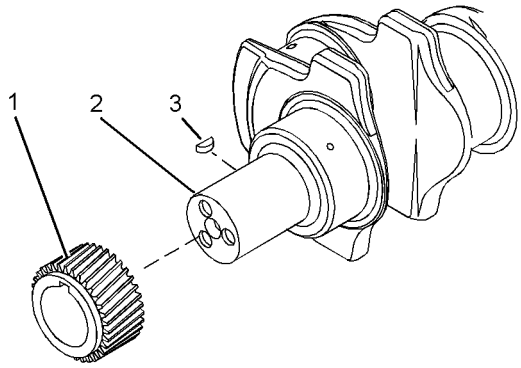


Illustration 248 g01367358
Typical example

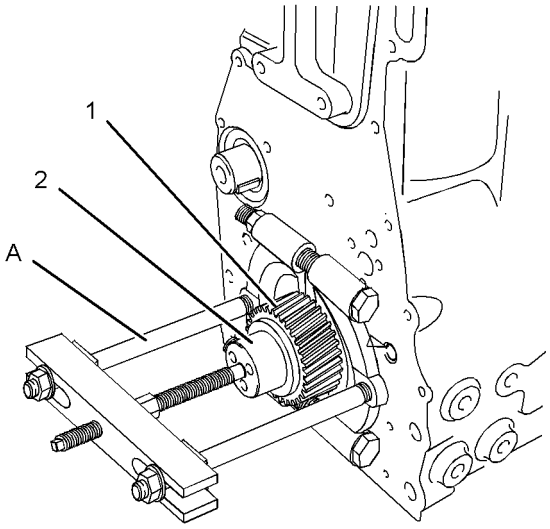


Illustration 249 g01270549
Typical example

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).

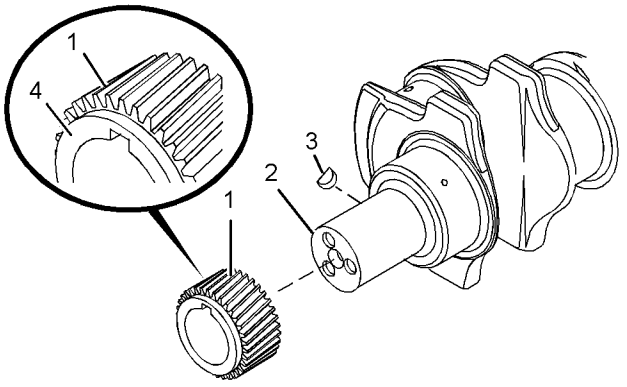
Note: Do not remove the key from the crankshaft unless the key is damaged.

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.



g01367359
Illustration 250
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 Manual, “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 - Install”.

i02748526

Bearing Clearance - Check

Measurement Procedure

Table 70

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 251.

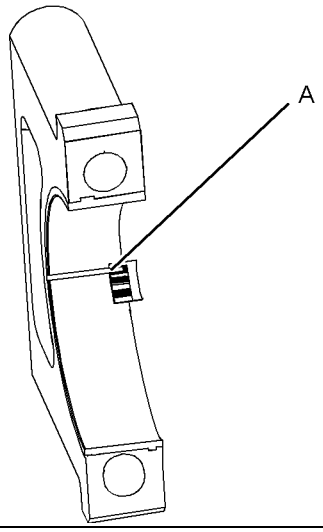


Illustration 251 g01152855
Typical Example

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.

i02628884

Glow Plugs - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Isolate the electrical supply.
2. If the engine is equipped with a cover over the fuel injectors remove the cover. Refer toDisassembly and Assembly, “Fuel Injector Cover - Remove and Install”.
3. Remove the breather tube from the valve mechanism cover. Refer toDisassembly and Assembly, “Crankcase Breather- Remove and Install”.

