Perkins®

Service Manual

1103A/B/C and 1104A/C Mechanical Engines

Models DC, DD, DF, DG, DJ, DK
RE, RG, RJ, RR and RS

Comprising:

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Perkins®

SEBU7833-03
September 2008

Operation and Maintenance Manual

1103 and 1104 Industrial Engines

DC (Engine)
DD (Engine)
DJ (Engine)
DK (Engine)
RE (Engine)
RG (Engine)
RJ (Engine)
RR (Engine)
RS (Engine)
RT (Engine)
DF (Engine)
DG (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 hav 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 haza 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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Foreword

Literature Information

This manual contains safety, operation instructions, lubrication and maintenance information. This manual should be stored in or near the engine area in a literature holder or literature storage area. Read, study and keep it with the literature and engine information.

English is the primary language for all Perkins publications. The English used facilitates translation and consistency.

Some photographs or illustrations in this manual show details or attachments that may be different from your engine. Guards and covers may have been removed for illustrative purposes. Continuing improvement and advancement of product design may have caused changes to your engine which are not included in this manual. Whenever a question arises regarding your engine, or this manual, please consult with your Perkins dealer or your Perkins distributor for the latest available information.

Safety

This safety section lists basic safety precautions. In addition, this section identifies hazardous, warning situations. Read and understand the basic precautions listed in the safety section before operating or performing lubrication, maintenance and repair on this product.

Operation

Operating techniques outlined in this manual are basic. They assist with developing the skills and techniques required to operate the engine more efficiently and economically. Skill and techniques develop as the operator gains knowledge of the engine and its capabilities.

The operation section is a reference for operators. Photographs and illustrations guide the operator through procedures of inspecting, starting, operating and stopping the engine. This section also includes a discussion of electronic diagnostic information.

Maintenance

The maintenance section is a guide to engine care. The illustrated, step-by-step instructions are grouped by service hours and/or calendar time maintenance intervals. Items in the maintenance schedule are referenced to detailed instructions that follow.

Recommended service should be performed at the appropriate intervals as indicated in the Maintenance Interval Schedule. The actual operating environment of the engine also governs the Maintenance Interval Schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

The maintenance schedule items are organized for a preventive maintenance management program. If the preventive maintenance program is followed, a periodic tune-up is not required. The implementation of a preventive maintenance management program should minimize operating costs through cost avoidances resulting from reductions in unscheduled downtime and failures.

Maintenance Intervals

Perform maintenance on items at multiples of the original requirement. We recommend that the maintenance schedules be reproduced and displayed near the machine as a convenient reminder. We also recommend that a maintenance record be maintained as part of the engine's permanent record.

Your authorized Perkins dealer or your Perkins distributor can assist you in adjusting your maintenance schedule to meet the needs of your operating environment.

Overhaul

Major engine overhaul details are not covered in the Operation and Maintenance Manual except for the interval and the maintenance items in that interval. Major repairs should only be carried out by Perkins authorized personnel. Your Perkins dealer or your Perkins distributor offers a variety of options regarding overhaul programs. If you experience a major engine failure, there are also numerous after failure overhaul options available. Consult with your Perkins dealer or your Perkins distributor for information regarding these options.

California Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm. Battery posts, terminals and related accessories contain lead and lead compounds. **Wash hands after handling**.

Safety Section

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Safety Messages

There may be several specific warning signs on an engine. The exact location of the hazards and the description of the hazards are reviewed in this section. Please become familiar with all warning signs.

Ensure that all of the warning signs are legible. Clean the warning signs or replace the warning signs if the words cannot be read or if the pictures are not visible. When the warning signs are cleaned, use a cloth, water, and soap. Do not use solvent, gasoline, or other harsh chemicals to clean the warning signs. Solvents, gasoline, or harsh chemicals could loosen the adhesive that secures the warning signs. The warning signs that are loosened could drop off of the engine.

Replace any damaged warning signs or missing warning signs. If a warning sign is attached to a part of the engine that is replaced, install a new warning sign on the replacement part. Perkins dealers or Perkins distributors can provide new warning signs.

Do not work on the engine and do not operate the engine unless the instructions and warnings in the Operation and Maintenance Manual are understood. Correct care is your responsibility. Failure to follow the instructions or failure to heed the warnings could result in injury or in death.

(1) Universal Warning

WARNING

Do not operate or work on this equipment unless you have read and understand the instructions and warnings in the Operation and Maintenance Manuals. Failure to follow the instructions or heed the warnings could result in serious injury or death.

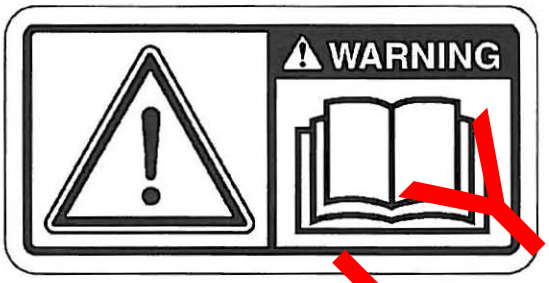

Illustration 1 g01154807

Typical example

The Universal Warning label (1) may be located on the valve mechanism cover or the inlet manifold. Refer to illustration 2.

Note: The location of this label will depend on the application of the engine.

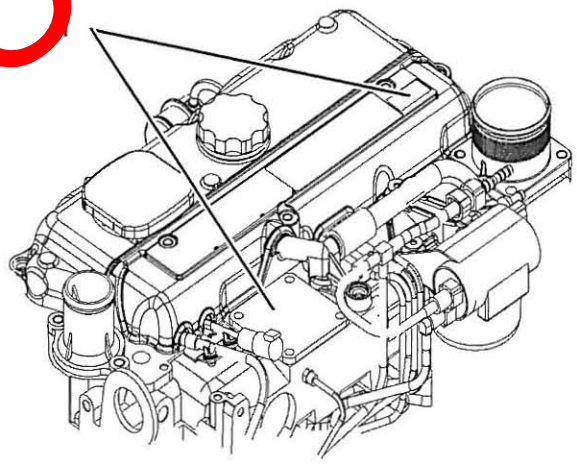

Illustration 2 g01682734

Typical example

(2) Ether

WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

Illustration 3 g01682820

The ether warning label (2) is located on the cover of the inlet manifold. Refer to illustration 4.

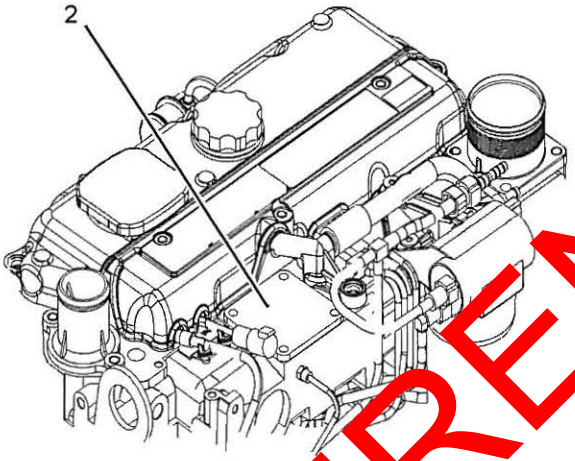

Illustration 4 g01682833
Typical example

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General Hazard Information

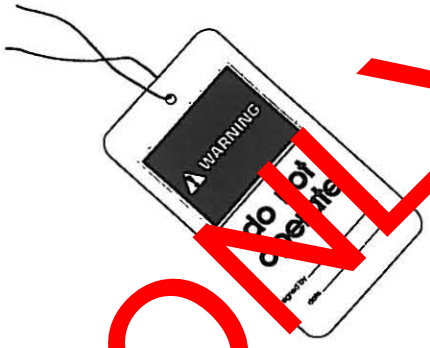

Illustration 5 g00104545

Attach a "Do Not Operate" warning tag or a similar warning tag to the start switch or to the controls before you service the equipment or before you repair the equipment.

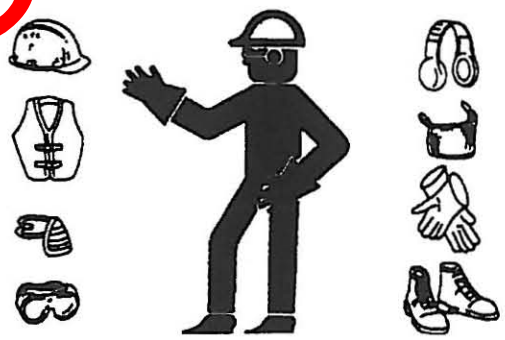

Illustration 6 g00702020

Wear a hard hat, protective glasses, and other protective equipment, as required.

Do not wear loose clothing or jewelry that can snag on controls or on other parts of the engine.

Make sure that all protective guards and all covers are secured in place on the engine.

Keep the engine free from foreign material. Remove debris, oil, tools, and other items from the deck, from walkways, and from steps.

Never put maintenance fluids into glass containers. Drain all liquids into a suitable container.

Obey all local regulations for the disposal of liquids.

Use all cleaning solutions with care.

Report all necessary repairs.

Do not allow unauthorized personnel on the equipment.

Ensure that the power supply is disconnected before you work on the bus bar or the glow plugs.

Perform maintenance on the engine with the equipment in the servicing position. Refer to the OEM information for the procedure for placing the equipment in the servicing position.

Pressure Air and Water

Pressurized air and/or water can cause debris and/or hot water to be blown out. This could result in personal injury.

The direct application of pressurized air or pressurized water to the body could result in personal injury.

When pressurized air and/or water is used for cleaning, wear protective clothing, protective shoes, and eye protection. Eye protection includes goggles or a protective face shield.

The maximum air pressure for cleaning purposes must be below 205 kPa (30 psi). The maximum water pressure for cleaning purposes must be below 275 kPa (40 psi).

Fluid Penetration

Pressure can be trapped in the hydraulic circuit long after the engine has been stopped. The pressure can cause hydraulic fluid or items such as pipe plugs to escape rapidly if the pressure is not relieved correctly.

Do not remove any hydraulic components or parts until pressure has been relieved or personal injury may occur. Do not disassemble any hydraulic components or parts until pressure has been relieved or personal injury may occur. Refer to the OEM information for any procedures that are required to relieve the hydraulic pressure.

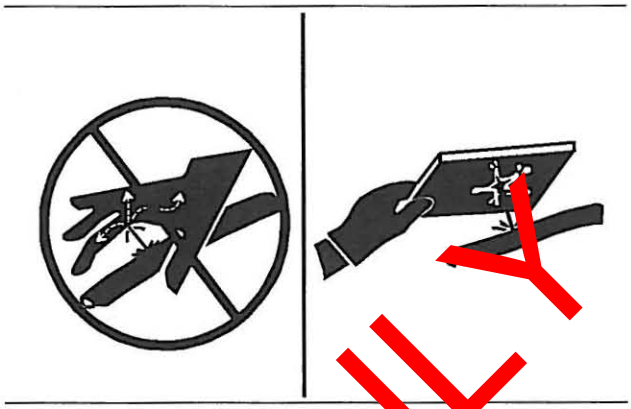

Illustration 7 g00687600

Always use a board or cardboard when you check for a leak. Leaking fluid that is under pressure can penetrate body tissue. Fluid penetration can cause serious injury and possible death. A pin hole leak can cause severe injury. If fluid is injected into your skin, you must get treatment immediately. Seek treatment from a doctor that is familiar with this type of injury.

Containing Fluid Spillage

Care must be taken in order to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the engine. Make provision to collect the fluid with a suitable container before any compartment is opened or before any component is disassembled.

- Only use the tools that are suitable for collecting fluids and equipment that is suitable for collecting fluids.
- Only use the tools that are suitable for containing fluids and equipment that is suitable for containing fluids.

Obey all local regulations for the disposal of liquids.

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Burn Prevention

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine. Relieve all pressure in the air system, in the hydraulic system, in the lubrication system, in the fuel system, or in the cooling system before any lines, fittings or related items are disconnected.

Coolant

When the engine is at operating temperature, the engine coolant is hot. The coolant is also under pressure. The radiator and all lines to the heaters or to the engine contain hot coolant.

Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained.

Check the coolant level after the engine has stopped and the engine has been allowed to cool.

Ensure that the filler cap is cool before removing the filler cap. The filler cap must be cool enough to touch with a bare hand. Remove the filler cap slowly in order to relieve pressure.

Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

Oils

Hot oil and hot lubricating components can cause personal injury. Do not allow hot oil to contact the skin. Also, do not allow hot components to contact the skin.

Batteries

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes. Always wear protective glasses for servicing batteries. Wash hands after touching the batteries and connectors. Use of gloves is recommended.

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Fire Prevention and Explosion Prevention

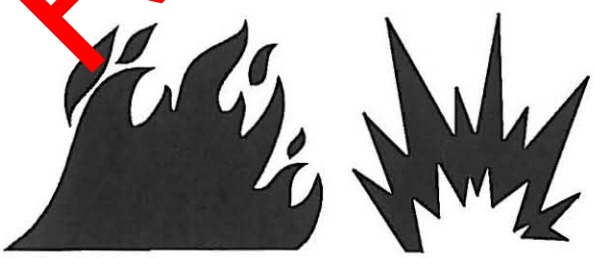

Illustration 8 g00704000

All fuels, most lubricants, and some coolant mixtures are flammable.

Flammable fluids that are leaking or spilled onto hot surfaces or onto electrical components can cause a fire. Fire may cause personal injury and property damage.

A flash fire may result if the covers for the engine crankcase are removed within fifteen minutes after an emergency shutdown.

Determine whether the engine will be operated in an environment that allows combustible gases to be drawn into the air inlet system. These gases could cause the engine to overspeed. Personal injury, property damage, or engine damage could result.

If the application involves the presence of combustible gases, consult your Perkins dealer and/or your Perkins distributor for additional information about suitable protection devices.

Remove all flammable combustible materials or conductive materials such as fuel, oil, and debris from the engine. Do not allow any flammable combustible materials or conductive materials to accumulate on the engine.

Store fuels and lubricants in correctly marked containers away from unauthorized persons. Store oily rags and any flammable materials in protective containers. Do not smoke in areas that are used for storing flammable materials.

Do not expose the engine to any flame.

Exhaust shields (if equipped) protect hot exhaust components from oil or fuel spray in case of a line, a tube, or a seal failure. Exhaust shields must be installed correctly.

Do not weld on lines or tanks that contain flammable fluids. Do not flame cut lines or tanks that contain flammable fluid. Clean any such lines or tanks thoroughly with a nonflammable solvent prior to welding or flame cutting.

Wiring must be kept in good condition. All electrical wires must be correctly routed and securely attached. Check all electrical wires daily. Repair any wires that are loose or frayed before you operate the engine. Clean all electrical connections and tighten all electrical connections.

Eliminate all wiring that is unattached or unnecessary. Do not use any wires or cables that are smaller than the recommended gauge. Do not bypass any fuses and/or circuit breakers.

Arcing or sparking could cause a fire. Secure connections, recommended wiring, and correctly maintained battery cables will help to prevent arcing or sparking.

Inspect all lines and hoses for wear or for deterioration. The hoses must be correctly routed. The lines and hoses must have adequate support and secure clamps. Tighten all connections to the recommended torque. Leaks can cause fires.

Oil filters and fuel filters must be correctly installed. The filter housings must be tightened to the correct torque.

Illustration 9 g00704059

Use caution when you are refueling an engine. Do not smoke while you are refueling an engine. Do not refuel an engine near open flames or sparks. Always stop the engine before refueling.

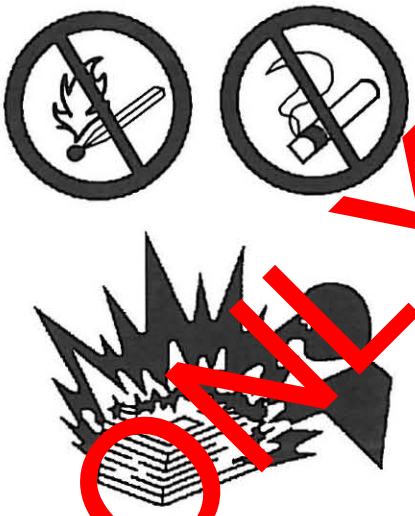

Illustration 10 g00704135

Gases from a battery can explode. Keep any open flames or sparks away from the top of a battery. Do not smoke in battery charging areas.

Never check the battery charge by placing a metal object across the terminal posts. Use a voltmeter or a hydrometer.

Incorrect jumper cable connections can cause an explosion that can result in injury. Refer to the Operation Section of this manual for specific instructions.

Do not charge a frozen battery. This may cause an explosion.

The batteries must be kept clean. The covers (if equipped) must be kept on the cells. Use the recommended cables, connections, and battery box covers when the engine is operated.

Fire Extinguisher

Make sure that a fire extinguisher is available. Be familiar with the operation of the fire extinguisher. Inspect the fire extinguisher and service the fire extinguisher regularly. Obey the recommendations on the instruction plate.

Lines, Tubes and Hoses

Do not bend high pressure lines. Do not strike high pressure lines. Do not install any lines that are bent or damaged. Do not clip any other items to the high pressure lines.

Repair any lines that are loose or damaged. Leaks can cause fires. Consult your Perkins dealer or your Perkins distributor for repair or for replacement parts.

Check lines, tubes and hoses carefully. Do not use your bare hand to check for leaks. Use a board or cardboard to check for leaks. Tighten all connections to the recommended torque.

Replace the parts if any of the following conditions are present:

- End fittings are damaged or leaking.
- Outer coverings are chafed or cut.
- Wires are exposed.
- Outer coverings are ballooning.
- Flexible part of the hoses are kinked.
- Outer covers have embedded armoring.
- End fittings are displaced.

Make sure that all clamps, guards, and heat shields are installed correctly. During engine operation, this will help to prevent vibration, rubbing against other parts, and excessive heat.

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Crushing Prevention and Cutting Prevention

Support the component correctly when work beneath the component is performed.

Unless other maintenance instructions are provided, never attempt adjustments while the engine is running.

Stay clear of all rotating parts and of all moving parts. Leave the guards in place until maintenance is performed. After the maintenance is performed, reinstall the guards.

Keep objects away from moving fan blades. The fan blades will throw objects or cut objects.

When objects are struck, wear protective glasses in order to avoid injury to the eyes.

Chips or other debris may fly off objects when objects are struck. Before objects are struck, ensure that no one will be injured by flying debris.

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Mounting and Dismounting

Inspect the steps, the handholds, and the work area before mounting the engine. Keep these items clean and keep these items in good repair.

Mount the engine and dismount the engine only at locations that have steps and/or handholds. Do not climb on the engine, and do not jump off the engine.

Face the engine in order to mount the engine or dismount the engine. Maintain three-point contact with the steps and handholds. Use two feet and one hand or use one foot and two hands. Do not use any controls as handholds.

Do not stand on components which cannot support your weight. Use an adequate ladder or use a work platform. Secure the climbing equipment so that the equipment will not move.

Do not carry tools or supplies when you mount the engine or when you dismount the engine. Use a hand line to raise and lower tools or supplies.

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Before Starting Engine

Before the initial start-up of an engine that is new, serviced or repaired, make provision to shut the engine off, in order to stop an overspeed. This may be accomplished by shutting off the air and/or fuel supply to the engine.

Overspeed shutdown should occur automatically for engines that are controlled electronically. If automatic shutdown does not occur, press the emergency stop button in order to cut the fuel and/or air to the engine.

Inspect the engine for potential hazards.

Before starting the engine, ensure that no one is on, underneath, or close to the engine. Ensure that the area is free of personnel.

If equipped, ensure that the lighting system for the engine is suitable for the conditions. Ensure that all lights work correctly, if equipped.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Do not bypass the automatic shutoff circuits. Do not disable the automatic shutoff circuits. The circuits are provided in order to help prevent personal injury. The circuits are also provided in order to help prevent engine damage.

See the Service Manual for repairs and for adjustments.

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Engine Starting

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

If a warning tag is attached to the engine start switch or to the controls, DO NOT start the engine or move the controls. Consult with the person that attached the warning tag before the engine is started.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Start the engine from the operator's compartment or from the engine start switch.

Always start the engine according to the procedure that is described in the Operation and Maintenance Manual, "Engine Starting" topic in the Operation Section. Knowing the correct procedure will help to prevent major damage to the engine components. Knowing the procedure will also help to prevent personal injury.

To ensure that the jacket water heater (if equipped) and/or the inlet oil heater (if equipped) is working correctly, check the water temperature gauge and the oil temperature gauge during the heater operation.

Engine exhaust contains products of combustion which can be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is started in an enclosed area, vent the engine exhaust to the outside.

Note: The engine is equipped with an automatic device for cold starting for normal conditions of operation. If the engine will be operated in very cold conditions, then an extra cold starting aid may be required. Normally, the engine will be equipped with the correct type of starting aid for your region of operation.

The engines are equipped with a glow plug starting aid in each individual cylinder that heats the intake air in order to improve starting.

i01928905

Engine Stopping

Stop the engine according to the procedure in the Operation and Maintenance Manual, "Engine Stopping (Operation Section)" in order to avoid overheating of the engine and accelerated wear of the engine components.