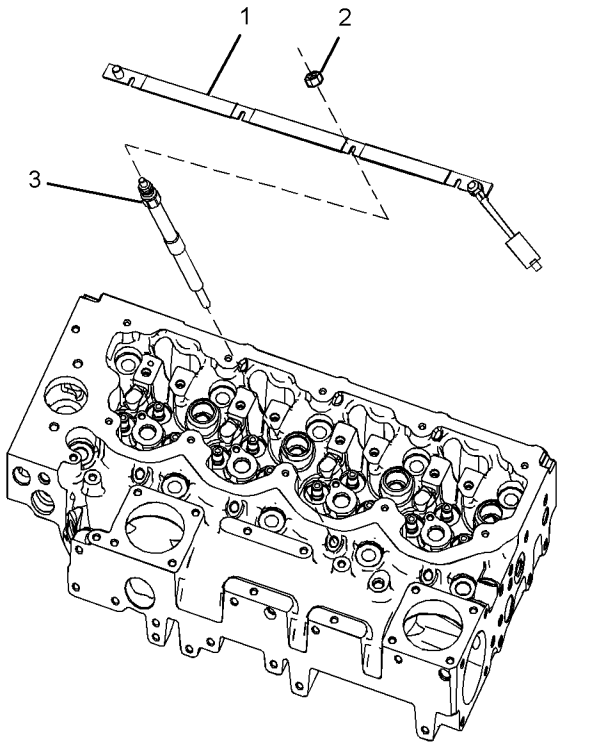


Illustration 252 g01346250
Typical example

4. Disconnect harness assembly from bus bar (1).

5. Remove nuts (2) that secure bus bar (1) to glow plugs (3).

6. Remove bus bar (1) from glow plugs (3).

7. Remove glow plugs (3) from the cylinder head.

Installation Procedure

Table 71

Required Tools			
Tool	**Part Number**	**Part Name**	**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.

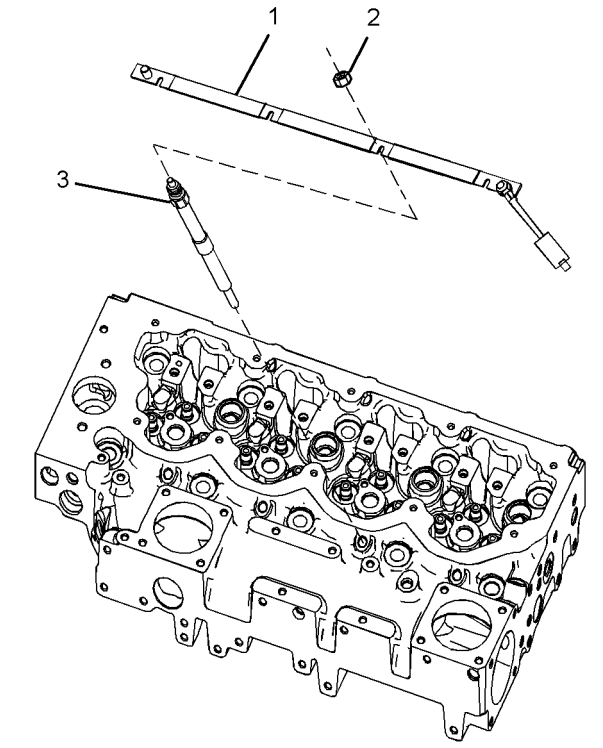


Illustration 253 g01346250
Typical example

2. Install glow plugs (3) 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 (3). 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 harness assembly to bus bar (1).

5. Install the breather tube to the valve mechanism cover. Refer toDisassembly and Assembly, “Crankcase Breather- Remove and Install”.

6. If the engine is equipped with a cover over the fuel injectors install the cover. Refer toDisassembly and Assembly, “Fuel Injector Cover - Remove and Install”.

7. Restore the electrical supply to the engine.

i02628912

V-Belts - Remove and Install (Engines Without an Automatic Belt Tensioner)

Removal Procedure

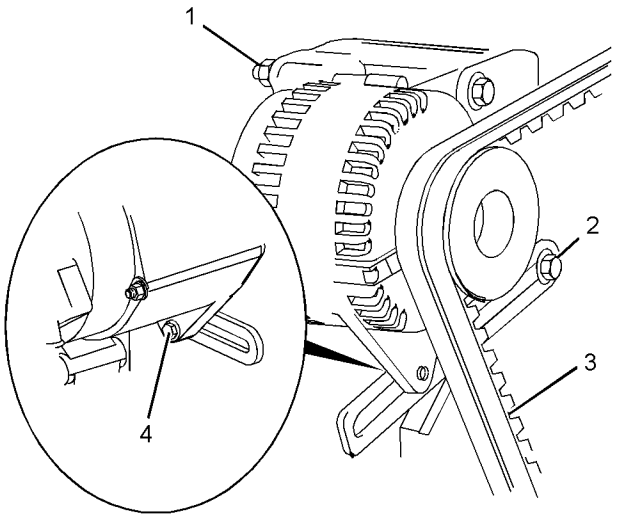


Illustration 254 g01254466

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 72

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Belt Tension Gauge	1

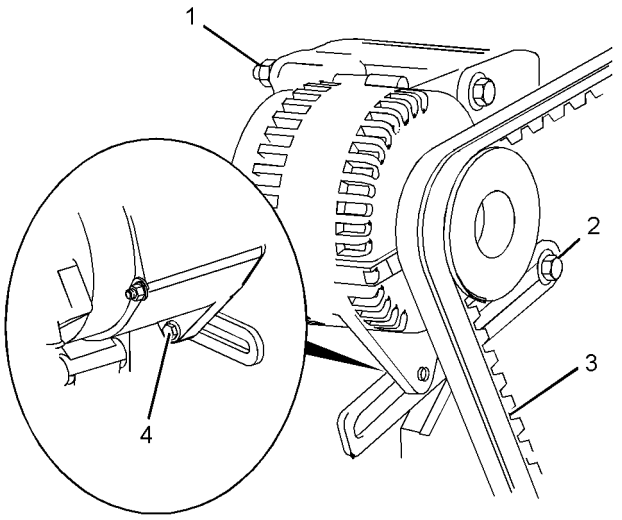


Illustration 255 g01254466

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 System Operation, Testing and Adjusting, “V-Belt -Test” 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.

i02589352

Alternator Belt - Remove and Install (Engines With an Automatic Belt Tensioner)

Removal Procedure

Table 73

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Locking Pin (Ø 8mm by 85 mm)	1

1. If the engine has fan guards, remove the fan guards.

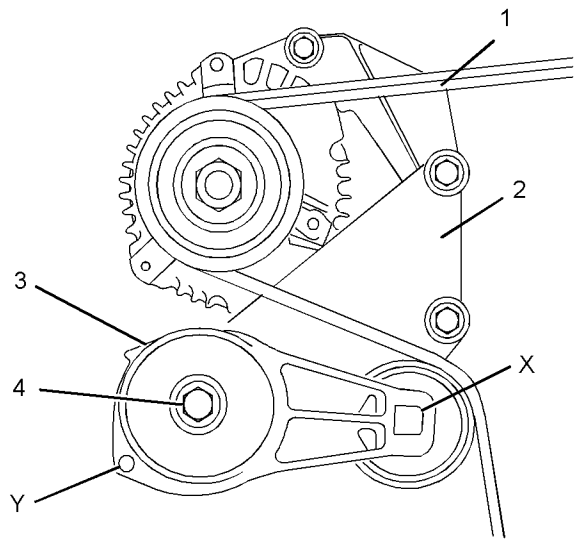


Illustration 256 g01260739

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 Steps 7.a and 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 74

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Locking Pin (Ø 8mm by 85 mm)	1

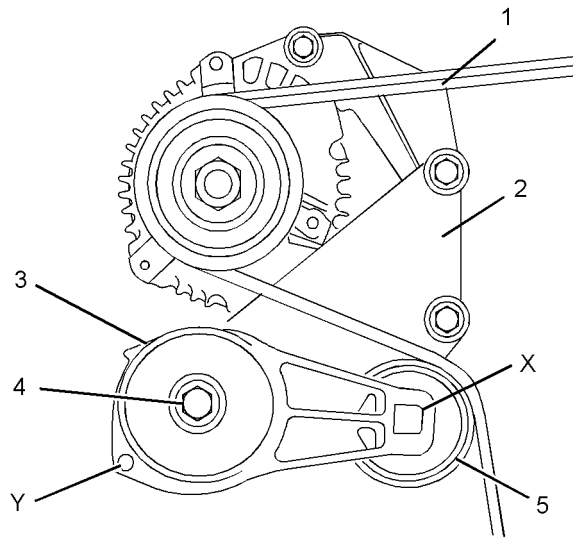


Illustration 257 g01270907

Typical example

1. If the tensioner was previously removed, follow Steps 1.a through 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 45 ± 5 N·m (33 ± 3 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 has fan guards, install the fan guards.

i02628844

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”.

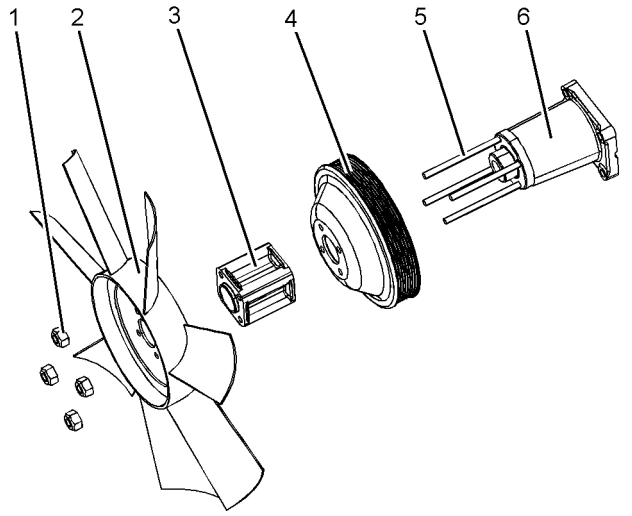


Illustration 258 g01270917
Typical example

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.