Use the Emergency Stop Button (if equipped) ONLY in an emergency situation. Do not use the Emergency Stop Button for normal engine stopping. After an emergency stop, DO NOT start the engine until the problem that caused the emergency stop has been corrected.

Stop the engine if an overspeed condition occurs during the initial start-up of a new engine or an engine that has been overhauled. This may be accomplished by shutting off the fuel supply to the engine and/or shutting off the air supply to the engine.

i02176668

Electrical System

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause the combustible gases that are produced by some batteries to ignite.

To help prevent sparks from igniting combustible gases that are produced by some batteries, the negative "–" jump start cable should be connected last from the external power source to the negative "–" terminal of the starting motor. If the starting motor is not equipped with a negative "–" terminal, connect the jump start cable to the engine block.

Check the electrical wires daily for wires that are loose or frayed. Tighten all loose electrical wires before the engine is started. Repair all frayed electrical wires before the engine is started. See the Operation and Maintenance Manual for specific starting instructions.

Grounding Practices

Correct grounding for the engine electrical system is necessary for optimum engine performance and reliability. Incorrect grounding will result in uncontrolled electrical circuit paths and in unreliable electrical circuit paths.

Uncontrolled electrical circuit paths can result in damage to main bearings, to crankshaft bearing journal surfaces, and to aluminum components.

Engines that are installed without engine-to-frame ground straps can be damaged by electrical discharge.

To ensure that the engine and the engine electrical systems function correctly, an engine-to-frame ground strap with a direct path to the battery must be used. This path may be provided by way of a direct engine ground to the frame.

All grounds should be tight and free of corrosion. The engine alternator must be grounded to the negative "-" battery terminal with a wire that is adequate to handle the full charging current of the alternator.

Product Information Section

Model Views

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Model View Illustrations

1104 Engine Model Views

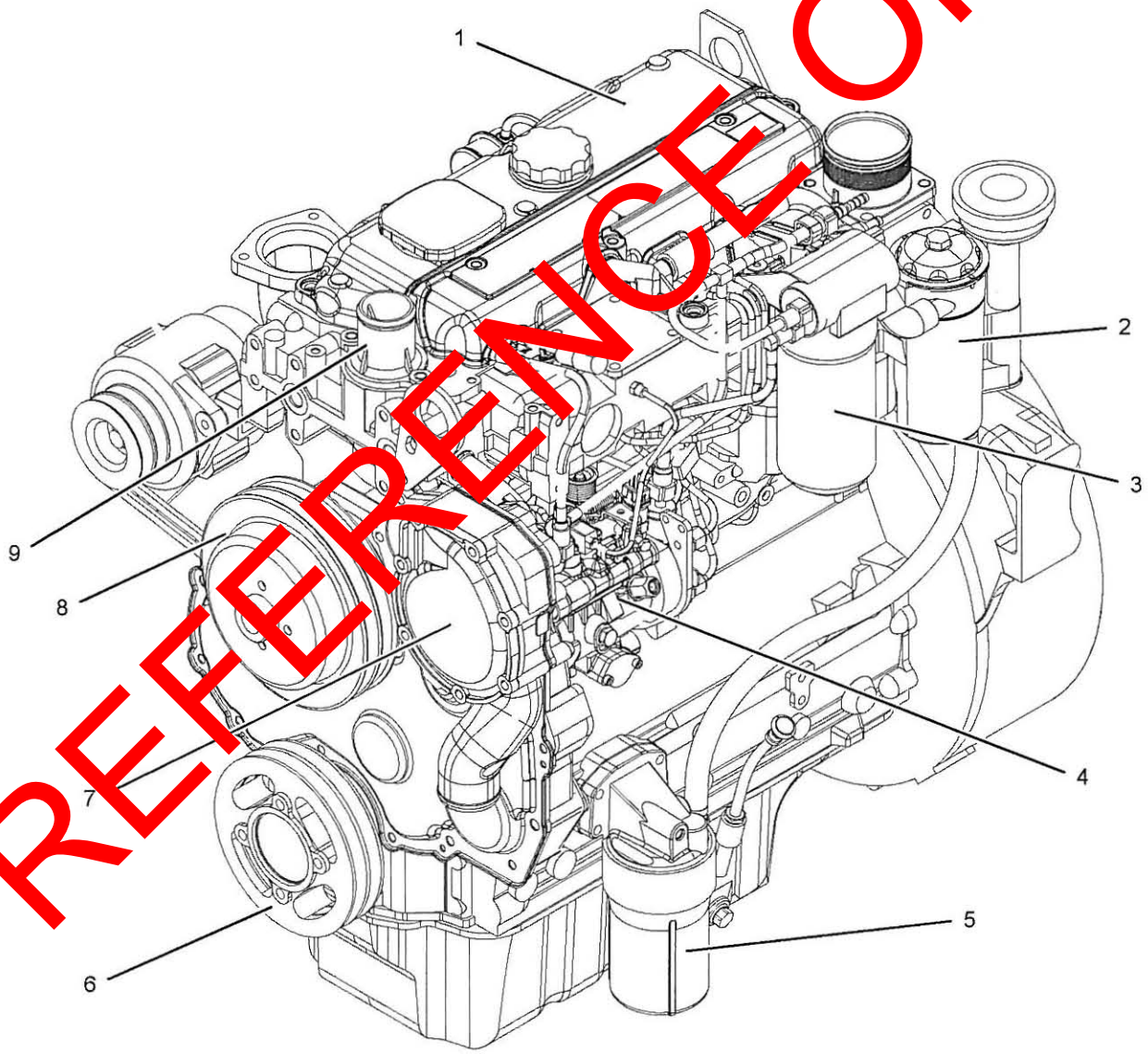

Illustration 11 g01012280

(1) Valve mechanism cover
(2) Crankcase breather
(3) Fuel filter
(4) Fuel injection pump
(5) Engine oil filter
(6) Crankshaft pulley
(7) Water pump
(8) Fan pulley
(9) Water temperature regulator housing

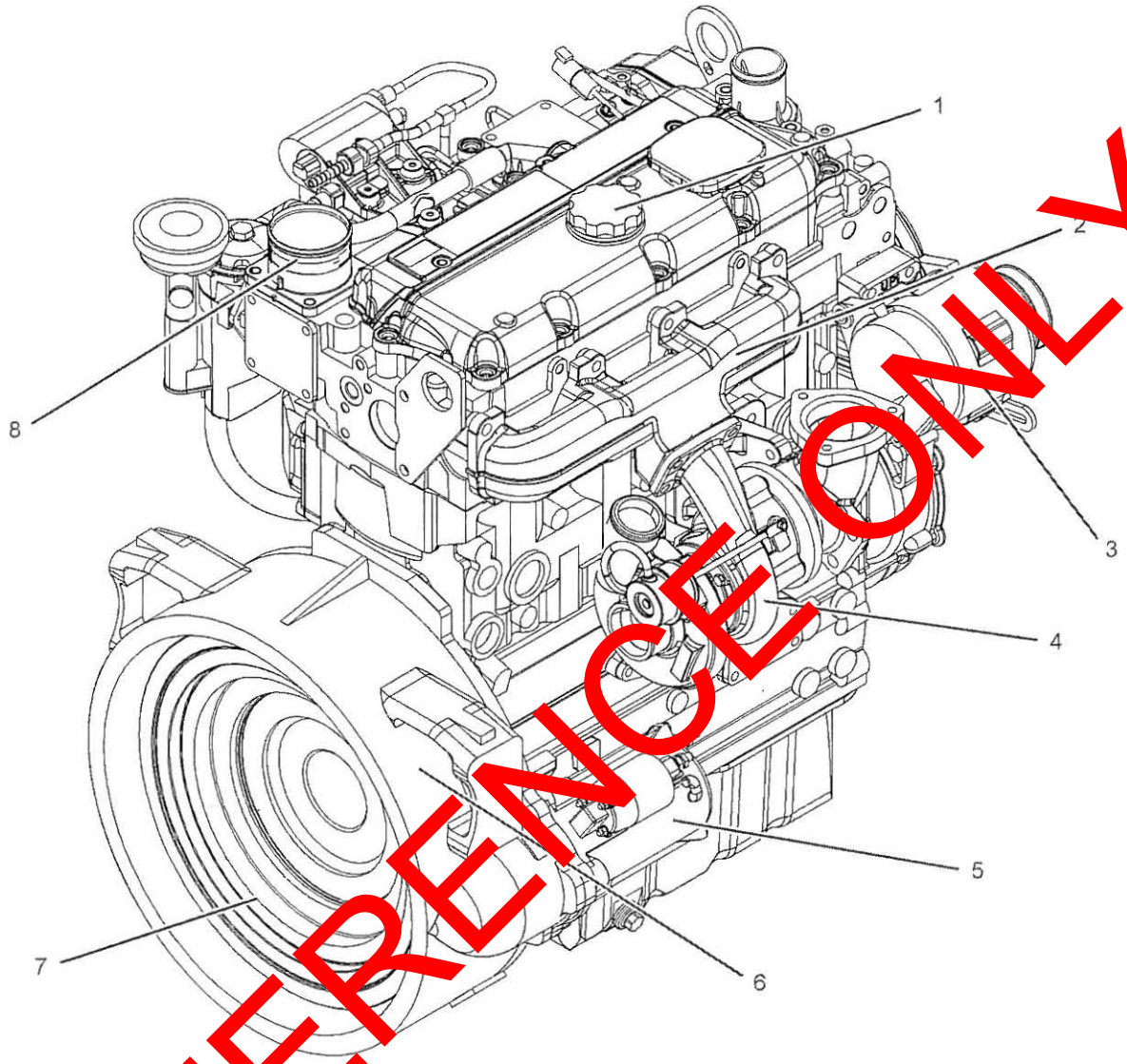

Illustration 12 g01012281

(1) Oil filler cap
(2) Exhaust manifold
(3) Alternator
(4) Turbocharger
(5) Starter motor
(6) Flywheel housing
(7) Flywheel
(8) Air intake

1103 Engine Model Views

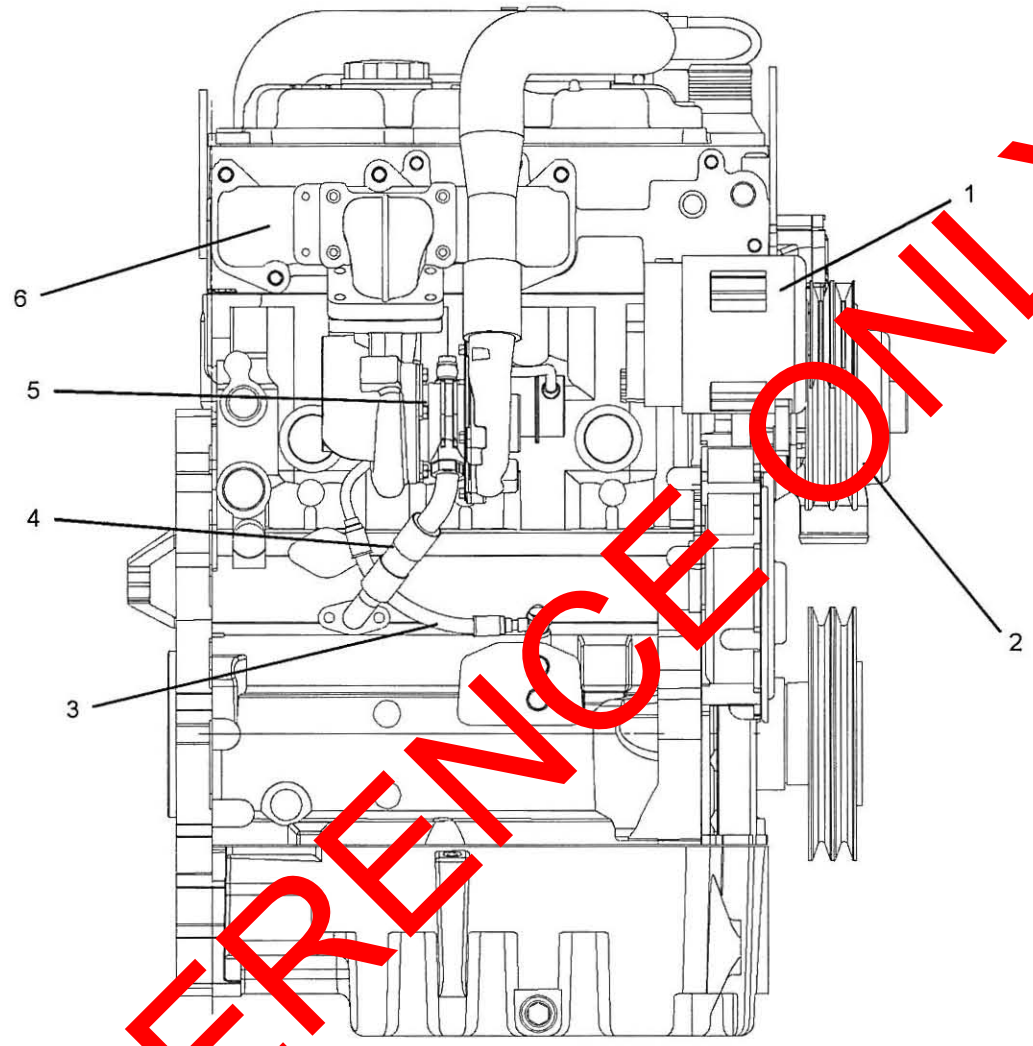

Illustration 13 g01011348

(1) Alternator
(2) Fan pull
(3) Turbocharger oil supply
(4) Turbocharger oil drain
(5) Turbocharger
(6) exhaust manifold

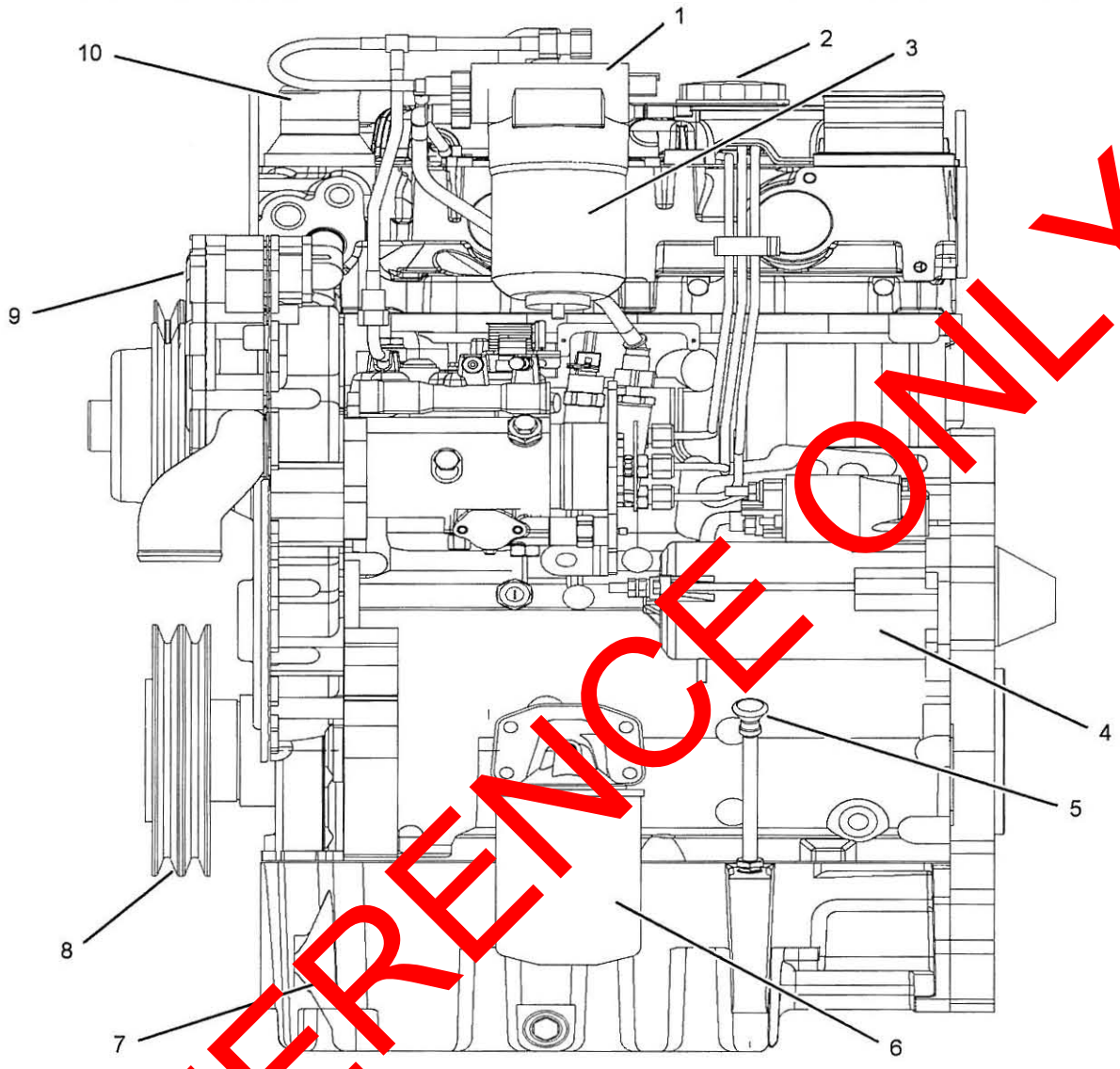

Illustration 14 g01011349

(1) Fuel transfer pump
(2) Oil filler cap
(3) Fuel filter
(4) Starter motor
(5) Dipstick
(6) Oil filter
(7) Oil pan
(8) Crankshaft pulley
(9) Water pump
(10) Water temperature regulator housing

i02196981

Engine Description

Perkins Engines are designed for the following applications: machine, genset, and industrial mobile equipment. The engines are available in the following types of aspiration:

- Turbocharged aftercooled
- Turbocharged
- Naturally aspirated

Engine Specifications

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right sides of the engine are determined from the flywheel end. The number 1 cylinder is the front cylinder.

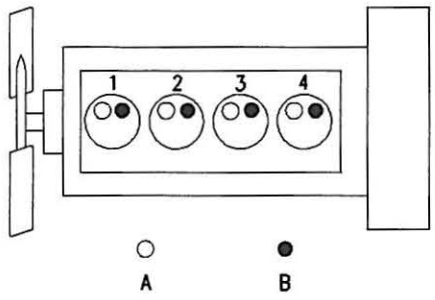

Illustration 15 g00984281

A typical example of the layout of the valves

(A) Inlet valves
(B) Exhaust valves

Table 1

1104 Industrial Engine Specifications	
Number of Cylinders	4 In-Line
Bore	105 mm (4.134 inch)
Stroke	127 mm (5.0 inch)
Aspiration	Turbocharged aftercooled Turbocharged Naturally aspirated
Compression Ratio	NA 19.25:1 T 18.23:1, TA
Displacement	4.4 L (268 in³)
Firing Order	1 3 4 2
Rotation (flywheel end)	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.45 mm (0.018 inch)

Table 2

1103 Industrial Engine Specifications	
Number of Cylinders	3 In-Line
Bore	105 mm (4.134 inch)
Stroke	127 mm (5.0 inch)
Aspiration	Turbocharged Naturally aspirated
Compression Ratio	NA 19.25:1 T 18.25:1
Displacement	3.3 L (201 in³)
Firing Order	1 2 3
Rotation (flywheel end)	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.45 mm (0.018 inch)

Table 3

1104 Genset Specifications	
Number of Cylinders	4 In-Line
Bore	105 mm (4.134 inch)
Stroke	127 mm (5.0 inch)
Aspiration	Turbocharged aftercooled Turbocharged Naturally aspirated
Compression Ratios	NA 19.25:1 T 17.25:1, T 18.23:1, TA 18.23:1
Displacement	4.4 L (268 in³)
Firing Order	1 3 4 2
Rotation (flywheel end)	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.45 mm (0.018 inch)

Table 4

1103 Genset Specifications	
Number of Cylinders	3 In-Line
Bore	105 mm (4.134 inch)
Stroke	127 mm (5.0 inch)
Aspiration	Turbocharged Naturally aspirated
Compression Ratio	NA 19.25:1 T 17.25:1
Displacement	3.3 L (201 in^3)
Firing Order	1 2 3
Rotation (flywheel end)	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.45 mm (0.018 inch)

Engine Cooling and Lubrication

The cooling system consists of the following components:

- Gear-driven centrifugal water pump
- Water temperature regulator which regulates the engine coolant temperature
- Gear-driven oil pump (gear type)
- Oil cooler

The engine lubricating oil is supplied by a gear type pump. The engine lubricating oil is cooled and the engine lubricating oil is filtered. Bypass valves provide unrestricted flow of lubrication oil to the engine parts when oil viscosity is high. Bypass valves can also provide unrestricted flow of lubrication oil to the engine parts if the oil cooler should become plugged or if the oil filter element should become plugged.

Engine efficiency, efficiency of emission controls, and engine performance depend on adherence to proper operation and maintenance recommendations. Engine performance and efficiency also depend on the use of recommended fuels, lubrication oils, and coolants. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for more information on maintenance items.

Engine Service Life

Engine efficiency and maximum utilization of engine performance depend on the adherence to proper operation and maintenance recommendations. In addition, use recommended fuels, coolants and lubricants. Use the Operation and Maintenance Manual as a guide for required engine maintenance.

Expected engine life is generally predicted by the average power that is demanded. The average power that is demanded is based on fuel consumption of the engine over a period of time. Reduced hours of operation at full throttle and/or operating at reduced throttle settings result in a lower average power demand. Reduced hours of operation will increase the length of operating time before an engine overhaul is required.

Product Identification Information

i02280116

Engine Identification

Perkins engines are identified by a serial number. This number is shown on a serial number plate that is mounted on the left hand side of the engine block.

An example of an engine number is RE12345U090001H.

RE _____ Type of engine

RE12345 _____ Engine List Number

U _____ Built in the United Kingdom

090001 _____ Engine Serial Number

H _____ Year of Manufacture

Perkins dealers need these numbers in order to determine the components that were included with the engine. This permits accurate identification of replacement part numbers.

i01940474

Serial Number Plate

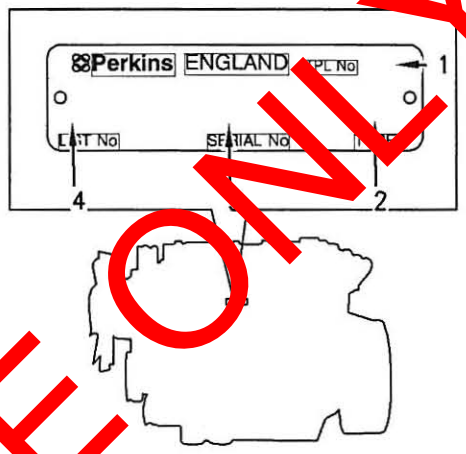

Illustration 16 g00994966

Typical serial number plate
(1) Temporary Parts List number
(2) Type
(3) Serial number
(4) List number

The Serial Number Plate is located on the left side of the cylinder block behind the high pressure pipes of the Fuel injection pump.

The following information is stamped on the Serial Number Plate: Engine serial number, Model, and Arrangement number.

i02164876

Reference Numbers

Information for the following items may be needed to order parts. Locate the information for your engine. Record the information in the appropriate space. Make a copy of this list for a record. Keep the information for future reference.

Record for Reference

Engine Model _____

Engine Serial number _____

Engine Low Idle rpm _____

Engine Full Load rpm _____

Primary Fuel Filter _____

Water Separator Element _____

Secondary Fuel Filter Element _____

Lubrication Oil Filter Element _____

Auxiliary Oil Filter Element _____

Total Lubrication System Capacity _____

Total Cooling System Capacity _____

Air Cleaner Element _____

Fan Drive Belt _____

Alternator Belt _____

i02758852

Emissions Certification Film

Label for compliant engines

Typical examples of emissions labels

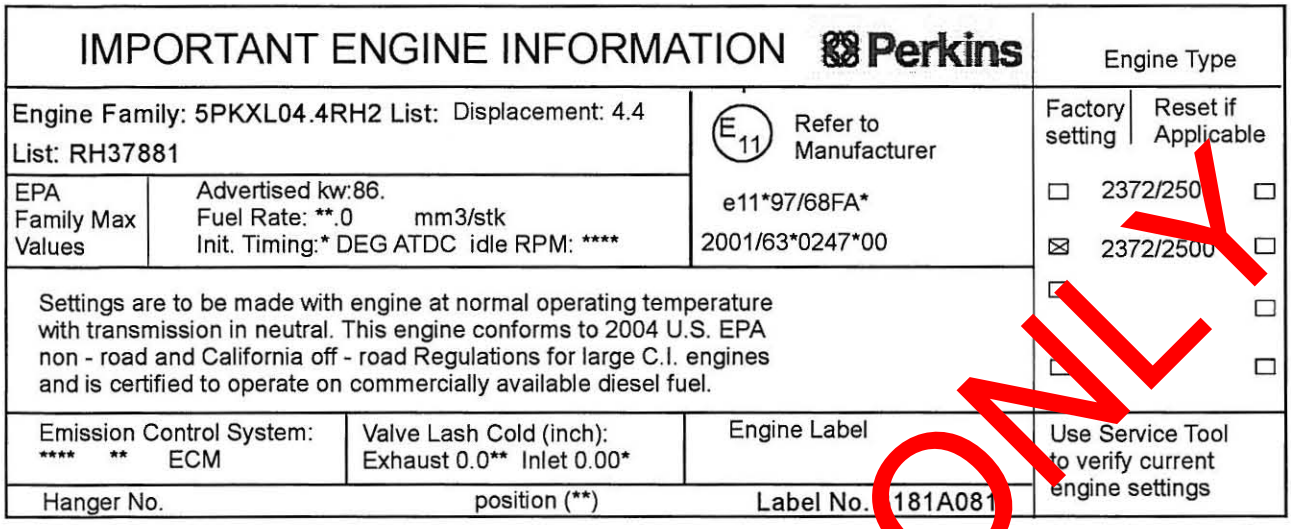

Illustration 17 g01173630

This typical example of a label is installed on engines that have electronic fuel injection systems and installed on engines that have electronic fuel injection pumps.

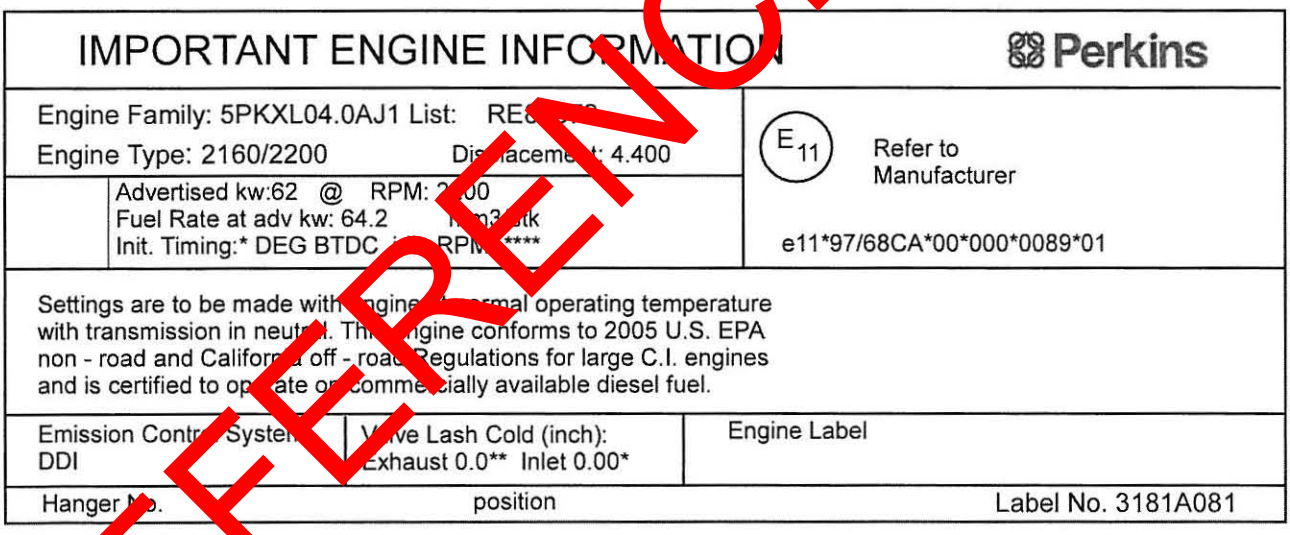

Illustration 18 g01156733

This typical example of a label is installed on engines that have mechanical fuel injection pumps.

Label for engines that comply with MSHA emissions

Perkins	LABEL NUMBER 3181
MSHA APPR NO.	
ENGINE MODEL	
CURVE NO.	
RATED HP RATED kW	AT rpm
HIGH IDLE	rpm
MAX ALT.	m
VENT RATE	cfm

Illustration 19 g01381316

Typical example

The label that is shown in illustration 19 is for engines that operate in underground coal mines in North America. The label is installed on engines that comply with the Mine Safety and Health Administration (MSHA) emissions. Approved diesel engines shall be identified by an approved mark that is legible and permanent. The approved mark is scribed with the approved MSHA number. The label should be securely attached to the diesel engine.

Label for engines that do not comply with emissions

EMISSIONS CONTROL INFORMATION Perkins

ENGINE FAMILY ******
ENGINE DISPLACEMENT= ****
MODEL YEAR: 2005

This non - road engine may be used as a REPLACEMENT engine within the EU, as per the provisions of Directive 97/68/EC

INFORMATION APPLICABLE TO USA ONLY

This non - road engine does not comply with either federal non - road or California off - road engine emission regulation requirements. Sale or installation of this engine is a violation of federal and California law subject to civil penalty for any purpose other than as an EXPORT - ONLY REPLACEMENT engine.
Export - only engine is indicated by an additional attached tag.

Hanger No** Position **** Label No. 3181A081

Illustration 20 g01156734

This typical example of a label is installed on engines that do not comply with emissions.

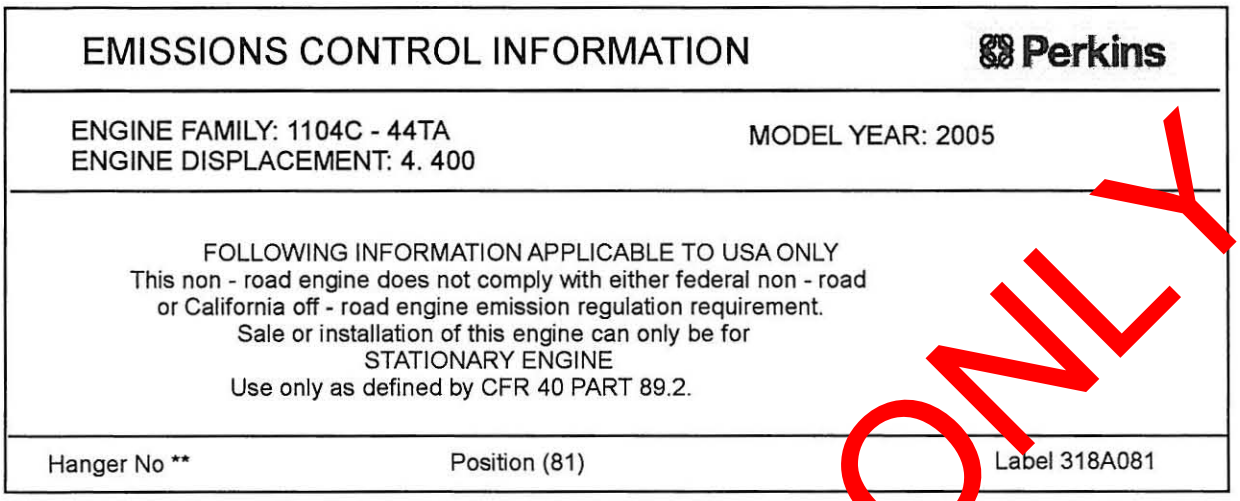

Illustration 21 g01157127

This typical example of a label is installed on engines that are stationary engines.

Operation Section

Lifting and Storage

i02164186

Engine Lifting

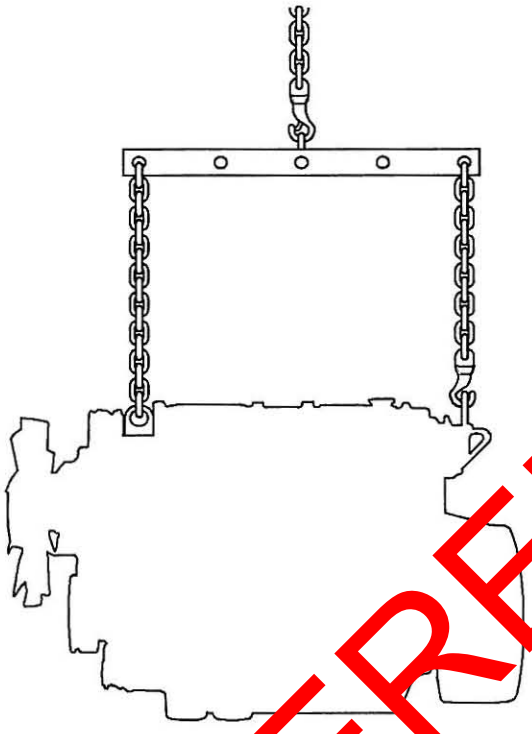

Illustration 22 g01097527

NOTICE

Never bend the eyebolts and the brackets. Only load the eyebolts and the brackets under tension. Remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90 degrees.

When it is necessary to remove a component at an angle, only use a link bracket that is properly rated for the weight.

Use a hoist to remove heavy components. Use an adjustable lifting beam to lift the engine. All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted.

Some removals require lifting the fixtures in order to obtain correct balance and safety.

To remove the engine ONLY, use the lifting eyes that are on the engine.

Lifting eyes are designed and installed for specific engine arrangements. Alterations to the lifting eyes and/or the engine make the lifting eyes and the lifting fixtures obsolete. If alterations are made, ensure that correct lifting devices are provided. Consult your Perkins dealer or your Perkins distributor for information regarding fixtures for correct engine lifting.

i01930351

Engine Storage

If the engine will not be started for several weeks, the lubricating oil will drain from the cylinder walls and from the piston rings. Rust can form on the cylinder walls. Rust on the cylinder walls will cause increased engine wear and a reduction in engine service life.

Lubrication System

To help prevent excessive engine wear, use the following guidelines:

Complete all of the lubrication recommendations that are listed in this Operation and Maintenance Manual, “Maintenance Interval Schedule” (Maintenance Section).

If an engine is out of operation and if use of the engine is not planned, special precautions should be made. If the engine will be stored for more than one month, a complete protection procedure is recommended.

Use the following guidelines :

- Completely clean the outside of the engine.
- Drain the fuel system completely and refill the system with preservative fuel.1772204 POWERPART Lay-Up 1 can be mixed with the normal fuel in order to change the fuel into preservative fuel.
- If preservative fuel is not available, the fuel system can be filled with normal fuel. This fuel must be discarded at the end of the storage period together with the fuel filter elements.
- Operate the engine until the engine reaches normal operating temperature. Stop any leaks from fuel, lubricating oil or air systems. Stop the engine and drain the lubricating oil from the oil pan.

- Renew the canister(s) of the lubricating oil filter.
- Fill the oil pan to the Full Mark on the dipstick with new, clean lubricating oil. Add 1762811 POWERPART Lay-Up 2 to the oil in order to protect the engine against corrosion. If 1762811 POWERPART Lay-Up 2 is not available, use a preservative of the correct specification instead of the lubricating oil. If a preservative is used, this must be drained completely at the end of the storage period and the oil pan must be refilled to the correct level with normal lubricating oil.

Cooling System

To help prevent excessive engine wear, use the following guidelines:

NOTICE
Do not drain the coolant while the engine is still hot and the system is under pressure because dangerous hot coolant can be discharged.

If freezing temperatures are expected, check the cooling system for adequate protection against freezing. See this Operation and Maintenance Manual, "General Coolant Information" (Maintenance Section).

NOTICE
To prevent frost damage, ensure that all the coolant is removed from the engine. This is important if the system is drained after it has been flushed with water, or if an antifreeze solution too weak to protect the system from frost has been used.

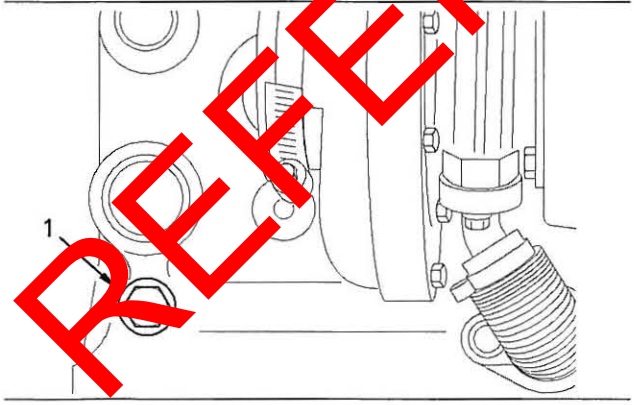

Illustration 23 g01003928

1. Ensure that the vehicle is on level ground.
2. Remove the filler cap of the cooling system.
3. Remove the drain plug (1) from the side of the cylinder block in order to drain the engine. Ensure that the drain hole is not restricted.
4. Open the tap or remove the drain plug at the bottom of the radiator in order to drain the radiator. If the radiator does not have a tap or a drain plug, disconnect the hose at the bottom of the radiator.
5. Flush the cooling system with clean water.
6. Fit the drain plugs and the filler cap. Close the tap or connect the radiator hose.
7. Fill the cooling system with an approved antifreeze mixture because this gives protection against corrosion. The maximum flow rate is 1 L (0.2200 Imp gal) per minute in order to fill the system.

Note: Certain corrosion inhibitors could cause damage to some engine components. Contact the Service Department of Perkins for advice.

8. Operate the engine for a short period in order to circulate the lubricating oil and the coolant in the engine.
9. Disconnect the battery. Put the battery into safe storage in a fully charged condition. Before the battery is put into storage, protect the terminals against corrosion.1734115 POWERPART Lay-Up can be used on the terminals.
10. Clean the crankcase breather if one is installed. Seal the end of the pipe.
11. Remove the fuel injector nozzles and spray 1762811 POWERPART Lay-Up 2 for one or two seconds into each cylinder bore with the piston at BDC.
12. Slowly rotate the crankshaft for one complete revolution and then replace the fuel injector nozzles.

Induction System

- Remove the air filter assembly. If necessary, remove the pipes that are installed between the air filter assembly and the turbocharger. Spray 1762811 POWERPART Lay-Up 2 into the turbocharger. The duration of the spray is printed on the container. Seal the turbocharger with waterproof tape.

Exhaust System

- Remove the exhaust pipe. Spray 1762811 POWERPART Lay-Up 2 into the turbocharger. The duration of the spray is printed on the container. Seal the turbocharger with waterproof tape.

General Items

- If the lubricating oil filler is installed on the rocker cover, remove the filler cap. If the lubricating oil filler cap is not installed on the rocker cover, remove the rocker cover. Spray 1762811 POWERPART Lay-Up 2 around the rocker shaft assembly. Replace the filler cap or the rocker cover.
- Seal the vent of the fuel tank or the fuel filler cap with waterproof tape.
- Remove the alternator drive belts and put the drive belts into storage.
- In order to prevent corrosion, spray the engine with 1734115 POWERPART Lay-Up 3. Do not spray the area inside the alternator.

When the engine protection has been completed in accordance with these instructions, this ensures that no corrosion will occur. Perkins are not responsible for damage which may occur when an engine is in storage after a period in service.

Your Perkins dealer or your Perkins distributor can assist in preparing the engine for extended storage periods.

Gauges and Indicators

i02164190

Gauges and Indicators

Your engine may not have the same gauges or all of the gauges that are described. For more information about the gauge package, see the OEM information.

Gauges provide indications of engine performance. Ensure that the gauges are in good working order. Determine the normal operating range by observing the gauges over a period of time.

Noticeable changes in gauge readings indicate potential gauge or engine problems. Problems may also be indicated by gauge readings that change even if the readings are within specifications. Determine and correct the cause of any significant change in the readings. Consult your Perkins dealer or your Perkins distributor for assistance.

NOTICE
If no oil pressure is indicated, STOP the engine. If maximum coolant temperature is exceeded, STOP the engine. Engine damage can result.

Engine Oil Pressure – The oil pressure should be greatest after a cold engine is started. The typical engine oil pressure with SAE10W30 is 207 to 413 kPa (30 to 60 psi) at rated rpm.

A lower oil pressure is normal at low idle. If the load is stable and the gauge reading changes, perform the following procedure:

1. Remove the load.
2. Reduce engine speed to low idle.
3. Check and maintain the oil level.

Coolant Water Coolant Temperature – Typical temperature range is 71 to 96°C (160 to 205°F). The maximum allowable temperature with the pressurized cooling system at 48 kPa (7 psi) is 110°C (230°F). Higher temperatures may occur under certain conditions. The water temperature reading may vary according to load. The reading should never exceed the boiling point for the pressurized system that is being used.

If the engine is operating above the normal range and steam becomes apparent, perform the following procedure:

1. Reduce the load and the engine rpm.
2. Inspect the cooling system for leaks.
3. Determine if the engine must be shut down immediately or if the engine can be cooled by reducing the load.

Tachometer – This gauge indicates engine speed (rpm). When the throttle control lever is moved to the full throttle position without load, the engine is running at high idle. The engine is running at the full load rpm when the throttle control lever is at the full throttle position with maximum rated load.

NOTICE
To help prevent engine damage, never exceed the high idle rpm. Overspeeding can result in serious damage to the engine. The engine can be operated at high idle without damage, but should never be allowed to exceed high idle rpm.

Ammeter – This gauge indicates the amount of charge or discharge in the battery charging circuit. Operation of the indicator should be to the right side of "0" (zero).

Fuel Level – This gauge indicates the fuel level in the fuel tank. The fuel level gauge operates when the "START/STOP" switch is in the "ON" position.