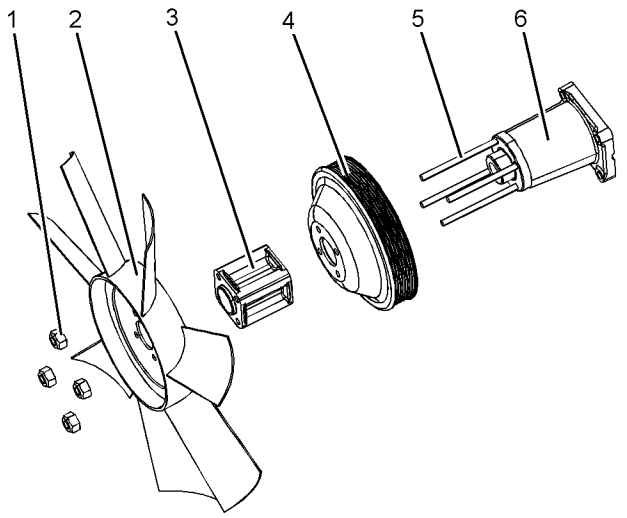


Illustration 259 g01270917
Typical example

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”.

i02628845

Fan Drive - Remove and Install

Removal Procedure

Start By:

a. Remove the fan. Refer to Disassembly and Assembly, “Fan - Remove and Install”.

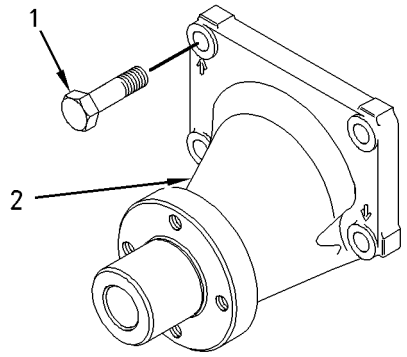


Illustration 260 g00944500
Typical example

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

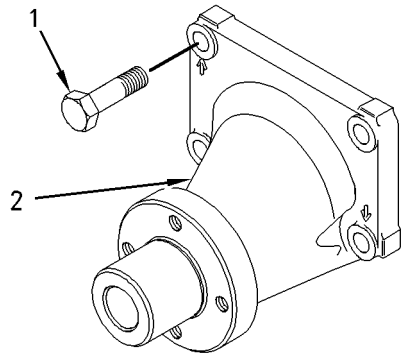


Illustration 261 g00944500
Typical example

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”.

i02725803

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. Isolate the electrical supply to the engine.

2. Make temporary identification marks on the connections of the harness assembly.

Note: The incorrect connection of the harness assembly can result in damage to the alternator or failure.

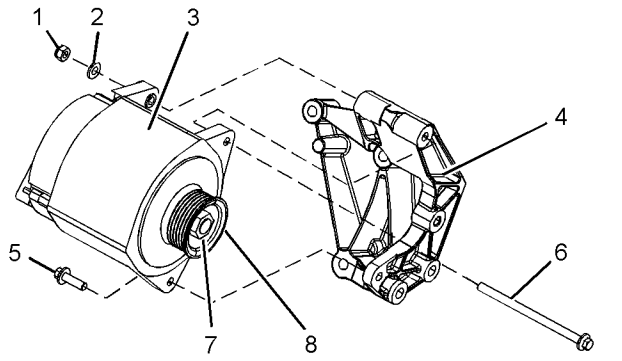


Illustration 262 g01271317
Typical example

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 Steps 6.a and 6 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 (1).

i02628804

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. Isolate the electrical supply to the engine.

2. Make temporary identification marks on the connections of the harness assembly.

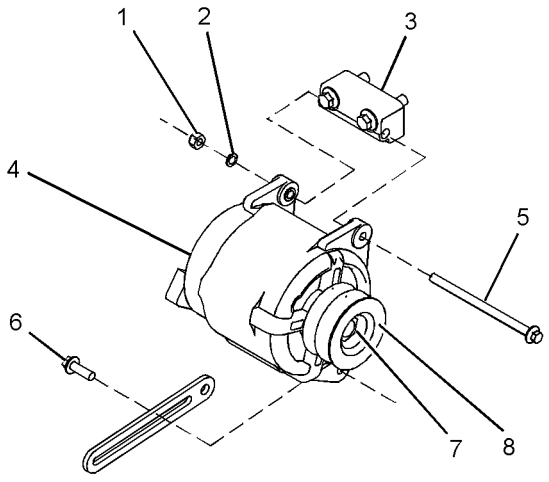


Illustration 263 g01255718
Typical Example

3. Disconnect the harness assembly from alternator (1).

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 Steps 6.a and 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).

i02725802

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.

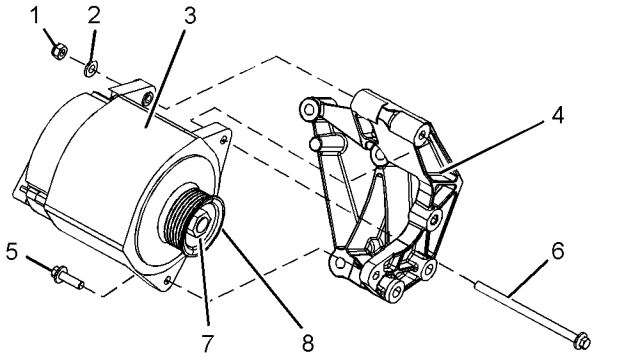


Illustration 264 g01271317
Typical example

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).

Note: The incorrect connection of the harness assembly can result in damage to the alternator or failure.

7. Install the alternator belt. Refer to Disassembly and Assembly, “Alternator Belt - Remove and Install”.

8. Restore the electrical supply.

i02628802

Alternator - Install (Engines Without an Automatic Belt Tensioner)

Installation Procedure

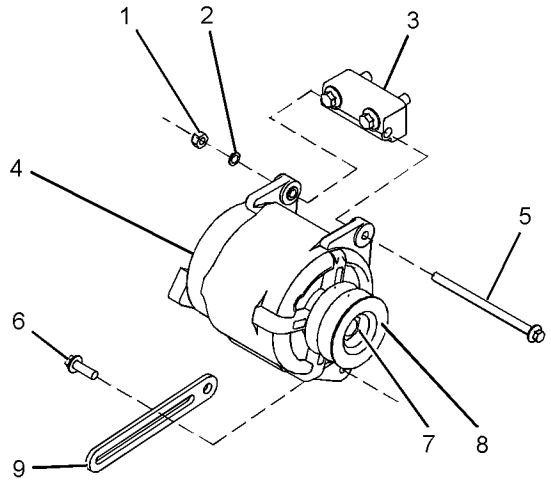


Illustration 265 g01263045
Typical example

1. If necessary, install the pulley to the alternator. Follow Steps 1.a and 1.b for the method 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 the 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 harness assembly to alternator (4).

8. Restore the electrical supply.

i02628831

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. Disconnect the battery.

2. If necessary, remove the hose for the crankcase breather. Refer to Disassembly and Assembly, “Crankcase Breather - Remove”.

3. Make temporary identification marks on the harness assemblies that are connected to the electric starting motor and to the solenoid.

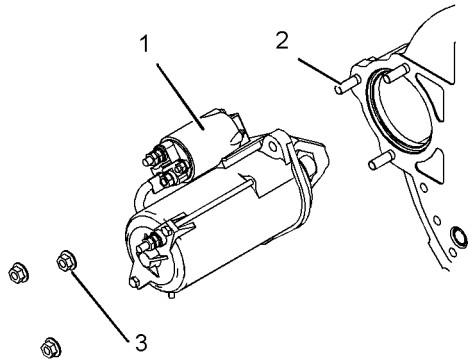


Illustration 266 g01261155
Typical example

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

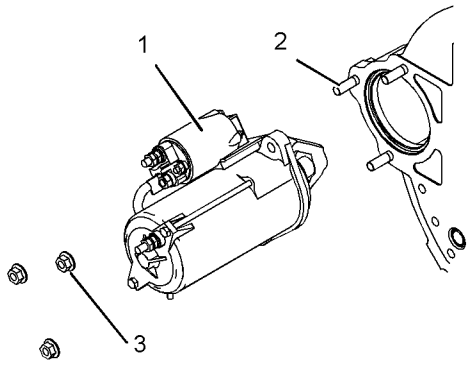


Illustration 267 g01261155

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). Different types of starting motor have different sized nuts.

Tighten M10 nuts to a torque of 44 ± 11 N·m (32 ± 8 lb ft).

Tighten M12 nuts to a torque of 78 ± 19.5 N·m (57 ± 14 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 - Install”.

6. Connect the battery.

i02628801

Air Compressor - Remove and Install

Removal Procedure

Table 75

Required Tools			
Tool	**Part Number**	**Part Name**	**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

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.