Service Hour Meter – The gauge indicates operating time of the engine.

Engine Starting

i02194223

Before Starting Engine

Before the engine is started, perform the required daily maintenance and any other periodic maintenance that is due. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for more information.

- For the maximum service life of the engine, make a thorough inspection within the engine compartment before the engine is started. Look for the following items: oil leaks, coolant leaks, loose bolts, and excessive dirt and/or grease. Remove any excess dirt and/or grease buildup. Repair any faults that were identified during the inspection.
- Inspect the cooling system hoses for cracks and for loose clamps.
- Inspect the alternator and accessory drive belts for cracks, breaks, and other damage.
- Inspect the wiring for loose connections and for worn wires or frayed wires.
- Check the fuel supply. Drain water from the water separator (if equipped). Open the fuel supply valve (if equipped).

NOTICE
All valves in the fuel return line must be open before and during engine operation to help prevent high fuel pressure. High fuel pressure may cause filter housing failure or other damage.

If the engine has not been started for several weeks, fuel may have drained from the fuel system. Air may have entered the filter housing. Also, when fuel filters have been changed, some air pockets will be trapped in the engine. In these instances, prime the fuel system. Refer to the Operation and Maintenance Manual, "Fuel System - Prime" for more information on priming the fuel system.

⚠ WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

- Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.
- Ensure that the areas around the rotating parts are clear.
- All of the guards must be put in place. Check for damaged guards or for missing guards. Repair any damaged guards. Replace damaged guards and/or missing guards.
- Disconnect any battery chargers that are not protected against the high current drain that is created when the electric starting motor is engaged. Check electrical cables and check the battery for poor connections and for corrosion.
- Reset all of the shutoffs or alarm components (if equipped).
- Check the engine lubrication oil level. Maintain the oil level between the "ADD" mark and the "FULL" mark on the engine oil level gauge.
- Check the coolant level. Observe the coolant level in the header tank (if equipped). Maintain the coolant level to the "FULL" mark on the header tank.
- If the engine is not equipped with a header tank maintain the coolant level within 13 mm (0.5 inch) of the bottom of the filler pipe. If the engine is equipped with a sight glass, maintain the coolant level in the sight glass.
- Observe the air cleaner service indicator (if equipped). Service the air cleaner when the yellow diaphragm enters the red zone, or when the red piston locks in the visible position.
- Ensure that any equipment that is driven by the engine has been disengaged from the engine. Minimize electrical loads or remove any electrical loads.

i02198348

Starting the Engine

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

Refer to the OMM for your type of controls. Use the following procedure to start the engine.

1. If equipped, move the throttle lever to the full throttle position before you start the engine.

NOTICE
Do not crank the engine for more than 30 seconds. Allow the electric starting motor to cool for two minutes before cranking the engine again.

2. Turn the engine start switch to the START position. Hold the engine start switch in the START position and crank the engine.
3. When the engine starts, release the engine start switch.
4. If equipped, slowly move the throttle lever to the low idle position and allow the engine to idle. Refer to the Operation and Maintenance Manual "After Starting Engine" topic.
5. If the engine does not start, release the engine start switch and allow the electric starting motor to cool. Then, repeat steps 2 through step 4.
6. Turn the engine start switch to the OFF position in order to stop the engine.

i02198092

Cold Weather Starting

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

Startability will be improved at temperatures below −18 °C (0 °F) from the use of a jacket water heater or extra battery capacity.

When Group 2 diesel fuel is used, the following items provide a means of minimizing starting problems and fuel problems in cold weather: engine oil pan heaters, jacket water heaters, fuel heaters, and fuel line insulation.

Use the procedure that follows for cold weather starting.

1. If equipped, move the throttle lever to the full throttle position before you start the engine.
2. If equipped, turn the engine start switch to the HEAT position. Hold the engine start switch in the HEAT position for 6 seconds until the glow plug indicator light illuminates. This will activate the glow plugs and aid in the starting of the engine.

NOTICE
Do not crank the engine for more than 30 seconds. Allow the electric starting motor to cool for two minutes before cranking the engine again.

3. When the glow plug indicator light is illuminated, turn the engine start switch to the START position and crank the engine.

Note: If the glow plug indicator light illuminates rapidly for 2 to 3 seconds, or if the glow plug indicator light fails to illuminate, a malfunction exists in the cold start system. Do not use ether or other starting fluids to start the engine.

4. When the engine starts, release the engine start switch key.
5. If the engine does not start, release the engine start switch and allow the starter motor to cool. Then, repeat steps 2 through step 4.
6. If the engine is equipped with a throttle allow the engine to idle for three to five minutes, or allow the engine to idle until the water temperature indicator begins to rise. The engine should run at low idle smoothly until speed is gradually increased to high idle. Allow the white smoke to disperse before proceeding with normal operation.
7. Operate the engine at low load until all systems reach operating temperature. Check the gauges during the warm-up period.
8. Turn the engine start switch to the OFF position in order to stop the engine.

i02177935

Starting with Jump Start Cables

⚠ WARNING

Improper jump start cable connections can cause an explosion resulting in personal injury.

Prevent sparks near the batteries. Sparks could cause vapors to explode. Do not allow jump start cable ends to contact each other or the engine.

Note: If it is possible, first diagnose the reason for the starting failure. Make any necessary repairs. If the engine will not start only due to the condition of the battery, either charge the battery, or start the engine with jump start cables. The condition of the battery can be rechecked after the engine has been switched OFF.

NOTICE

Using a battery source with the same voltage as the electric starting motor. Use ONLY equal voltage for jump starting. The use of higher voltage will damage the electrical system.

Do not reverse the battery cables. The alternator can be damaged. Attach ground cable last and remove first.

When using an external electrical source to start the engine, turn the generator set control switch to the "OFF" position. Turn all electrical accessories OFF before attaching the jump start cables.

Ensure that the main power switch is in the OFF position before attaching the jump start cables to the engine being started.

1. Turn the start switch to the OFF position. Turn off all the engine's accessories.
2. Connect one positive end of the jump start cable to the positive cable terminal of the discharged battery. Connect the other positive end of the jump start cable to the positive cable terminal of the electrical source.
3. Connect one negative end of the jump start cable to the negative cable terminal of the electrical source. Connect the other negative end of the jump start cable to the engine block or to the chassis ground. This procedure helps to prevent potential sparks from igniting the combustible gases that are produced by some batteries.
4. Start the engine.
5. Immediately after the stalled engine is started, disconnect the jump start cables in reverse order.

After jump starting, the alternator may not be able to fully recharge batteries that are severely discharged. The batteries must be replaced or recharged to the correct voltage with a battery charger after the engine is stopped. Many batteries which are considered unusable are still rechargable. Refer to Operation and Maintenance Manual, "Battery - Replace" and Testing and Adjusting Manual, "Battery - Test".

i01903609

After Starting Engine

Note: In temperatures from 0 to 60°C (32 to 140°F), the warm-up time is approximately three minutes. In temperatures below 0°C (32°F), additional warm-up time may be required.

When the engine idles during warm-up, observe the following conditions:

- Check for any fluid or for any air leaks at idle rpm and at one-half full rpm (no load on the engine) before operating the engine under load. This is not possible in some applications.
- Operate the engine at low idle until all systems achieve operating temperatures. Check all gauges during the warm-up period.

Note: Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

Engine Operation

i02176671

Engine Operation

Correct operation and maintenance are key factors in obtaining the maximum life and economy of the engine. If the directions in the Operation and Maintenance Manual are followed, costs can be minimized and engine service life can be maximized.

The engine can be operated at the rated rpm after the engine reaches operating temperature. The engine will reach normal operating temperature sooner during a low engine speed (rpm) and during a low power demand. This procedure is more effective than idling the engine at no load. The engine should reach operating temperature in a few minutes.

Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

i01909404

Engine Warm-up

1. Run the engine at low idle for three to five minutes, or run the engine at low idle until the jacket water temperature starts to rise.

   More time may be necessary when the temperature is below −18°C (0°F).

2. Check all of the gauges during the warm-up period.

3. Perform a walk-around inspection. Check the engine for fluid leaks and air leaks.

4. Increase the rpm to the rated rpm. Check for fluid leaks and air leaks. The engine may be operated at full rated rpm and at full load when the temperature of the water jacket reaches 60°C (140°F).

i02330149

Fuel Conservation Practices

The efficiency of the engine can affect the fuel economy. Perkins design and technology in manufacturing provides maximum fuel efficiency in all applications. Follow the recommended procedures in order to attain optimum performance for the life of the engine.

- Avoid spilling fuel.

Fuel expands when the fuel is warmed up. The fuel may overflow from the fuel tank. Inspect fuel lines for leaks. Repair the fuel lines, as needed.

- Be aware of the properties of the different fuels. Use only the recommended fuels.

- Avoid unnecessary idling.

Shut off the engine rather than idle for long periods of time.

- Observe the air cleaner service indicator frequently. Keep the air cleaner elements clean.

  Maintain the electrical systems.

One damaged battery cell will overwork the alternator. This will consume excess power and excess fuel.

- Ensure that the drive belts are correctly adjusted. The drive belts should be in good condition.

- Ensure that all of the connections of the hoses are tight. The connections should not leak.

- Ensure that the driven equipment is in good working order.

- Cold engines consume excess fuel. Utilize heat from the jacket water system and the exhaust system, when possible. Keep cooling system components clean and keep cooling system components in good repair. Never operate the engine without water temperature regulators. All of these items will help maintain operating temperatures.

Engine Stopping

i01929389

Stopping the Engine

NOTICE
Stopping the engine immediately after it has been working under load can result in overheating and accelerated wear of the engine components.

If the engine has been operating at high rpm and/or high loads, run at low idle for at least three minutes to reduce and stabilize internal engine temperature before stopping the engine.

Avoiding hot engine shutdowns will maximize turbocharger shaft and bearing life.

Prior to stopping an engine that is being operated at low loads, operate the engine at low idle for 30 seconds before stopping. If the engine has been operating at highway speeds and/or at high loads, operate the engine at low idle for at least three minutes. This procedure will cause the internal engine temperature to be reduced and stabilized.

Ensure that the engine stopping procedure is understood. Stop the engine according to the shutoff system on the engine or refer to the instructions that are provided by the OEM.

- To stop the engine, turn the ignition key switch to the OFF position.

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Emergency Stopping

NOTICE
Emergency shutoff controls are for EMERGENCY use ONLY. DO NOT use emergency shutoff devices or controls for normal stopping procedure.

The OEM may have equipped the application with an emergency stop button. For more information about the emergency stop button, refer to the OEM information.

Ensure that any components for the external system that support the engine operation are secured after the engine is stopped.

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After Stopping Engine

Note: Before you check the engine oil, do not operate the engine for at least 10 minutes in order to allow the engine oil to return to the oil pan.

- Check the crankcase oil level. Maintain the oil level between the "ADD" mark and the "FULL" mark on the oil level dipstick.
- If necessary, perform minor adjustments. Repair any leaks and tighten any loose bolts.
- Note the required service interval. Perform the maintenance that is in the Operation and Maintenance Manual, "Maintenance Interval Schedule".
- Fill the fuel tank in order to help prevent accumulation of moisture in the fuel. Do not overfill the fuel tank.

NOTICE
Only use antifreeze/coolant mixtures recommended in the Coolant Specifications that are in the Operation and Maintenance Manual. Failure to do so can cause engine damage.

- Allow the engine to cool. Check the coolant level.
- If freezing temperatures are expected, check the coolant for the correct antifreeze protection. The cooling system must be protected against freezing to the lowest expected outside temperature. Add the correct coolant/water mixture, if necessary.
- Perform all required periodic maintenance on all driven equipment. This maintenance is outlined in the instructions from the OEM.

Cold Weather Operation

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Cold Weather Operation

Perkins Diesel Engines can operate effectively in cold weather. During cold weather, the starting and the operation of the diesel engine is dependent on the following items:

- The type of fuel that is used
- The viscosity of the engine oil
- The operation of the glow plugs
- Optional Cold starting aid
- Battery condition

This section will cover the following information:

- Potential problems that are caused by cold weather operation
- Suggest steps which can be taken in order to minimize starting problems and operating problems when the ambient air temperature is between 0° to −40 °C (32° to 40 °F).

The operation and maintenance of an engine in freezing temperatures is complex. This is because of the following conditions:

- Weather conditions
- Engine application

Recommendations from your Perkins dealer or your Perkins distributor are based on past proven practices. The information that is contained in this section provides guidelines for cold weather operation.

Hints for Cold Weather Operation

- If the engine will start, operate the engine until a minimum operating temperature of 81 °C (177.8 °F) is achieved. Achieving operating temperature will help prevent the intake valves and exhaust valves from sticking.
- The cooling system and the lubrication system for the engine do not lose heat immediately upon shutdown. This means that an engine can be shut down for a period of time and the engine can still have the ability to start readily.
- Install the correct specification of engine lubricant before the beginning of cold weather.
- Check all rubber parts (hoses, fan drive belts, etc) weekly.
- Check all electrical wiring and connections for any fraying or damaged insulation.
- Keep all batteries fully charged and warm.
- Fill the fuel tank at the end of each shift.
- Check the air cleaners and the air intake daily. Check the air intake more often when you operate in snow.
- Ensure that the glow plugs are in working order. Refer to Testing and Adjusting Manual, “Glow Plug - Test”.

⚠ WARNING

Personal injury or property damage can result from alcohol or starting fluids.

Alcohol or starting fluids are highly flammable and toxic and if improperly stored could result in injury or property damage.

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

- For jump starting with cables in cold weather, refer to the Operation and Maintenance Manual, “Starting with Jump Start Cables.” for instructions.

Viscosity of the Engine Lubrication Oil

Correct engine oil viscosity is essential. Oil viscosity affects the amount of torque that is needed to crank the engine. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for the recommended viscosity of oil.

Recommendations for the Coolant

Provide cooling system protection for the lowest expected outside temperature. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for the recommended coolant mixture.

In cold weather, check the coolant often for the correct glycol concentration in order to ensure adequate freeze protection.

Engine Block Heaters

Engine block heaters (if equipped) heat the engine jacket water that surrounds the combustion chambers. This provides the following functions:

- Startability is improved.
- Warm up time is reduced.

An electric block heater can be activated once the engine is stopped. An effective block heater is typically a 1250/1500 W unit. Consult your Perkins dealer or your Perkins distributor for more information.

Idling the Engine

When idling after the engine is started in cold weather, increase the engine rpm from 1000 to 1200 rpm. This will warm up the engine more quickly. Maintaining an elevated low idle speed for extended periods will be easier with the installation of a hand throttle. The engine should not be "raced" in order to speed up the warm up process.

While the engine is idling, the application of a light load (parasitic load) will assist in achieving the minimum operating temperature. The minimum operating temperature is 82 °C (179 °F).

Recommendations for Coolant Warm Up

Warm up an engine that has cooled below normal operating temperatures due to inactivity. This should be performed before the engine is returned to full operation. During operation in very cold temperature conditions, damage to engine valve mechanisms can result from engine operation for short intervals. This can happen when the engine is started and the engine is stopped many times without being operated in order to warm up completely.

When the engine is operated below normal operating temperatures, fuel and oil are not completely burned in the combustion chamber. This fuel and oil causes soft carbon deposits to form on the valve stems. Generally, the deposits do not cause problems and the deposits are burned off during operation at normal engine operating temperatures.

When the engine is started and the engine is stopped many times without being operated in order to warm up completely, the carbon deposits become thicker. This can cause the following problems:

- Free operation of the valves is prevented.
- Valves become stuck.
- Pushrods may become bent.
- Other damage to valve train components can result.

For this reason, when the engine is started, the engine must be operated until the coolant temperature is 71 °C (160 °F) minimum. Carbon deposits on the valve stems will be kept at a minimum and the free operation of the valves and the valve components will be maintained.

In addition, the engine must be thoroughly warmed in order to keep other engine parts in better condition and the service life of the engine will be generally extended. Lubrication will be improved. There will be less acid and less sludge in the oil. This will provide longer service life for the engine bearings, the piston rings, and other parts. However, limit unnecessary idle time to ten minutes in order to reduce wear and unnecessary fuel consumption.

The Water Temperature Regulator and Insulated Heater Lines

The engine is equipped with a water temperature regulator. When the engine coolant is below the correct operating temperature jacket water circulates through the engine cylinder block and into the engine cylinder head. The coolant then returns to the cylinder block via an internal passage that bypasses the valve of the coolant temperature regulator. This ensures that coolant flows around the engine under cold operating conditions. The water temperature regulator begins to open when the engine jacket water has reached the correct minimum operating temperature. As the jacket water coolant temperature rises above the minimum operating temperature the water temperature regulator opens further allowing more coolant through the radiator to dissipate excess heat.

The progressive opening of the water temperature regulator operates the progressive closing of the bypass passage between the cylinder block and head. This ensures maximum coolant flow to the radiator in order to achieve maximum heat dissipation.

Note: Perkins discourages the use of all air flow restriction devices such as radiator shutters. Restriction of the air flow can result in the following: high exhaust temperatures, power loss, excessive fan usage, and reduction in fuel economy.

A cab heater is beneficial in very cold weather. The feed from the engine and the return lines from the cab should be insulated in order to reduce heat loss to the outside air.

Insulating the Air Inlet and Engine Compartment

When temperatures below −18 °C (−0 °F) will be frequently encountered, an air cleaner inlet that is located in the engine compartment may be specified. An air cleaner that is located in the engine compartment may also minimize the entry of snow into the air cleaner. Also, heat that is rejected by the engine helps to warm the intake air.

Additional heat can be retained around the engine by insulating the engine compartment.

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Fuel and the Effect from Cold Weather

Note: Only use grades of fuel that are recommended by Perkins. Refer to this Operation and Maintenance Manual, “Fluid Recommendations”.

The following fuels can be used in this series of engine.

- Group 1
- Group 2
- Group 3
- Special Fuels

Perkins prefers only Group 1 and Group 2 fuels for use in this series of engines.

Group 1 fuels are the preferred Group of Fuels for general use by Perkins. Group 1 fuels maximize engine life and engine performance. Group 1 fuels are usually less available than Group 2 fuels. Frequently, Group 1 fuels are not available in colder climates during the winter.

Note: Group 2 fuels must have a maximum wear scar of 650 micrometers (HFRR to ISO 12156-1).

Group 2 fuels are considered acceptable for issues of warranty. This group of fuels may reduce the life of the engine, the engine’s maximum power, and the engine’s fuel efficiency.

When Group 2 diesel fuels are used the following components provide a means of minimizing problems in cold weather:

- Glow plugs (if equipped)
- Engine coolant heaters, which may be an OEM option
- Fuel heaters, which may be an OEM option
- Fuel line insulation, which may be an OEM option

There are three major differences between Group 1 fuels and Group 2 fuels. Group 1 fuels have the following different characteristics to Group 2 fuels.

- A lower cloud point
- A lower pour point
- A higher energy per unit volume of fuel

Note: Group 3 fuels reduce the life of the engine. The use of Group 3 fuels is not covered by the Perkins warranty.

Group 3 fuels include Low Temperature Fuels and Aviation Kerosene Fuels.

Special fuels include Biofuel.

The cloud point is a temperature that allows wax crystals to form in the fuel. These crystals can cause the fuel filters to plug.

The pour point is the temperature when diesel fuel will thicken. The diesel fuel becomes more resistant to flow through fuel lines, fuel filters,and fuel pumps.

Be aware of these facts when diesel fuel is purchased. Consider the average ambient air temperature for the engine’s application. Engines that are fueled in one climate may not operate well if the engines are moved to another climate. Problems can result due to changes in temperature.

Before troubleshooting for low power or for poor performance in the winter, check the fuel for waxing.

Low temperature fuels may be available for engine operation at temperatures below 0 °C (32 °F). These fuels limit the formation of wax in the fuel at low temperatures.

For more information on cold weather operation, refer to the Operation and Maintenance Manual, “Cold Weather Operation and Fuel Related Components in Cold Weather”.

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Fuel Related Components in Cold Weather

Fuel Tanks

Condensation can form in partially filled fuel tanks. Top off the fuel tanks after you operate the engine.

Fuel tanks should contain some provision for draining water and sediment from the bottom of the tanks. Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe.

Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Drain the water and sediment from any fuel storage tank at the following intervals: weekly, oil changes, and refueling of the fuel tank. This will help prevent water and/or sediment from being pumped from the fuel storage tank and into the engine fuel tank.

Fuel Filters

It is possible that a primary fuel filter is installed between the fuel tank and the engine fuel inlet. After you change the fuel filter, always prime the fuel system in order to remove air bubbles from the fuel system. Refer to the Operation and Maintenance Manual in the Maintenance Section for more information on priming the fuel system.

The micron rating and the location of a primary fuel filter is important in cold weather operation. The primary fuel filter and the fuel supply line are the most common components that are affected by cold fuel.

Fuel Heaters

Note: The OEM may equip the application with fuel heaters. If this is the case, disconnect an electric type of fuel heater in warm weather in order to prevent overheating of the fuel. If the type of fuel heater is a heat exchanger, the OEM should have included a bypass for warm weather. Ensure that the bypass is operational during warm weather in order to prevent overheating of the fuel.

For more information about fuel heaters (if equipped), refer to the OEM information.

Maintenance Section

Refill Capacities

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Refill Capacities

Lubrication System

The refill capacities for the engine crankcase reflect the approximate capacity of the crankcase or sump plus standard oil filters. Auxiliary oil filter systems will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter. Refer to the Operation and Maintenance Manual, "Maintenance Section" for more information on Lubricant Specifications.

1104 Engine

Table 5

1104 Engine		
Compartment or System	**Liters**	**Qu**
Standard Oil Sump for the Engine Crankcase (1)	6.5	7

(1) These values are the approximate capacities for the crankcase oil sump which include the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.

1103 Engine

Table 6

1103 Engine		
Compartment or System	**Liters**	**Quarts**
Standard Oil Sump for the Engine Crankcase (1)	6.5	7

(1) These values are the approximate capacities for the crankcase oil sump which include the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.

Cooling System

To maintain the cooling system, the Total Cooling System capacity must be known. The approximate capacity for the engine cooling system is listed below. External System capacities will vary among applications. Refer to the OEM specifications for the External System capacity. This capacity information will be needed in order to determine the amount of coolant/antifreeze that is required for the Total Cooling System.

1104 Engine

Table 7

1104 Naturally Aspirated Engine		
Compartment or System	**Liters**	**Quarts**
Engine Only	10.4	11
External cooling system capacity (OEM recommendation) (1)		
Total Cooling System (2)		

(1) The external cooling system includes a radiator or an expansion tank with the following components: heat exchanger, aftercooler, and piping. Refer to the OEM specifications. Enter the value for the external system capacity in this row.

(2) The Total Cooling System includes the capacity for the engine cooling system plus the capacity for the external cooling system. Enter the total in this row.

Table 8

1104 Turbocharged Engine		
Compartment or System	**Liters**	**Quarts**
Engine Only	11.4	12
External cooling System capacity (OEM recommendation) (1)		
Total Cooling System (2)		

(1) The external cooling system includes a radiator or an expansion tank with the following components: heat exchanger, aftercooler, and piping. Refer to the OEM specifications. Enter the value for the external cooling system capacity in this row.

(2) The Total Cooling System includes the capacity for the engine cooling system plus the capacity for the external cooling system. Enter the total in this row.

1103 Engine

Table 9

1103 Naturally Aspirated Engine without an oil cooler		
Compartment or System	**Liters**	**Quarts**
Engine Only	4.21	4
External cooling system capacity (OEM recommendation) (1)		
Total Cooling System (2)		

(1) The external cooling system includes a radiator or an expansion tank with the following components: heat exchanger, aftercooler, and piping. Refer to the OEM specifications. Enter the value for the external system capacity in this row.
(2) The Total Cooling System includes the capacity for the engine cooling system plus the capacity for the external cooling system. Enter the total in this row.

Table 10

1103 Naturally Aspirated Engines and Turbocharged Engines with an oil cooler		
Compartment or System	**Liters**	**Quarts**
Engine Only	4.43	4.02
External cooling system capacity (OEM recommendation) (1)		
Total Cooling System (2)		

(1) The external cooling system includes a radiator or an expansion tank with the following components: heat exchanger, aftercooler, and piping. Refer to the OEM specifications. Enter the value for the external system capacity in this row.
(2) The Total Cooling System includes the capacity for the engine cooling system plus the capacity for the external cooling system. Enter the total in this row.

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Fluid Recommendations

General Lubricant Information

Because of government regulations regarding the certification of exhaust emissions from the engine, the lubricant recommendations must be followed.

Engine Manufacturers Association (EMA) Oils

The "Engine Manufacturers Association Recommended Guideline on Diesel Engine Oil" is recognized by Perkins. For detailed information about this guideline, see the latest edition of EMA publication, "EMA DHD -1".

API Oils

The Engine Oil Licensing and Certification System by the American Petroleum Institute (API) is recognized by Perkins. For detailed information about this system, see the latest edition of the "API publication No. 1509". Engine oils that bear the API symbol are authorized by API.

Illustration 4 g00546535
Typical API symbol

Diesel engine oils CC, CD, CD-2, and CE have not been API authorized classifications since 1 January 1996. Table 11 summarizes the status of the classifications.

Table 11

API Classifications	
Current	**Obsolete**
CF-4, CG-4, CH-4	CE
CF	CC, CD
CF-2(1)	CD-2(1)

(1) The classifications CD-2 and American Petroleum Institute CF-2 are for two-cycle diesel engines. Perkins does not sell engines that utilize CD-2 and API CF-2 oils.

Terminology

Certain abbreviations follow the nomenclature of "SAE J754". Some classifications follow "SAE J183" abbreviations, and some classifications follow the "EMA Recommended Guideline on Diesel Engine Oil". In addition to Perkins definitions, there are other definitions that will be of assistance in purchasing lubricants. Recommended oil viscosities can be found in this publication, "Fluid Recommendations/Engine Oil" topic (Maintenance Section).

Engine Oil

Commercial Oils

The performance of commercial diesel engine oils is based on American Petroleum Institute (API) classifications. These API classifications are developed in order to provide commercial lubricants for a broad range of diesel engines that operate at various conditions.

Only use commercial oils that meet the following classifications:

- EMA DHD-1 multigrade oil (preferred oil)
- API CH-4 multigrade oil (preferred oil)
- ACEAE3

In order to make the correct choice of a commercial oil, refer to the following explanations:

EMA DHD-1 – The Engine Manufacturers Association (EMA) has developed lubricant recommendations as an alternative to the API oil classification system. DHD-1 is a Recommended Guideline that defines a level of oil performance for these types of diesel engines: high speed, four stroke cycle, heavy-duty, and light duty. DHD-1 oils may be used in Perkins engines when the following oils are recommended: API CH-4, API CG-4, and API CF-4. DHD-1 oils are intended to provide superior performance in comparison to API CG-4 and API CF-4.

DHD-1 oils will meet the needs of high performance Perkins diesel engines that are operating in many applications. The tests and the test limits that are used to define DHD-1 are similar to the new API CH-4 classification. Therefore, these oils will also meet the requirements for diesel engines that require low emissions. DHD-1 oils are designed to control the harmful effects of soot with improved wear resistance and improved resistance to plugging of the oil filter. These oils will also provide superior piston deposit control in engines with either two-piece steel pistons or aluminum pistons.

All DHD-1 oils must complete a full test program with the base stock and with the viscosity grade of the finished commercial oil. The use of "API Base Oil Interchange Guidelines" are not appropriate for DHD-1 oils. This feature reduces the variation in performance that can occur when base stocks are changed in commercial oil formulations.

DHD-1 oils are recommended for use in extended oil change interval programs that optimize the life of the oil. These oil change interval programs are based on oil analysis. DHD-1 oils are recommended for conditions that demand a premium oil. Your Perkins dealer or your Perkins distributor has the specific guidelines for optimizing oil change intervals.

API CH-4 – API CH-4 oils were developed in order to meet the requirements of the new high performance diesel engines. Also, the oil was designed to meet the requirements of the low emissions diesel engines. API CH-4 oils are also acceptable for use in older diesel engines and in diesel engines that use high sulfur diesel fuel. API CH-4 oils may be used in Perkins engines that use API CG-4 and API CF-4 oils. API CH-4 oils will generally exceed the performance of API CG-4 oils in the following criteria: deposits on pistons, control of oil consumption, wear of piston rings, valve train wear, viscosity control, and corrosion.

Three new engine tests were developed for the API CH-4 oil. The first test specifically evaluates deposits on pistons for engines with the two-piece steel piston. This test (piston deposit) also measures the control of oil consumption. A second test is conducted with moderate oil soot. The second test measures the following criteria: wear of piston rings, wear of cylinder liners, and resistance to corrosion. A third new test measures the following characteristics with high levels of soot in the oil: wear of the valve train, resistance of the oil in plugging the oil filter, and control of sludge.

In addition to the new tests, API CH-4 oils have tougher limits for viscosity control in applications that generate high soot. The oils also have improved oxidation resistance. API CH-4 oils must pass an additional test (piston deposit) for engines that use aluminum pistons (single piece). Oil performance is also established for engines that operate in areas with high sulfur diesel fuel.

All of these improvements allow the API CH-4 oil to achieve optimum oil change intervals. API CH-4 oils are recommended for use in extended oil change intervals. API CH-4 oils are recommended for conditions that demand a premium oil. Your Perkins dealer or your Perkins distributor has specific guidelines for optimizing oil change intervals.

Some commercial oils that meet the API classifications may require reduced oil change intervals. To determine the oil change interval, closely monitor the condition of the oil and perform a wear metal analysis.

NOTICE
Failure to follow these oil recommendations can cause shortened engine service life due to deposits and/or excessive wear.

Total Base Number (TBN) and Fuel Sulfur Levels for Direct Injection (DI) Diesel Engines

The Total Base Number (TBN) for an oil depends on the fuel sulfur level. For direct injection engines that use distillate fuel, the minimum TBN of the new oil must be 10 times the fuel sulfur level. The TBN is defined by "ASTM D2896". The minimum TBN of the oil is 5 regardless of fuel sulfur level. Illustration 25 demonstrates the TBN.

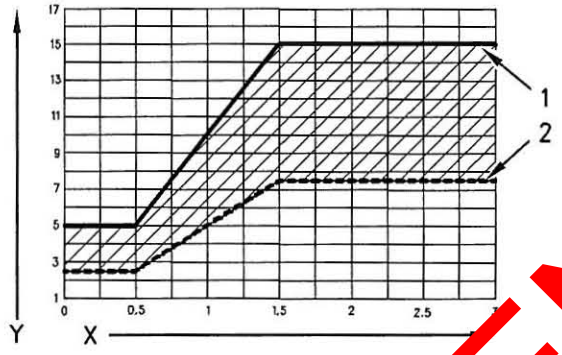

Illustration 25

(Y) TBN by "ASTM D2896"
(X) Percentage of fuel sulfur by weight
(1) TBN of new oil
(2) Change the oil when the TBN deteriorates to 50 percent of the original TBN.

Use the following guidelines for fuel sulfur levels that exceed 1.5 percent.

- Choose an oil with the highest TBN that meets one of these classifications: EMA DHD-1 and API CH-4.
- Reduce the oil change interval. Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis.

Excessive piston deposits can be produced by an oil with a high TBN. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

NOTICE
Operating Direct Injection (DI) diesel engines with fuel sulphur levels over 0.5 percent will require shortened oil change intervals in order to help maintain adequate wear protection.

Table 12

Percentage of Sulfur in the fuel	Oil change interval
Lower than 0.5	Normal
0.5 to 1.0	0.75 of normal
Greater than 1.0	0.50 of normal

Lubricant Viscosity Recommendations for Direct Injection (DI) Diesel Engines

The correct SAE viscosity grade of oil is determined by the minimum ambient temperature during cold engine start-up, and the maximum ambient temperature during engine operation.

Refer to Table 13 (minimum temperature) in order to determine the required oil viscosity for starting a cold engine.

Refer to Table 13 (maximum temperature) in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Generally, use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

Table 13

Engine Oil Viscosity		
EMA LRG-1 API CH-4 Viscosity Grade	Ambient Temperature	
	Minimum	Maximum
SAE 0W20	−40 °C (−40 °F)	10 °C (50 °F)
SAE 0W30	−40 °C (−40 °F)	30 °C (86 °F)
SAE 0W40	−40 °C (−40 °F)	40 °C (104 °F)
SAE 5W30	−30 °C (−22 °F)	30 °C (86 °F)
SAE 5W40	−30 °C (−22 °F)	40 °C (104 °F)
SAE 10W30	−20 °C (−4 °F)	40 °C (104 °F)
SAE 15W40	−10 °C (14 °F)	50 °C (122 °F)

Synthetic Base Stock Oil

Synthetic base oils are acceptable for use in these engines if these oils meet the performance requirements that are specified for the engine.

Synthetic base oils generally perform better than conventional oils in the following two areas:

- Synthetic base oils have improved flow at low temperatures especially in arctic conditions.
- Synthetic base oils have improved oxidation stability especially at high operating temperatures.

Some synthetic base oils have performance characteristics that enhance the service life of the oil. Perkins does not recommend the automatic extending of the oil change intervals for any type of oil.

Re-refined base stock oil

Re-refined base stock oil are acceptable for use in Perkins engines if these oils meet the performance requirements that are specified by Perkins.Re-refined base stock oil can be used exclusively in finished oil or in a combination with new base stock oil . The US military specifications and the specifications of other heavy equipment manufacturers also allow the use of re-refined base stock oil that meet the same criteria.

The process that is used to make re-refined base stock oil should adequately remove all wear metals that are in the used oil and all the additives that are in the used oil. The process that is used to make re-refined base stock oil generally involves the process of vacuum distillation and hydrotreating the used oil. Filtering is adequate for the production of high quality, re-refined base stock oil.

Lubricants for Cold Weather

When an engine is started and an engine is operated in ambient temperatures below −20 °C (−4 °F), use multigrade oils that are capable of flowing at low temperatures.

These oils have lubricant viscosity grades of SAE 0W or SAE 5W.

When an engine is started and operated in ambient temperatures below −30 °C (−22 °F), use a synthetic base stock multigrade oil with an 0W viscosity grade or with a 5W viscosity grade. Use an oil with a pour point that is lower than −50 °C (−58 °F).

The number of acceptable lubricants is limited in cold weather conditions. Perkins recommends the following lubricants for use in cold weather conditions:

First Choice – Use oil with an EMA DHD-1 Recommended Guideline. Use a CH-4 oil that has an API license. The oil should be either SAE 0W20, SAE 0W30, SAE 0W40, SAE 5W30, or SAE 5W40 lubricant viscosity grade.

Second Choice – Use an oil that has a CH-4 additive package. Although the oil has not been tested for the requirements of the API license, the oil must be either SAE 0W20, SAE 0W30, SAE 0W40, SAE 5W30, or SAE 5W40.

NOTICE
Shortened engine service life could result if second choice oils are used.

Aftermarket Oil Additives

Perkins does not recommend the use of aftermarket additives in oil. It is not necessary to use aftermarket additives in order to achieve the engine's maximum service life or rated performance. Fully formulated, finished oils consist of base oils and of commercial additive packages. These additive packages are blended into the base oils at precise percentages in order to help provide finished oils with performance characteristics that meet industry standards.

There are no industry standard tests that evaluate the performance or the compatibility of aftermarket additives in finished oils. Aftermarket additives may not be compatible with the finished oil's additive package, which could lower the performance of the finished oil. The aftermarket additive could fail to mix with the finished oil. This could produce sludge in the crankcase. Perkins discourages the use of aftermarket additives in finished oils.

To achieve the best performance from a Perkins engine, conform to the following guidelines:

- Select the correct oil, or a commercial oil that meets the "EMA Recommended Guideline on Diesel Engine Oil" or the recommended API classification.
- See the appropriate "Lubricant Viscosities" table in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine. Use new oil and install a new oil filter.
- Perform maintenance at the intervals that are specified in the Operation and Maintenance Manual, "Maintenance Interval Schedule".

S·O·S Oil analysis

Some engines may be equipped with an oil sampling valve. If S·O·S oil analysis is required the oil sampling valve is used to obtain samples of the engine oil. The S·O·S oil analysis will complement the preventive maintenance program.

The S·O·S oil analysis is a diagnostic tool that is used to determine oil performance and component wear rates. Contamination can be identified and measured through the use of the S·O·S oil analysis. The S·O·S oil analysis includes the following tests:

- The Wear Rate Analysis monitors the wear of the engine's metals. The amount of wear metal and type of wear metal that is in the oil is analyzed. The increase in the rate of engine wear metal in the oil is as important as the quantity of engine wear metal in the oil.
- Tests are conducted in order to detect contamination of the oil by water, glycol or fuel.
- The Oil Condition Analysis determines the loss of the oil's lubricating properties. An infrared analysis is used to compare the properties of new oil to the properties of the used oil sample. This analysis allows technicians to determine the amount of deterioration of the oil during use. This analysis also allows technicians to verify the performance of the oil according to the specification during the entire oil change interval.

Fuel Specifications

Fuel Recommendations

To get the correct power and performance from the engine, use a fuel of the correct quality. The recommended fuel specification for Perkins engines is shown below:

- Cetane number_____45 minimum
- Viscosity_____2,0 to 4.5 cSt at 40 °C (104 °F)
- Density_____0.835 to 0.85 Kg/liter
- Sulfur_____0.2% of mass, maximum
- Distillation_____85% at 350 °C (662 °F)
- Lubricity_____460 micrometers maximum wear scar on "ISO 12156 - 1"

Cetane number

This indicates the properties of ignition of the fuel. Fuel with a low cetane number can be the root cause of problems during cold start. This will affect combustion.

Viscosity

This is the resistance to flow of a fluid. If this resistance is outside the limits, the engine and the engine starting performance in particular can be affected.

Sulfur

High sulfur content of the fuel is not normally found in Europe, North America or Australasia. This can cause engine wear. When only high sulfur fuels are available, it will be necessary that high alkaline lubricating oil is used in the engine or that the lubricating oil change interval is reduced.

Distillation

This is an indication of the mixture of different hydrocarbons in the fuel. A high ratio of light weight hydrocarbons can affect the characteristics of combustion.

Lubricity

This is the capability of the fuel to prevent pump wear.

Diesel engines have the ability to burn a wide variety of fuels. These fuels are divided into four general groups:

- Group 1 (preferred fuels)
- Group 2 (permissible fuels)
- Group 3 (aviation kerosene fuels)
- Other fuels

Group 1 (preferred fuels): Specification

"DERV to EN590"

Note: Only use Arctic fuels when the temperature is below 0 °C (32 °F). Do not use Arctic fuels when the ambient temperature is above 0 °C (32 °F). To ensure that the time period between cranking the engine and first fire is kept to a minimum, only use fuel of the correct viscosity and at the correct temperature.

Gas oil to "BS2869 Class A2"

"ASTM D975 - 91 Class 2D" This can only be used if the fuel has the correct specification of lubricity.

"JIS K2204 (1992) Grades 1,2,3 and Special Grade 3" This can only be used if the fuel has the correct specification of lubricity.

Note: If low sulfur or low sulfur aromatic fuels are used, then fuel additives can be used to increase lubricity.

Group 2 (permissible fuels): Specification

These fuel specifications are considered acceptable for issues of warranty. However,these fuels may reduce the life of the engine, the engine's maximum power and the engine's fuel efficiency.

"ASTM D975 - 91 Class 1D"

"JP7, Mil T38219"

"NATO F63"

NOTICE
These fuels should have a wear scar value of 650 micrometers maximum *HFRR to ISO 12156 - 1.*

Group 3 (aviation kerosene fuels): Specification

These fuels need additives to achieve lubricity of 650 micrometers wear scar and the reliability of the fuel injection pump will be reduced. The fuel injection pump is not covered by a warranty, even when the additives are included.

"JP5 MIL T5624 (Avcat FSII, NATO F44"

"JP8 T83133 (Avtur FSII, NATO F34"

"Jet A"

"Jet A1, NATO F35, XF63"

Low temperature fuels

Special fuels for use in cold weather may be available for engine operation at temperatures below 0 °C (32 °F). These fuels limit the formation of wax in the fuel oil at low temperatures. If wax forms in the fuel oil, this could stop the flow of fuel oil through the filter.

Note: These fuels that lack lubricity may cause the following problems:

- Low engine power
- Difficult starting in hot conditions or in cold conditions
- White smoke
- Deterioration of emissions and misfire at certain operating conditions

Biofuel Specification

Biofuel: A 5% mix of RME to EN14214 in conventional fuel is permitted.

NOTICE
Water emulsion fuels: These fuels are not permitted

Refer to the following fuel specifications for North America.

The preferred fuels provide maximum engine service life and performance. The preferred fuels are distillate fuels. These fuels are commonly called diesel fuel or gas oil.

The permissible fuels are crude oils or blended fuels. Use of these fuels can result in higher maintenance costs and in reduced engine service life.

Diesel fuels that meet the specifications in Table 14 will help to provide maximum engine service life and performance. In North America, diesel fuel that is identified as No. 2-D in "ASTM D975" generally meets the specifications. Table 14 is for diesel fuels that are distilled from crude oil. Diesel fuels from other sources could exhibit detrimental properties that are not defined or controlled by this specification.