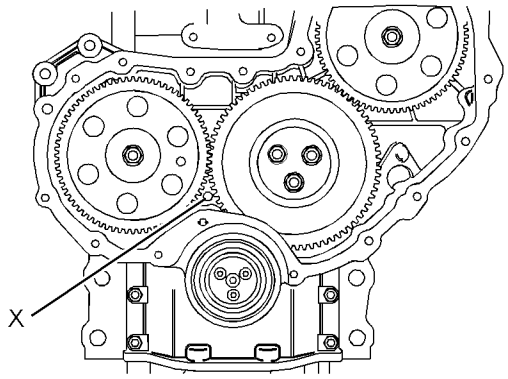


Illustration 268 g01272266
Typical example

6. Install Tooling (B) through hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft.

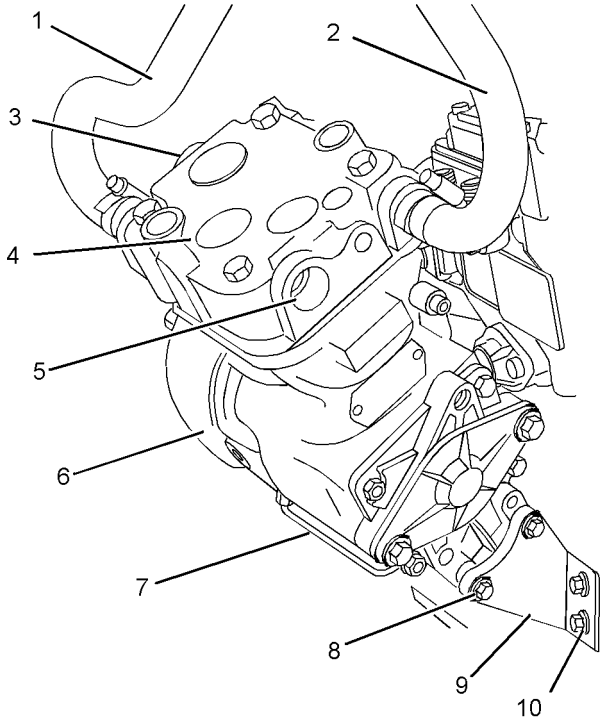


Illustration 269 g01250794
Typical example

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.

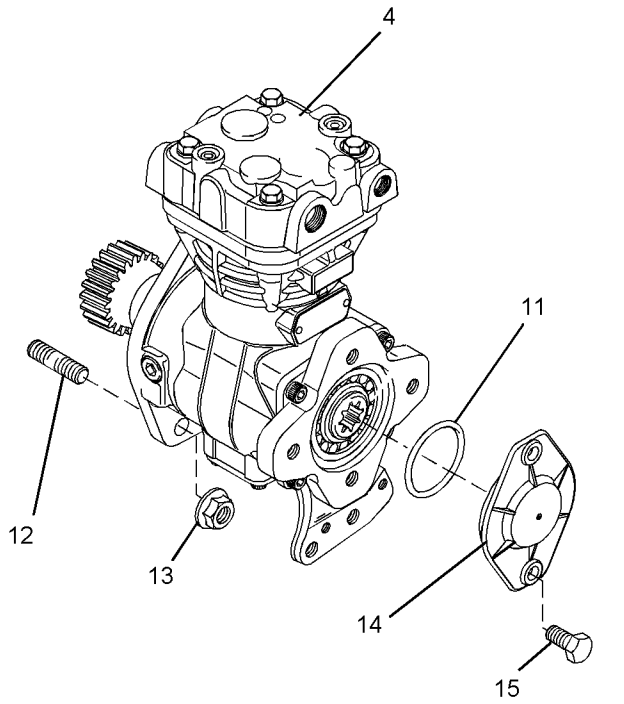


Illustration 270 g01250816
Typical example

11. Support air compressor (4). Remove nuts (13) and remove the air compressor from front housing (6).

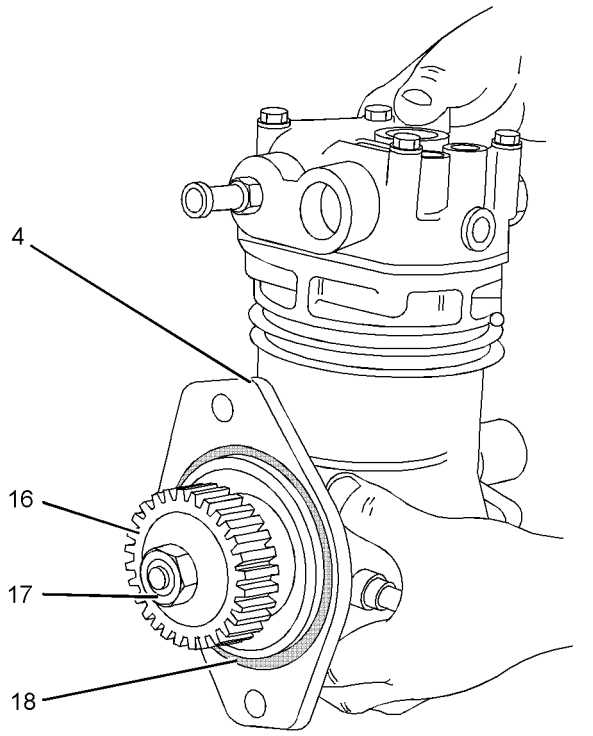


Illustration 271 g01250889
Typical example

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 270.

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 76

Required Tools			
Tool	**Part Number**	**Part Name**	**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.

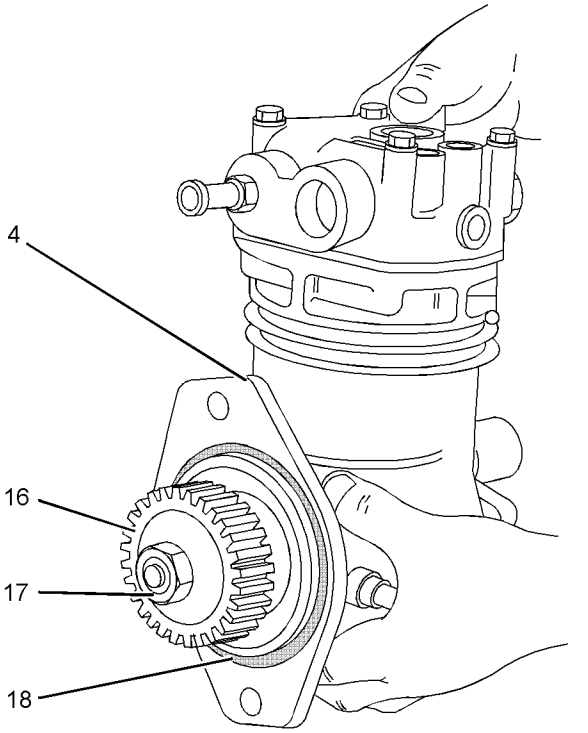


Illustration 272 g01250889
Typical example

1. If necessary, follow Steps 1.a through 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 the 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.

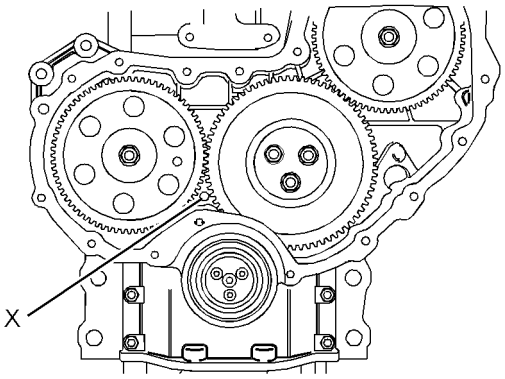


Illustration 273 g01272266
Typical example

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.

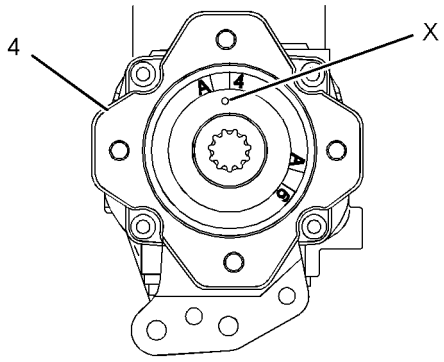


Illustration 274 g01250968
Typical air compressor with a SAE drive

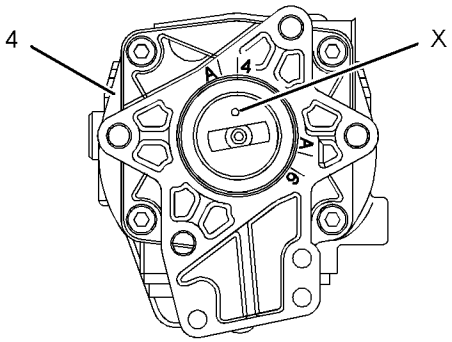


Illustration 275 g01251223

Typical air compressor with a DIN drive

5. Rotate the crankshaft of the air compressor until the timing mark (X) is aligned with the timing mark A4 on the rear face of air compressor (4). Refer to Illustration 274 for air compressors with a SAE drive. Refer to Illustration 275 for air compressors with a DIN drive.