Table 14

Perkins Specifications for Distillate Diesel Fuel		
Specifications	**Requirements**	**ASTM Test**
Aromatics	35% maximum	"D1319"
Ash	0.02% maximum (weight)	"D482"
Carbon Residue on 10% Bottoms	0.35% maximum (weight)	"D524"
Cetane Number	40 minimum (DI engines)	"D613"
Cloud Point	The cloud point must not exceed the lowest expected ambient temperature.	-

(continued)

(Table 14, contd)

Copper Strip Corrosion	No. 3 maximum	"D130"
Distillation	10% at 282 °C (540 °F) maximum	"D86"
	90% at 360 °C (680 °F) maximum	
Flash Point	legal limit	"D93"
API Gravity	30 minimum	"D287"
	45 maximum	
Pour Point	6 °C (10 °F) minimum below ambient temperature	"D97"
Sulfur (1)	0.2% maximum	"D3605" or "D1552"
Kinematic Viscosity (2)	2.0 cSt minimum and 4.5 cSt maximum at 40 °C (104 °F)	"D445"
Water and Sediment	0.1% maximum	"D1796"
Water	0.1% maximum	"D1744"
Sediment	0.05% maximum (weight)	"D473"
Gum and Resins (3)	10 mg per 100 mL maximum	"D381"
Lubricity (4)	0.38 mm (0.015 inch) maximum at 25 °C (77 °F)	"D6079"

(1) Perkins fuel systems and engine components can operate on high sulfur fuels. Fuel sulfur levels affect exhaust emissions. High sulfur fuels also increase the potential for corrosion of internal components. Fuel sulfur levels above 0.5 percent may significantly shorten the oil change interval. For additional information, see this publication, "Fluid Recommendations/Engine Oil" topic (Maintenance Section).

(2) The values of the fuel viscosity are the values as the fuel is delivered to the fuel injection pumps. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain a 1.4 cSt viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to bring down the viscosity to a 20 cSt viscosity.

(3) Follow the test conditions and procedures for gasoline (motor).

(4) The lubricity of a fuel is a concern with low sulfur fuel. To determine the lubricity of the fuel, use either the "ASTM D6078 Scuffing Load Wear Test (SBOCLE)" or the "ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

NOTICE
Operating with fuels that do not meet the Perkins recommendations can cause the following effects: Starting difficulty, poor combustion, deposits in the fuel injectors, reduced service life of the fuel system, deposits in the combustion chamber, and reduced service life of the engine.

NOTICE
Heavy Fuel Oil (HFO), Residual fuel, or Blended fuel must NOT be used in Perkins diesel engines. Severe component wear and component failures will result if HFO type fuels are used in engines that are configured to use distillate fuel.

In extreme cold ambient conditions, you may use the distillate fuels that are specified in Table 15. However, the fuel that is selected must meet the requirements that are specified in Table 14. These fuels are intended to be used in operating temperatures that are down to −54 °C (−65 °F).

Table 15

Distillate Fuels (1)	
Specification	**Grade**
"MIL-T-5624R"	JP-5
"ASTM D1655"	Jet-A-1
"MIL-T-83133D"	JP-8

(1) The fuels that are listed in this Table may not meet the requirements that are specified in the "Perkins Specifications for Distillate Diesel Fuel" Table. Consult the supplier for the recommended additives in order to maintain the correct fuel lubricity.

These fuels are lighter than the No. 2 grades of fuel. The cetane number of the fuels in Table 15 must be at least 40. If the viscosity is below 1.4 cSt at 38 °C (100 °F), use the fuel only in temperatures below 0 °C (32 °F). Do not use any fuels with a viscosity of less than 1.2 cSt at 38 °C (100 °F). Fuel cooling may be required in order to maintain the minimum viscosity of 1.4 cSt at the fuel injection pump.

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in this specification. To ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in Table 14.

Cooling System Specifications

General Coolant Information

NOTICE
Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

NOTICE
If the engine is to be stored in, or shipped to an area with below freezing temperatures, the cooling system must be either protected to the lowest outside temperature or drained completely to prevent damage.

NOTICE
Frequently check the specific gravity of the coolant for proper freeze protection or for anti-boil protection.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

Many engine failures are related to the cooling system. The following problems are related to cooling system failures: Overheating, leakage of the water pump, and plugged radiators or heat exchangers.

These failures can be avoided with correct cooling system maintenance. Cooling system maintenance is as important as maintenance of the fuel system and the lubrication system. Quality of the coolant is as important as the quality of the fuel and the lubricating oil.

Coolant is normally composed of three elements: Water, additives, and glycol.

Water

Water is used in the cooling system in order to transfer heat.

Distilled water or deionized water is recommended for use in engine cooling systems.

DO NOT use the following types of water in cooling systems: Hard water, softened water that has been conditioned with salt, and sea water.

If distilled water or deionized water is not available, use water with the properties that are listed in Table 16.

Table 16

Perkins Minimum Acceptable Water Requirements	
Property	**Maximum Limit**
Chloride (Cl)	40 mg/L
Sulfate (SO_4)	100 mg/L
Total Hardness	170 mg/L
Total Solids	340 mg/L
Acidity	pH of 5.5 to 9.0

For a water analysis, consult one of the following sources:

- Local water utility company
- Agricultural agent
- Independent laboratory

Additives

Additives help to protect the metal surfaces of the cooling system. A lack of coolant additives or insufficient amounts of additives enable the following conditions to occur:

- Corrosion
- Formation of mineral deposits
- Rust
- Scale
- Foaming of the coolant

Many additives are depleted during engine operation. These additives must be replaced periodically.

Additives must be added at the correct concentration. Overconcentration of additives can cause the inhibitors to drop out-of-solution. The deposits can enable the following problems to occur:

- Formation of gel compounds
- Reduction of heat transfer
- Leakage of the water pump seal
- Plugging of radiators, coolers, and small passages

Glycol

Glycol in the coolant helps to provide protection against the following conditions:

- Boiling
- Freezing
- Cavitation of the water pump

For optimum performance, Perkins recommends a 1:1 mixture of a water/glycol solution.

Note: Use a mixture that will provide protection against the lowest ambient temperature.

Note: 100 percent pure glycol will freeze at a temperature of −23 °C (−9 °F).

Most conventional coolant/antifreezes use ethylene glycol. Propylene glycol may also be used. In a 1:1 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling. See Tables 17 and 18.

Table 17

Ethylene Glycol		
Concentration	**Freeze Protection**	**Boil Protection**
50 Percent	−36 °C (−33 °F)	106 °C (223 °F)
60 Percent	−51 °C (−60 °F)	111 °C (232 °F)

NOTICE
Do not use propylene glycol in concentrations that exceed 50 percent glycol because of propylene glycol's reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing.

Table 18

Propylene Glycol		
Concentration	**Freeze Protection**	**Anti-Boil Protection**
50 percent	−29 °C (−20 °F)	106 °C (223 °F)

To check the concentration of glycol in the coolant, measure the specific gravity of the coolant.

Coolant Recommendations

The following two coolants are used in Perkins diesel engines:

Preferred – Perkins Extended Life Coolant (ELC)

Acceptable – A commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" specifications

NOTICE
Do not use a commercial coolant/antifreeze that only meets the ASTM D3306 specification. This type of coolant/antifreeze is made for light automotive applications.

Perkins recommends a 1:1 mixture of water and glycol. This mixture of water and glycol will provide optimum heavy-duty performance as a coolant/antifreeze. This ratio may be increased to 1:2 water to glycol if extra freezing protection is required.

Note: A commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" specifications MAY require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

In stationary engine applications and marine engine applications that do not require anti-boil protection or freeze protection, a mixture of SCA and water is acceptable. Perkins recommends a six percent to eight percent concentration of SCA in those cooling systems. Distilled water or deionized water is preferred. Water which has the recommended properties may be used.

Engines that are operating in an ambient temperature above 43 °C (109.4 °F) must use SCA and water. Engines that operate in an ambient temperature above 43 °C (109.4 °F) and below 0 °C (32 °F) due to seasonal variations consult your Perkins dealer or your Perkins distributor for the correct level of protection.

Table 19

Coolant Service Life	
Coolant Type	**Service Life**
Perkins ELC	12,000 Service Hours or Six Years
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D4985"	3000 Service Hours or Two Years
Perkins POWERPART SCA	3000 Service Hours or Two Years
Commercial SCA and Water	3000 Service Hours or Two Years

Extended Life Coolant (ELC)

Perkins provides Extended Life Coolant (ELC) for use in the following applications:

- Heavy-duty spark ignited gas engines

- Heavy-duty diesel engines
- Automotive applications

The anti-corrosion package for ELC is different from the anti-corrosion package for other coolants. ELC is an ethylene glycol base coolant. However, ELC contains organic corrosion inhibitors and antifoam agents with low amounts of nitrite. Perkins ELC has been formulated with the correct amount of these additives in order to provide superior corrosion protection for all metals in engine cooling systems.

ELC extends the service life of the coolant to 12000 service hours or six years. ELC does not require a frequent addition of a Supplemental Coolant Additive (SCA). An Extender is the only additional maintenance that is needed at 6000 service hours or one half of the ELC service life.

ELC is available in a 1:1 premixed cooling solution with distilled water. The Premixed ELC provides freeze protection to −36 °C (−33 °F). The Premixed ELC is recommended for the initial fill of the cooling system. The Premixed ELC is also recommended for topping off the cooling system.

ELC Concentrate is also available. ELC Concentrate can be used to lower the freezing point to −51 °C (−60 °F) for arctic conditions.

Containers of several sizes are available. Consult your Perkins dealer or your Perkins distributor for the part numbers.

ELC Cooling System Maintenance

Correct additions to the Extended Life Coolant

NOTICE

Use only Perkins products for pre-mixed or concentrated coolants.

Use only Perkins Extender with Extended Life Coolant.

Mixing Extended Life Coolant with other products reduces the Extended Life Coolant service life. Failure to follow the recommendations can reduce cooling system components life unless appropriate corrective action is performed.

In order to maintain the correct balance between the antifreeze and the additives, you must maintain the recommended concentration of Extended Life Coolant (ELC). Lowering the proportion of antifreeze lowers the proportion of additive. This will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

NOTICE

Do not use a conventional coolant to top-off a cooling system that is filled with Extended Life Coolant (ELC).

Do not use standard supplemental coolant additive (SCA). Only use ELC Extender in cooling systems that are filled with ELC.

Perkins ELC Extender

ELC Extender is added to the cooling system halfway through the ELC service life. Treat the cooling system with ELC Extender at 6000 hours or three years. Use Table 20 in order to determine the correct amount of ELC Extender that is required.

Containers of several sizes are available. Consult your Perkins dealer or your Perkins distributor for the part numbers.

Use the formula in Table 20 to determine the correct amount of ELC Extender for your cooling system. Refer to Operation and Maintenance Manual, "Refill Capacities" in order to determine the capacity of the cooling system.

Table 20

Formula For Adding ELC Extender To ELC
V × 0.02 = X
V is the total capacity of the cooling system.
X is the amount of ELC Extender that is required.

Table 21 is an example for using the formula that is in Table 20.

Table 21

Example Of The Equation For Adding ELC Extender To ELC		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of ELC Extender that is Required (X)**
9 L (2.4 US gal)	× 0.02	0.18 L (0.05 US gal) or (6 fl oz)

NOTICE

When using Perkins ELC, do not use standard SCA's or SCA filters.

ELC Cooling System Cleaning

Note: If the cooling system is already using ELC, cleaning agents are not required to be used at the specified coolant change interval. Cleaning agents are only required if the system has been contaminated by the addition of some other type of coolant or by cooling system damage.

Clean water is the only cleaning agent that is required when ELC is drained from the cooling system.

After the cooling system is drained and after the cooling system is refilled, operate the engine while the cooling system filler cap is removed. Operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture in order to fill the system to the specified level.

Changing to Perkins ELC

To change from heavy-duty coolant/antifreeze to the Perkins ELC, perform the following steps:

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

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant into a suitable container.
2. Dispose of the coolant according to local regulations.
3. Flush the system with clean water in order to remove any debris.
4. Use Perkins cleaner to clean the system. Follow the instruction on the label.
5. Drain the cleaner into a suitable container. Flush the cooling system with clean water.
6. Fill the cooling system with clean water and operate the engine until the engine is warmed to 49° to 66°C (120° to 150°F).

NOTICE
Incorrect or incomplete flushing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all the signs of the cleaning agent are gone.

7. Drain the cooling system into a suitable container and flush the cooling system with clean water.

Note: The cooling system cleaner must be thoroughly flushed from the cooling system. Cooling system cleaner that is left in the system will contaminate the coolant. The cleaner may also corrode the cooling system.

8. Repeat Steps 6 and 7 until the system is completely clean.
9. Fill the cooling system with the Perkins Premixed ELC.

ELC Cooling System Contamination

NOTICE
Mixing ELC with other products reduces the effectiveness of the ELC and shortens the ELC service life. Use only Perkins Products for premixed or concentrate coolants. Use only Perkins ELC extender with Perkins ELC. Failure to follow these recommendations can result in shortened cooling system component life.

ELC cooling systems can withstand contamination to a maximum of ten percent of conventional heavy-duty coolant/antifreeze or SCA. If the contamination exceeds ten percent of the total system capacity, perform ONE of the following procedures:

- Drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Flush the system with clean water. Fill the system with the Perkins ELC.
- Drain a portion of the cooling system into a suitable container according to local regulations. Then, fill the cooling system with premixed ELC. This should lower the contamination to less than 10 percent.
- Maintain the system as a conventional Heavy-Duty Coolant. Treat the system with an SCA. Change the coolant at the interval that is recommended for the conventional Heavy-Duty Coolant.

Commercial Heavy-Duty Coolant/ Antifreeze and SCA

NOTICE
Commercial Heavy-Duty Coolant which contains Amine as part of the corrision protection system must not be used.

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the correct operating temperature. Cooling system problems can develop without water temperature regulators.

Check the coolant/antifreeze (glycol concentration) in order to ensure adequate protection against boiling or freezing. Perkins recommends the use of a refractometer for checking the glycol concentration.

Perkins engine cooling systems should be tested at 500 hour intervals for the concentration of Supplemental Coolant Additive (SCA).

Additions of SCA are based on the results of the test. An SCA that is liquid may be needed at 500 hour intervals.

Refer to Table 22 for part numbers and for quantities of SCA.

Table 22

Perkins Liquid SCA	
Part Number	**Quantity**
21825735	

Adding the SCA to Heavy-Duty Coolant at the Initial Fill

Commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" specifications MAY require an addition of SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

Use the equation that is in Table 23 to determine the amount of Perkins SCA that is required when the cooling system is initially filled.

Table 23

Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill
V × 0.045 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 24 is an example for using the equation that is in Table 23.

Table 24

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.045	0.7 L (24 oz)

Adding The SCA to The Heavy-Duty Coolant For Maintenance

Heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of an SCA.

Test the coolant/antifreeze periodically for the concentration of SCA. For the interval, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section). Test the concentration of SCA.

Additions of SCA are based on the results of the test. The size of the cooling system determines the amount of SCA that is needed.

Use the equation that is in Table 25 to determine the amount of Perkins SCA that is required, if necessary:

Table 25

Equation For Adding The SCA To The Heavy-Duty Coolant For Maintenance
V × 0.014 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 26 is an example for using the equation that is in Table 25.

Table 26

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant For Maintenance		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.014	0.2 L (7 oz)

Cleaning the System of Heavy-Duty Coolant/Antifreeze

Perkins cooling system cleaners are designed to clean the cooling system of harmful scale and corrosion. Perkins cooling system cleaners dissolve mineral scale, corrosion products, light oil contamination and sludge.

- Clean the cooling system after used coolant is drained or before the cooling system is filled with new coolant.
- Clean the cooling system whenever the coolant is contaminated or whenever the coolant is foaming.

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Maintenance Interval Schedule

When Required

Battery - Replace 54
Battery or Battery Cable - Disconnect 55
Engine - Clean 60
Engine Air Cleaner Element (Dual Element) - Clean/Replace 61
Engine Air Cleaner Element (Single Element) - Inspect/Replace 63
Engine Oil Sample - Obtain 64
Fuel Injector - Test/Change 68
Fuel System - Prime 69
Severe Service Application - Check 75

Daily

Alternator and Fan Belts - Inspect/Adjust/Replace 53
Cooling System Coolant Level - Check 59
Driven Equipment - Check 60
Engine Air Cleaner Service Indicator - Inspect 63
Engine Oil Level - Check 64
Fuel System Primary Filter/Water Separator - Drain 70
Walk-Around Inspection 77

Every 50 Service Hours or Weekly

Fuel Tank Water and Sediment - Drain 72

Every 500 Service Hours or 1 Year

Battery Electrolyte Level - Check 54
Engine Air Cleaner Element (Dual Element) - Clean/Replace 61
Engine Air Cleaner Element (Single Element) - Inspect/Replace 63
Engine Ground - Inspect/Clean 64
Engine Oil and Filter - Change 65
Fuel System Primary Filter (Water Separator) Element - Replace 70
Fuel System Secondary Filter - Replace 71
Hoses and Clamps - Inspect/Replace 74
Radiator - Clean 75

Every 1000 Service Hours

Engine Valve Lash - Inspect/Adjust 67

Every 2000 Service Hours

Aftercooler Core - Inspect 52
Alternator - Inspect 53
Engine Mounts - Inspect 64
Starting Motor - Inspect 76
Turbocharger - Inspect 76
Water Pump - Inspect 78

Every 2 Years

Cooling System Coolant - Change 58

Every 3000 Service Hours

Fuel Injector - Test/Change 68

Every 3000 Service Hours or 2 Years

Cooling System Coolant (Commercial Heavy Duty) - Change 55

Every 4000 Service Hours

Aftercooler Core - Clean/Test 52

Every 6000 Service Hours or 3 Years

Cooling System Coolant Extender (ELC) - Add 59

Every 12 000 Service Hours or 6 Years

Cooling System Coolant (ELC) - Change 57

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Aftercooler Core - Clean/Test

1. Remove the core. Refer to the OEM information for the correct procedure.

2. Turn the aftercooler core upside-down in order to remove debris.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

3. Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction of the fan's air flow. Hold the nozzle approximately 6 mm (.25 inch) away from the fins. Slowly move the air nozzle in a direction that is parallel with the tubes. This will remove debris that is between the tubes.

4. Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

NOTICE

Do not use a high concentration of caustic cleaner to clean the core. A high concentration of caustic cleaner can attack the internal metals of the core and cause leakage. Only use the recommended concentration of cleaner.

5. Back flush the core with a suitable cleaner.

6. Steam clean the core in order to remove any residue. Flush the fins of the aftercooler core. Remove any other trapped debris.

7. Wash the core with hot, soapy water. Rinse the core thoroughly with clean water.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

8. Dry the core with compressed air. Direct the air in the reverse direction of the normal flow.

9. Inspect the core in order to check the cleanliness. Pressure test the core. If necessary, repair the core.

10. Install the core. Refer to the OEM information for the correct procedures.

11. After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

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Aftercooler Core - Inspect

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the aftercooler for these items: damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the aftercooler, if necessary.

For air-to-air aftercoolers, use the same methods that are used for cleaning radiators.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a “comb”.

Note: If parts of the aftercooler system are repaired or replaced, a leak test is highly recommended.

Inspect these items for good condition: Welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

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Alternator - Inspect

Perkins recommends a scheduled inspection of the alternator. Inspect the alternator for loose connections and correct battery charging. Check the ammeter (if equipped) during engine operation in order to ensure correct battery performance and/or correct performance of the electrical system. Make repairs, as required.

Check the alternator and the battery charger for correct operation. If the batteries are correctly charged, the ammeter reading should be very near zero. All batteries should be kept charged. The batteries should be kept warm because temperature affects the cranking power. If the battery is too cold, the battery will not crank the engine. When the engine is not run for long periods of time or if the engine is run for short periods, the batteries may not fully charge. A battery with a low charge will freeze more easily than a battery with a full charge.

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Alternator and Fan Belts - Inspect/Adjust/Replace

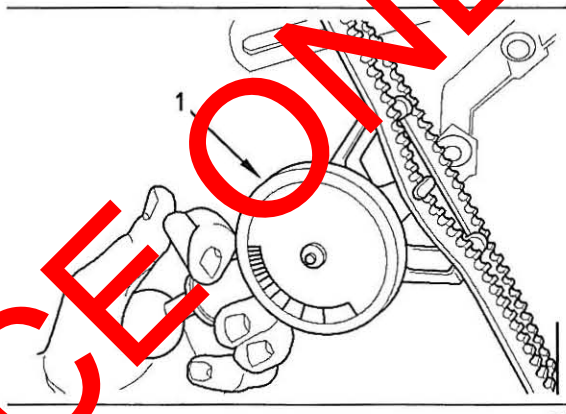
Inspection

To maximize the engine performance, inspect the belts for wear and for cracking. Replace belts that are worn or damaged.

For applications that require multiple drive belts, replace the belts in matched sets. Replacing only one belt of a matched set will cause the new belt to carry more load because the older belt is stretched. The additional load on the new belt could cause the new belt to break.

If the belts are too loose, vibration causes unnecessary wear on the belts and pulleys. Loose belts may slip enough to cause overheating.

To accurately check the belt tension, a suitable gauge should be used.



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Typical example

(1) Burroughs Gauge

Fit the gauge (1) at the center of the longest free length and check the tension. The correct tension is 535 N (120 lb). If the tension of the belt is below 250 N (56 lb) adjust the belt to 535 N (120 lb).

If twin belts are installed, check and adjust the tension on both belts.

Adjustment

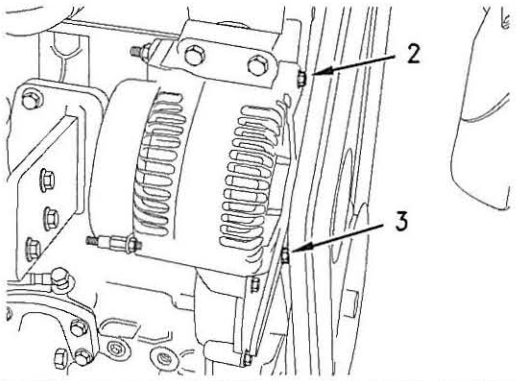

Illustration 27 g01003939

1. Loosen The alternator pivot bolt (2) and the bolt (3).

2. Move the alternator in order to increase or decrease the belt tension. Tighten the alternator pivot bolt and the link bolt to 22 N·m (16 lb ft).(1).

Replacement

Refer to the Disassembly and Assembly Manual for the installation procedure and the removal procedure for the belt.

i02322315

Battery - Replace

⚠ WARNING

Batteries give off combustible gases which can explode. A spark can cause the combustible gases to ignite. This can result in severe personal injury or death.

Ensure proper ventilation for batteries that are in an enclosure. Follow the proper procedures in order to help prevent electrical arcs and/or sparks near batteries. Do not smoke when batteries are serviced.

⚠ WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Switch the engine to the OFF position. Remove all electrical loads.
2. Turn off any battery chargers. Disconnect any battery chargers.
3. The NEGATIVE "-" cable connects the NEGATIVE "-" battery terminal to the NEGATIVE "-" terminal on the starting motor. Disconnect the cable from the NEGATIVE "-" battery terminal.
4. The POSITIVE "+" cable connects the POSITIVE "+" battery terminal to the POSITIVE "+" terminal on the starting motor. Disconnect the cable from the POSITIVE "+" battery terminal.

Note: Always recycle a battery. Never discard a battery. Dispose of used batteries to an appropriate recycling facility.

5. Remove the used battery.
6. Install the new battery.

Note: Before the cables are connected, ensure that the engine start switch is OFF.

7. Connect the cable from the starting motor to the POSITIVE "+" battery terminal.
8. Connect the NEGATIVE "-" cable to the NEGATIVE "-" battery terminal.

i02747977

Battery Electrolyte Level - Check

When the engine is not run for long periods of time or when the engine is run for short periods, the batteries may not fully recharge. Ensure a full charge in order to help prevent the battery from freezing. If batteries are correctly charged, the ammeter reading should be very near zero, when the engine is in operation.

⚠ WARNING

All lead-acid batteries contain sulfuric acid which can burn the skin and clothing. Always wear a face shield and protective clothing when working on or near batteries.

1. Remove the filler caps. Maintain the electrolyte level to the "FULL" mark on the battery.

   If the addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

2. Check the condition of the electrolyte with a suitable battery tester.
3. Install the caps.
4. Keep the batteries clean.

   Clean the battery case with one of the following cleaning solutions:

   - Use a solution of 0.1 kg (0.2 lb) baking soda and 1 L (1 qt) of clean water.
   - Use a solution of ammonium hydroxide.

   Thoroughly rinse the battery case with clean water.

i02323088

Battery or Battery Cable - Disconnect

WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Turn the start switch to the OFF position. Turn the ignition switch (if equipped) to the OFF position and remove the key and all electrical loads.
2. Disconnect the negative battery terminal. Ensure that the cable cannot contact the terminal. When four 12 volt batteries are involved, two negative connection must be disconnected.
3. Remove the positive connection.
4. Clean all disconnected connection and battery terminals.
5. Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright and shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit correctly. Coat the clamps and the terminals with a suitable silicone lubricant or petroleum jelly.
6. Tape the cable connections in order to help prevent accidental starting.
7. Proceed with necessary system repairs.
8. In order to connect the battery, connect the positive connection before the negative connector.

i02203590

Cooling System Coolant (Commercial Heavy-Duty) - Change

NOTICE

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

Dispose of all fluids according to Local regulations and mandates.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator and the hoses, if necessary.

Drain

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

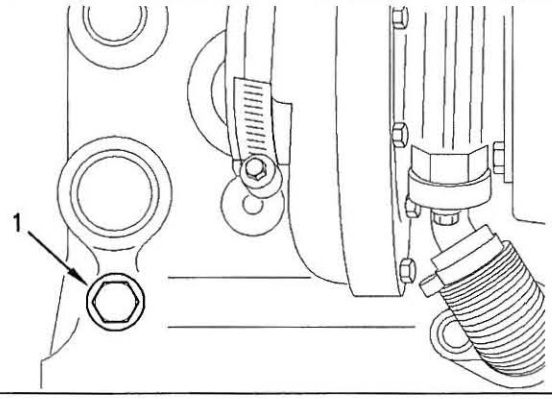

Illustration 28 g01003928

2. Open the drain cock or remove the drain plug (1) on the engine. Open the drain cock or remove the drain plug on the radiator.

   Allow the coolant to drain.

NOTICE
Dispose of used engine coolant or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Perkins to reclaim the coolant.

For information regarding the disposal and the recycling of used coolant, consult your Perkins dealer or your Perkins distributor.

Flush

1. Flush the cooling system with clean water in order to remove any debris.

2. Close the drain cock or install the drain plug in the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

3. Fill the cooling system with clean water. Install the cooling system filler cap.

4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain cock or remove the drain plug on the engine. Open the drain cock or remove the drain plug on the radiator. Allow the water to drain. Flush the cooling system with clean water.

Fill

1. Close the drain cock or install the drain plug on the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

2. Fill the cooling system with Commercial Heavy-Duty Coolant. Add Supplemental Coolant Additive to the coolant. For the correct amount, refer to the Operation and Maintenance Manual, "Fluid Recommendations" topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.

3. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Stop the engine.

4. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level in the expansion bottle (if equipped) at the correct level.

5. Clean the cooling system filler cap. Inspect the gasket that is on the cooling system filler cap. If the gasket that is on the cooling system filler cap is damaged, discard the old cooling system filler cap and install a new cooling system filler cap. If the gasket that is on the cooling system filler cap is not damaged, use a suitable pressurizing pump in order to pressure test the cooling system filler cap. The correct pressure for the cooling system filler cap is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not retain the correct pressure, install a new cooling system filler cap.

6. Start the engine. Inspect the cooling system for leaks and for correct operating temperature.

i02203595

Cooling System Coolant (ELC) - Change

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

Dispose of all fluids according to Local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed when the ELC is drained and replaced.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator and the hoses, if necessary.

Drain

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

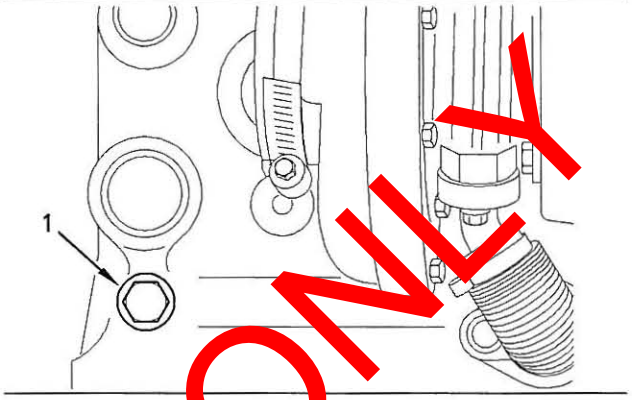

Illustration 29 g01003928
Typical example

2. Open the drain cock or remove the drain plug (1) on the engine. Open the drain cock or remove the drain plug on the radiator.

   Allow the coolant to drain.

NOTICE
Dispose of used engine coolant or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Perkins to reclaim the coolant.

For information regarding the disposal and the recycling of used coolant, consult your Perkins dealer or your Perkins distributor.

Flush

1. Flush the cooling system with clean water in order to remove any debris.
2. Close the drain cock or install the drain plug in the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

3. Fill the cooling system with clean water. Install the cooling system filler cap.
4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain cock or remove the drain plug on the engine. Open the drain cock or remove the drain plug on the radiator. Allow the water to drain. Flush the cooling system with clean water.

Fill

1. Close the drain cock or install the drain plug on the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

2. Fill the cooling system with Extended Life Coolant (ELC). Refer to the Operation and Maintenance Manual, "Fluid Recommendations" topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.

3. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Stop the engine.

4. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level in the expansion bottle (if equipped) at the correct level.

5. Clean the cooling system filler cap. Inspect the gasket that is on the cooling system filler cap. If the gasket that is on the cooling system filler cap is damaged, discard the old cooling system filler cap and install a new cooling system filler cap. If the gasket that is on the cooling system filler cap is not damaged, use a suitable pressurizing pump in order to pressure test the cooling system filler cap. The correct pressure for the cooling system filler cap is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not retain the correct pressure, install a new cooling system filler cap.

6. Start the engine. Inspect the cooling system for leaks and for correct operating temperature.

i01929799

Cooling System Coolant - Change

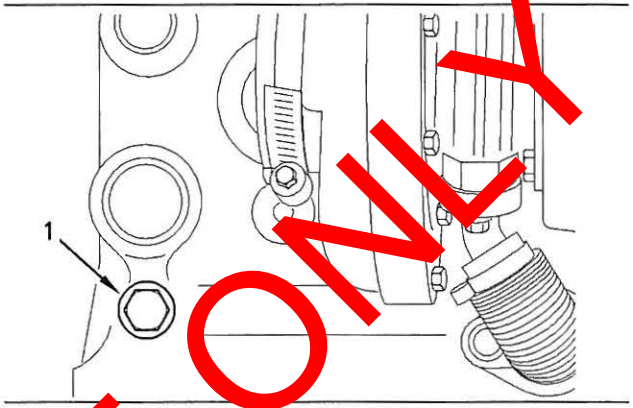

Illustration 30 g01003928
Drain plug

NOTICE
Do not drain the coolant while the engine is still hot and the system is under pressure because dangerous hot coolant can be discharged.

Note: The radiator may not have been provided by Perkins. The following is a general procedure for changing the coolant. Refer to the OEM information for the correct procedure.

1. Ensure that the vehicle is on level ground.

2. Remove the filler cap of the cooling system.

3. Remove the drain plug (1) from the side of the cylinder block in order to drain the engine. Ensure that the drain hole is not restricted.

4. Open the radiator drain tap or remove the drain plug at the bottom of the radiator in order to drain the radiator. If the radiator does not have a radiator drain tap or a drain plug, disconnect the hose at the bottom of the radiator.

5. Flush the coolant system with clean water.

6. Install the drain plugs and close the radiator drain tap. Install the radiator hose if the radiator hose was previously removed.

7. Fill the system with an approved antifreeze mixture. The maximum flow rate is 1 L (0.2200 Imp gal) per minute in order to fill the system. Install the filler cap.

8. Run the engine and check for coolant leaks.

i02335364

Cooling System Coolant Extender (ELC) - Add

The Perkins Extended Life Coolant (ELC) does not need the frequent addition of Supplemental Coolant Additives (SCA) that are associated with conventional coolants. The Extender only needs to be added once.

Check the cooling system only when the engine is stopped and cool.

1. Loosen the cooling system filler cap slowly in order to relieve pressure. Remove the cooling system filler cap.
2. It may be necessary to drain enough coolant from the cooling system in order to add the Extender.
3. Add Extender according to the requirements for your engine's cooling system capacity. Refer to this Operation and Maintenance Manual, "Refill Capacities" in the Maintenance Section for the capacity of the cooling system for your engine. Refer to this Operation and Maintenance Manual, "Fluid Recommendations" information for the Perkins ELC Extender.
4. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.

i02335378

Cooling System Coolant Level - Check

Engines With a Coolant Recovery Tank

Note: The cooling system may not have been provided by Perkins. The procedure that follows is for typical cooling systems. Refer to the OEM information for the correct procedures.

Check the coolant level when the engine is stopped and cool.

1. Observe the coolant level in the coolant recovery tank. Maintain the coolant level to "COLD FULL" mark on the coolant recovery tank.

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

2. Loosen filler cap slowly in order to relieve any pressure. Remove the filler cap.
3. Pour the correct coolant mixture into the tank. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" for information on the correct mixture and type of coolant. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" for the cooling system capacity. Do not fill the coolant recovery tank above "COLD FULL" mark.

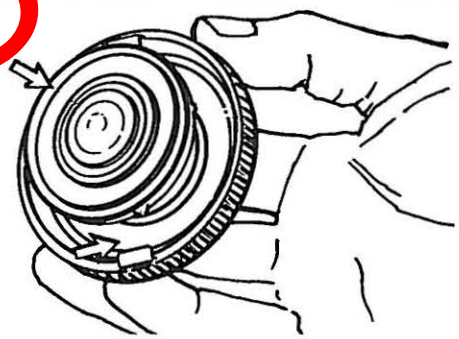

Illustration 31 g00103639

4. Clean filler cap and the receptacle. Reinstall the filler cap and inspect the cooling system for leaks.

Note: The coolant will expand as the coolant heats up during normal engine operation. The additional volume will be forced into the coolant recovery tank during engine operation. When the engine is stopped and cool, the coolant will return to the engine.

Engines Without a Coolant Recovery Tank

Check the coolant level when the engine is stopped and cool.

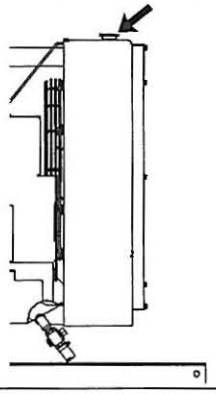

Illustration 32 g00285520

Cooling system filler cap

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly in order to relieve pressure.
2. Maintain the coolant level within 13 mm (0.5 inch) of the bottom of the filler pipe. If the engine is equipped with a sight glass, maintain the coolant level to the correct level in the sight glass.
3. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.
4. Inspect the cooling system for leaks.

i00174798

Driven Equipment - Check

Refer to the OEM specifications for more information on the following maintenance recommendations for the driven equipment:

- Inspection
- Adjustment
- Lubrication
- Other maintenance recommendations

Perform any maintenance for the driven equipment which is recommended by the OEM.

i01930350

Engine - Clean

⚠ WARNING

Personal injury or death can result from high voltage.

Moisture can create paths of electrical conductivity.

Make sure that the electrical system is OFF. Lock out the starting controls and tag the controls "DO NOT OPERATE".

NOTICE

Accumulated grease and oil on an engine is a fire hazard. Keep the engine clean. Remove debris and fluid spills whenever a significant quantity accumulates on the engine.

NOTICE

Failure to protect some engine components from washing may make your engine warranty invalid. Allow the engine to cool for one hour before washing the engine.

Periodic cleaning of the engine is recommended. Steam cleaning the engine will remove accumulated oil and grease. A clean engine provides the following benefits:

- Easy detection of fluid leaks
- Maximum heat transfer characteristics
- Ease of maintenance

Note: Caution must be used in order to prevent electrical components from being damaged by excessive water when the engine is cleaned. Pressure washers and steam cleaners should not be directed at any electrical connectors or the junction of cables into the rear of the connectors. Avoid electrical components such as the alternator and the starter. Protect the fuel injection pump from fluids in order to wash the engine.

i01915869

Engine Air Cleaner Element (Dual Element) - Clean/Replace

NOTICE
Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent air-borne debris from entering the air inlet.

NOTICE
Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

Servicing the Air Cleaner Elements

Note: The air filter system may not have been provided by Perkins. The procedure that follows is for a typical air filter system. Refer to the OEM information for the correct procedure.

If the air cleaner element becomes plugged, the air can split the material of the air cleaner element. Unfiltered air will drastically accelerate internal engine wear. Refer to the OEM information for the correct air cleaner elements for your application.

- Check the precleaner (if equipped) and the dust bowl daily for accumulation of dirt and debris. Remove any dirt and debris, as needed.
- Operating conditions (dust, dirt and debris) may require more frequent service of the air cleaner element.
- The air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Replace the dirty air cleaner elements with clean air cleaner elements. Before installation, the air cleaner elements should be thoroughly checked for tears and/or holes in the filter material. Inspect the gasket or the seal of the air cleaner element for damage. Maintain a supply of suitable air cleaner elements for replacement purposes.

Dual Element Air Cleaners

The dual element air cleaner contains a primary air cleaner element and a secondary air cleaner element. The primary air cleaner element can be used up to six times if the element is properly cleaned and properly inspected. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

The secondary air cleaner element is not serviceable or washable. Refer to the OEM information for instructions in order to replace the secondary air cleaner element. When the engine is operating in environments that are dusty or dirty, air cleaner elements may require more frequent replacement.

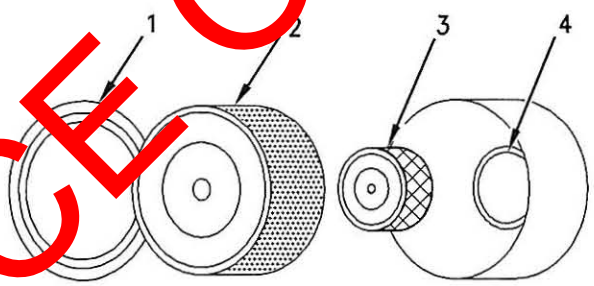

Illustration 33 g00736431

(1) Cover
(2) Primary air cleaner element
(3) Secondary air cleaner element
(4) Air inlet

1. Remove the cover. Remove the primary air cleaner element.
2. The secondary air cleaner element should be removed and discarded for every three cleanings of the primary air cleaner element.

Note: Refer to "Cleaning the Primary Air Cleaner Elements".

3. Cover the air inlet with tape in order to keep dirt out.
4. Clean the inside of the air cleaner cover and body with a clean, dry cloth.
5. Remove the tape for the air inlet. Install the secondary air cleaner element. Install a primary air cleaner element that is new or cleaned.
6. Install the air cleaner cover.
7. Reset the air cleaner service indicator.

Cleaning the Primary Air Cleaner Elements

NOTICE
Observe the following guidelines if you attempt to clean the filter element:

Do not tap or strike the filter element in order to remove dust.

Do not wash the filter element.

Use low pressure compressed air in order to remove the dust from the filter element. Air pressure must not exceed 207 kPa (30 psi). Direct the air flow up the pleats and down the pleats from the inside of the filter element. Take extreme care in order to avoid damage to the pleats.

Do not use air filters with damaged pleats, gaskets, or seals. Dirt entering the engine will cause damage to engine components.

Refer to the OEM information in order to determine the number of times that the primary filter element can be cleaned. When the primary air cleaner element is cleaned, check for rips or tears in the filter material. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

NOTICE
Do not clean the air cleaner elements by bumping or tapping. This could damage the seals. Do not use elements with damaged pleats, gaskets or seals. Damaged elements will allow dirt to pass through. Engine damage could result.

Visually inspect the primary air cleaner elements before cleaning. Inspect the air cleaner elements for damage to the seal, the gaskets, and the outer cover. Discard any damaged air cleaner elements.

There are two common methods that are used to clean primary air cleaner elements:

- Pressurized air
- Vacuum cleaning

Pressurized Air

Pressurized air can be used to clean primary air cleaner elements that have not been cleaned more than two times. Pressurized air will not remove deposits of carbon and oil. Use filtered, dry air with a maximum pressure of 207 kPa (30 psi).

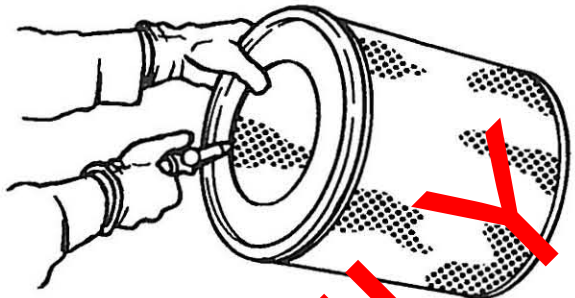

Illustration 34 g00281692

Note: When the primary air cleaner elements are cleaned, always begin with the clean side (inside) in order to force dirt particles toward the dirty side (outside).

Aim the hose so that the air flows inside the element along the length of the filter in order to help prevent damage to the paper pleats. Do not aim the stream of air directly at the primary air cleaner element. Dirt could be forced further into the pleats.

Note: Refer to "Inspecting the Primary Air Cleaner Elements".

Vacuum Cleaning

Vacuum cleaning is a good method for cleaning primary air cleaner elements which require daily cleaning because of a dry, dusty environment. Cleaning with pressurized air is recommended prior to vacuum cleaning. Vacuum cleaning will not remove deposits of carbon and oil.

Note: Refer to "Inspecting the Primary Air Cleaner Elements".

Inspecting the Primary Air Cleaner Elements

Illustration 35 g00281693

Inspect the clean, dry primary air cleaner element. Use a 60 watt blue light in a dark room or in a similar facility. Place the blue light in the primary air cleaner element. Rotate the primary air cleaner element. Inspect the primary air cleaner element for tears and/or holes. Inspect the primary air cleaner element for light that may show through the filter material. If it is necessary in order to confirm the result, compare the primary air cleaner element to a new primary air cleaner element that has the same part number.