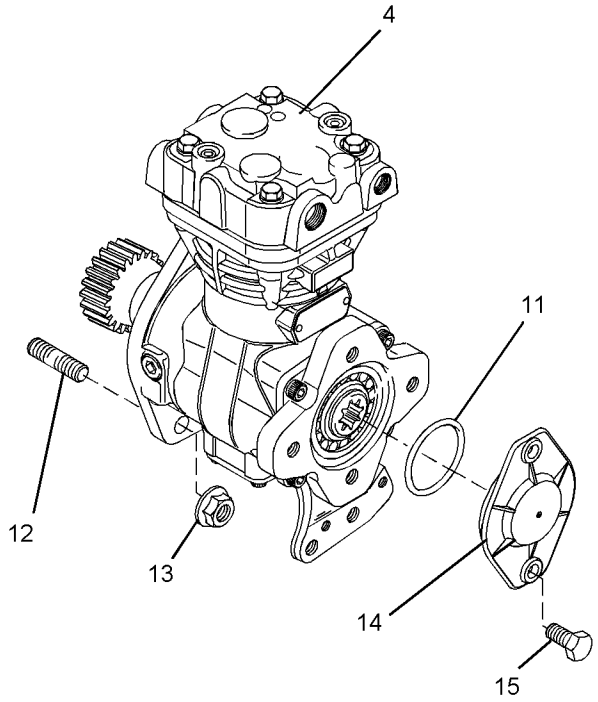


Illustration 276 g01250816

Typical example

6. Align the 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 the timing mark A4. Refer to Illustration 274 for air compressors with a SAE drive. Refer to Illustration 275 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 Steps 8.a through 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).

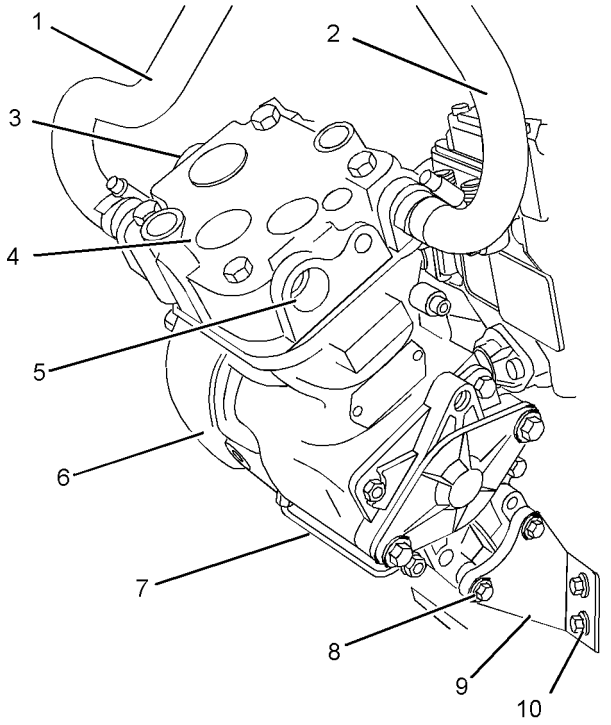


Illustration 277 g01250794

Typical example

9. Position support bracket (9) onto air compressor (4). Install bolts (8) finger tight.

10. Install bolts (10) finger tight.

11. Tighten the bolts (8) to a torque of 22 N·m (16 lb ft). Tighten the 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 the Operation and Maintenance Manual.

i02628914

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.

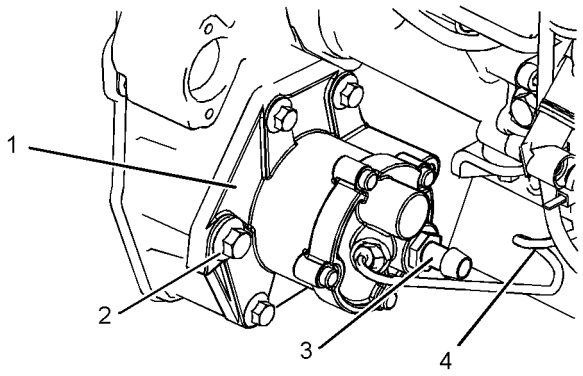


Illustration 278 g01254510
Typical example

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 joint.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

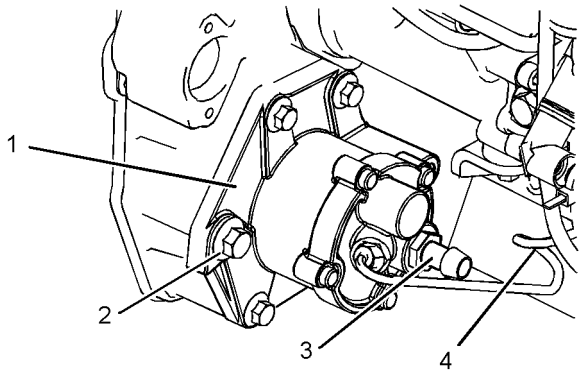


Illustration 279 g01254510
Typical example

1. Ensure that the vacuum pump is clean and free from damage. If necessary, replace the vacuum pump.

2. Clean the mating surfaces on the front housing.

3. Install a new joint 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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