Do not use a primary air cleaner element that has any tears and/or holes in the filter material. Do not use a primary air cleaner element with damaged pleats, gaskets or seals. Discard damaged primary air cleaner elements.

i02152042

Engine Air Cleaner Element (Single Element) - Inspect/Replace

Refer to Operation and Maintenance Manual, "Engine Air Cleaner Service Indicator-Inspect".

NOTICE
Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent airborne debris from entering the air inlet.

NOTICE
Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

A wide variety of air cleaners may be installed for use with this engine. Consult the OEM information for the correct procedure to replace the air cleaner.

i01909507

Engine Air Cleaner Service Indicator - Inspect

Some engines may be equipped with a different service indicator.

Some engines are equipped with a differential gauge for inlet air pressure. The differential gauge for inlet air pressure displays the difference in the pressure that is measured before the air cleaner element and the pressure that is measured after the air cleaner element. As the air cleaner element becomes dirty, the pressure differential rises. If your engine is equipped with a different type of service indicator, follow the OEM recommendations in order to service the air cleaner service indicator.

The service indicator may be mounted on the air cleaner element or in a remote location.

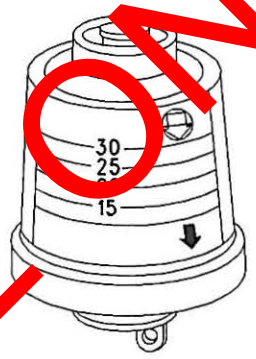

Illustration 36 g00103777
Typical service indicator

Observe the service indicator. The air cleaner element should be cleaned or the air cleaner element should be replaced when one of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.

Test the Service Indicator

Service indicators are important instruments.

- Check for ease of resetting. The service indicator should reset in less than three pushes.
- Check the movement of the yellow core when the engine is accelerated to the engine rated speed. The yellow core should latch approximately at the greatest vacuum that is attained.

If the service indicator does not reset easily, or if the yellow core does not latch at the greatest vacuum, the service indicator should be replaced. If the new service indicator will not reset, the hole for the service indicator may be restricted.

The service indicator may need to be replaced frequently in environments that are severely dusty.

i01941505

Engine Ground - Inspect/Clean

Inspect the wiring harness for good connections.

Perkins use the starter motor in order to ground the engine. Check the connection on the starter motor at every oil change. Ground wires and straps should be combined at engine grounds. All grounds should be tight and free of corrosion.

- Clean the grounding stud on the starter motor and the terminals with a clean cloth.
- If the connections are corroded, clean the connections with a solution of baking soda and water.
- Keep the grounding stud and the strap clean and coated with suitable grease or petroleum jelly.

i02323089

Engine Mounts - Inspect

Note: The engine mounts may not have been supplied by Perkins. Refer to the OEM information for further information on the engine mounts and the correct bolt torque.

Inspect the engine mounts for deterioration and for correct bolt torque. Engine vibration can be caused by the following conditions:

- Incorrect mounting of the engine
- Deterioration of the engine mounts
- Loose engine mounts

Any engine mount that shows deterioration should be replaced. Refer to the OEM information for the recommended torques.

i02335785

Engine Oil Level - Check

⚠ WARNING

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

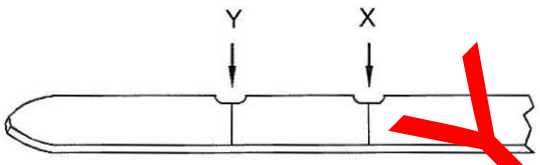

Illustration 37 g01165836

(Y) "Min" mark. (X) "Max" mark.

NOTICE
Perform this maintenance with the engine stopped.

Note: Ensure that the engine is either level or that the engine is in the normal operating position in order to obtain a true level indication.

Note: After the engine has been switched OFF, wait for ten minutes in order to allow the engine oil to drain to the oil pan before checking the oil level.

1. Maintain the oil level between the "ADD" mark (Y) and the "FULL" mark (X) on the engine oil dipstick. Do not fill the crankcase above the "FULL" mark (X).

NOTICE
Operating your engine when the oil level is above the "FULL" mark could cause your crankshaft to dip into the oil. The air bubbles created from the crankshaft dipping into the oil reduces the oil's lubricating characteristics and could result in the loss of power.

2. Remove the oil filler cap and add oil, if necessary. Clean the oil filler cap. Install the oil filler cap.

i02202699

Engine Oil Sample - Obtain

The condition of the engine lubricating oil may be checked at regular intervals as part of a preventive maintenance program. Perkins include an oil sampling valve as an option. The oil sampling valve (if equipped) is included in order to regularly sample the engine lubricating oil. The oil sampling valve is positioned on the oil filter head or the oil sampling valve is positioned on the cylinder block.

Perkins recommends using a sampling valve in order to obtain oil samples. The quality and the consistency of the samples are better when a sampling valve is used. The location of the sampling valve allows oil that is flowing under pressure to be obtained during normal engine operation.

Obtain the Sample and the Analysis

WARNING

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

In order to help obtain the most accurate analysis, record the following information before an oil sample is taken:

- The date of the sample
- Engine model
- Engine number
- Service hours on the engine
- The number of hours that have accumulated since the last oil change
- The amount of oil that has been added since the last oil change

Ensure that the container for the sample is clean and dry. Also ensure that the container for the sample is clearly labelled.

To ensure that the sample is representative of the oil in the crankcase, obtain a warm, well mixed oil sample.

To avoid contamination of the oil samples, the tools and the supplies that are used for obtaining oil samples must be clean.

The sample can be checked for the following: the quality of the oil, the existence of any coolant in the oil, the existence of any ferrous metal particles in the oil, and the existence of any nonferrous metal particles in the oil.

i01929323

Engine Oil and Filter - Change

WARNING

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

Do not drain the oil when the engine is cold. As the oil cools, suspended waste particles settle on the bottom of the oil pan. The waste particles are not removed with the draining cold oil. Drain the crankcase with the engine stopped. Drain the crankcase with the oil warm. This draining method allows the waste particles that are suspended in the oil to be drained properly.

Failure to follow this recommended procedure will cause the waste particles to be recirculated through the engine lubrication system with the new oil.

Drain the Engine Oil

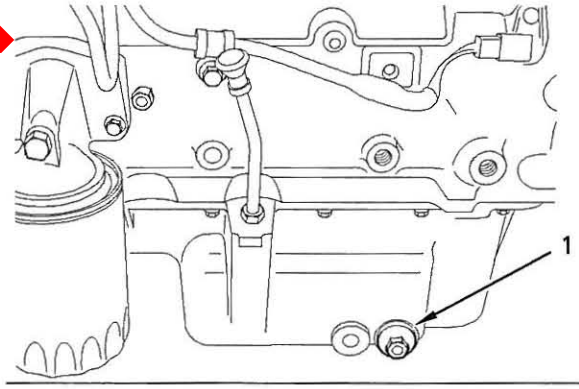

Illustration 38 g01003623

Oil drain plug

After the engine has been run at the normal operating temperature, stop the engine. Use one of the following methods to drain the engine crankcase oil:

- If the engine is equipped with a drain valve, turn the drain valve knob counterclockwise in order to drain the oil. After the oil has drained, turn the drain valve knob clockwise in order to close the drain valve.
- If the engine is not equipped with a drain valve, remove the oil drain plug (1) in order to allow the oil to drain. If the engine is equipped with a shallow sump, remove the bottom oil drain plugs from both ends of the oil pan.

After the oil has drained, the oil drain plugs should be cleaned and installed. If necessary, renew the O ring seal on the drain plug.

Some types of oil pans have oil drain plugs that are on both sides of the oil pan, because of the shape of the pan. This type of oil pan requires the engine oil to be drained from both plugs.

Replace the Spin-on Oil Filter

NOTICE
Perkins oil filters are manufactured to Perkins specifications. Use of an oil filter that is not recommended by Perkins could result in severe damage to the engine bearings, crankshaft, etc., as a result of the larger waste particles from unfiltered oil entering the engine lubricating system. Only use oil filters recommended by Perkins.

1. Remove the oil filter with a suitable tool.

Note: The following actions can be carried out as part of the preventive maintenance program.

2. Cut the oil filter open with a suitable tool. Break apart the pleats and inspect the oil filter for metal debris. An excessive amount of metal debris in the oil filter may indicate early wear or a pending failure.

   Use a magnet to differentiate between the ferrous metals and the nonferrous metals that are found in the oil filter element. Ferrous metals may indicate wear on the steel and cast iron parts of the engine.

   Nonferrous metals may indicate wear on the aluminum parts, brass parts or bronze parts of the engine. Parts that may be affected include the following items: main bearings, rod bearings, turbocharger bearings, and cylinder heads.

   Due to normal wear and friction, it is not uncommon to find small amounts of debris in the oil filter.

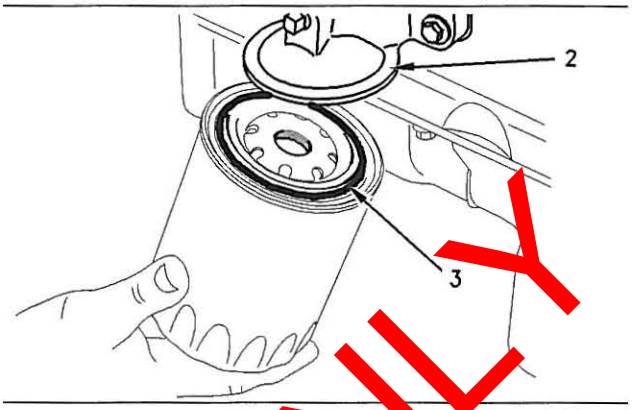

Illustration 39 g01003628

(2) Filter head
(3) O ring seal

3. Clean the sealing surface of the oil filter head (2). Ensure that the union (not shown) in the oil filter head is secure.

4. Apply clean engine oil to the O ring seal (3) on the oil filter.

NOTICE
Do not fill the oil filters with oil before installing them. The oil would not be filtered and could be contaminated. Contaminated oil can cause accelerated wear to engine components.

5. Install the oil filter. Tighten the oil filter by hand according to the instructions that are shown on the oil filter. Do not overtighten the oil filter.

Replace the Element for the Oil Filter

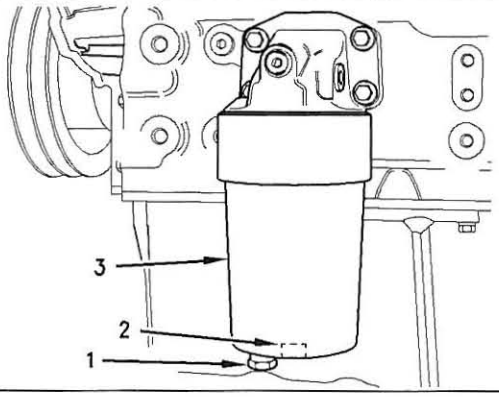

Illustration 40 g01003662

(1) Drain plug
(2) Square hole
(3) Filter bowl

1. Place a suitable container under the oil filter. Remove the drain plug (1) and the seal, from the oil filter.

2. Locate a suitable wrench into the square hole (2) in order to remove the filter bowl (3).

3. Remove the filter bowl (3) and remove the element from the filter bowl. Clean the filter bowl.

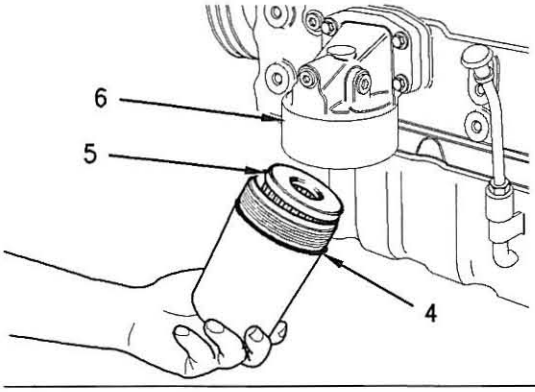

Illustration 41 g01003675

(4) O ring seal
(5) Element
(6) Filter head

4. Install a new O ring (4) onto the filter bowl and lubricate the O ring with clean engine oil. Install the filter element (5) into the filter bowl.

5. Install the filter bowl into the oil filter head (6). Tighten the filter bowl to the following torque: 25 N·m (18 lb ft).

6. Install a new seal onto the drain plug (1) and install the drain plug into the oil filter. Tighten the drain plug to the following torque: 12 N·m (8 lb ft).

Note: Some engines may have a horizontally mounted oil filter. This oil filter has a drain plug that is located in the oil filter head.

Fill the Engine Crankcase

1. Remove the oil filler cap. Refer to the Operation and Maintenance Manual for more information on lubricant specifications. Fill the crankcase with the proper amount of oil. Refer to the Operation and Maintenance Manual for more information on refill capacities.

NOTICE
If equipped with an auxiliary oil filter system or a remote oil filter system, follow the OEM or filter manufacturer's recommendations. Under filling or overfilling the crankcase with oil can cause engine damage.

NOTICE
To prevent crankshaft bearing damage, crank the engine with the fuel OFF. This will fill the oil filters before starting the engine. Do not crank the engine for more than 30 seconds.

2. Start the engine and run the engine at "LOW IDLE" for two minutes. Perform this procedure in order to ensure that the lubrication system has oil and that the oil filters are filled. Inspect the oil filter for oil leaks.

3. Stop the engine and allow the oil to drain back to the sump for a minimum of ten minutes.

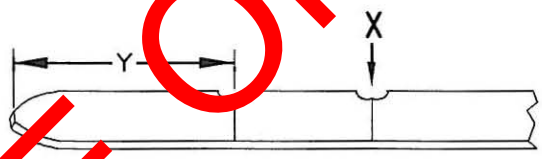

Illustration 42 g00998024

(Y) "ADD" mark. (X) "FULL" mark.

4. Remove the oil level gauge in order to check the oil level. Maintain the oil level between the "ADD" and "FULL" marks on the engine oil dipstick.

i02171102

Engine Valve Lash - Inspect/Adjust

This maintenance is recommended by Perkins as part of a lubrication and preventive maintenance schedule in order to help provide maximum engine life.

NOTICE
Only qualified service personel should perform this maintenance. Refer to the Service Manual or your authorized Perkins dealer or your Perkins distributor for the complete valve lash adjustment procedure.

Operation of Perkins engines with incorrect valve lash can reduce engine efficiency, and also reduce engine component life.

⚠ WARNING

Ensure that the engine can not be started while this maintenance is being performed. To help prevent possible injury, do not use the starting motor to turn the flywheel.

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

Ensure that the engine is stopped before measuring the valve lash. The engine valve lash can be inspected and adjusted when the temperature of the engine is hot or cold.

Refer to Systems Operation/Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust" for more information.

i02198352

Fuel Injector - Test/Change

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

NOTICE
If a fuel injector is suspected of operating outside of normal parameters it should be removed by a qualified technician. The suspect fuel injector should be taken to an authorised agent for inspection.

The fuel injector (1) in illustration 43 has no fuel return. The fuel injector (2) has a fuel return.

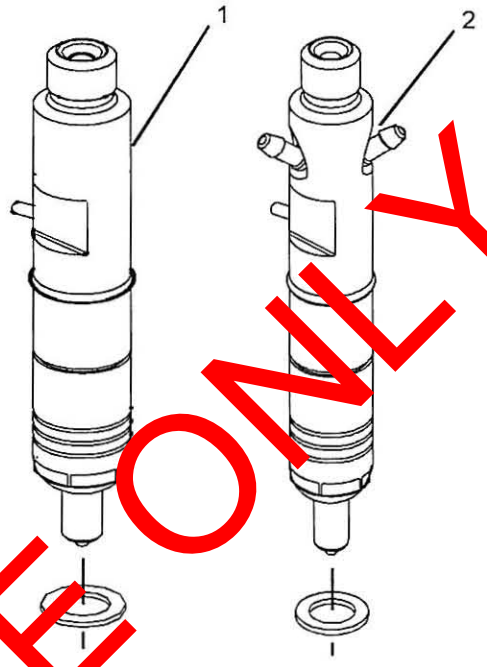

Illustration 43 g01110422
Typical fuel Injectors

The fuel injector (1) will need to be removed and the injector will need to be checked for performance.

The fuel injectors should not be cleaned as cleaning with incorrect tools can damage the nozzle. The fuel injectors should be renewed only if a fault with the fuel injectors occurs. Some of the problems that may indicate that new fuel injectors are needed are listed below:

- The engine will not start or the engine is difficult to start.
- Not enough power
- The engine misfires or the engine runs erratically.
- High fuel consumption
- Black exhaust smoke
- The engine knocks or there is vibration in the engine.
- Excessive engine temperature

Removal and Installation of the Fuel Injectors

⚠ WARNING

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

⚠ WARNING

Make sure that you wear eye protection at all times during testing. When fuel injection nozzles are tested, test fluids travel through the orifices of the nozzle tip with high pressure. Under this amount of pressure, the test fluid can pierce the skin and cause serious injury to the operator. Always keep the tip of the fuel injection nozzle pointed away from the operator and into the fuel collector and extension.

NOTICE
If your skin comes into contact with high pressure fuel, obtain medical assistance immediately.

Operate the engine at a fast idle speed in order to identify the faulty fuel injector. Individually loosen and tighten the union nut for the high pressure pipe to each fuel injector. Do not loosen the union nut more than half a turn. There will be little effect on the engine speed when the union nut to the faulty fuel injection nozzle is loosened. Refer to the Disassembly and Assembly Manual for more information. Consult your authorized Perkins dealer or your Perkins distributor for assistance.

i02890360

Fuel System - Prime

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

- The fuel tank is empty or the fuel tank has been partially drained.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system.
- The fuel filter is replaced.
- A new injection pump is installed.

Use the following procedure in order to remove air from the fuel system:

1. Ensure that all low pressure fuel connections and high pressure fuel lines are installed correctly.
2. Turn the ignition key to the RUN position. Leave the ignition key in the RUN position for three minutes. If a manual purging screw is installed, the purging screw should be slackened during priming the fuel system.

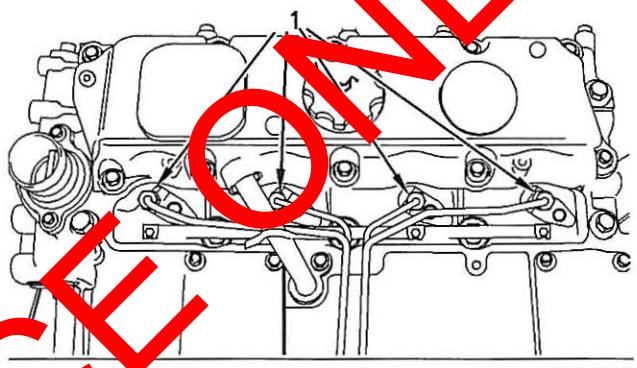

Illustration 44 g01003929
Typical example

3. Crank the engine with the throttle lever in the CLOSED position until the engine starts.

Note: If necessary, loosen the union nuts (1) on the fuel injection lines at the connection with the fuel injector until fuel is evident. Stop cranking the engine. Tighten the union nuts (1) to a torque of 30 N·m (22 lb ft).

4. Start the engine and run the engine at idle for one minute.

NOTICE
Do not crank the engine continuously for more than 30 seconds. Allow the starting motor to cool for two minutes before cranking the engine again.

5. Cycle the throttle lever from the low idle position to the high idle position three times. The cycle time for the throttle lever is one second to six seconds for one complete cycle.

Note: In order to purge air from the fuel injection pump on Perkins engines with a fixed throttle, the engine should be run at full load for thirty seconds. The load should then be decreased until the engine is at high idle. This should be repeated three times. This will assist in removing trapped air from the fuel injection pump.

6. Check for leaks in the fuel system.

i02206563

Fuel System Primary Filter (Water Separator) Element - Replace

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

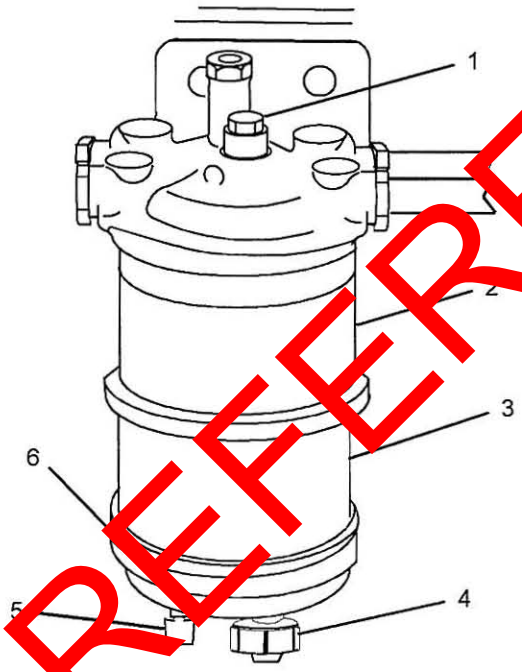

Illustration 45 g01118416

(1) Screw
(2) Element
(3) Glass bowl
(4) Sensor connection
(5) Drain
(6) Bottom cover

1. Turn the fuel supply valve (if equipped) to the OFF position.
2. Place a suitable container under the water separator. Clean the outside of the water separator.
3. Open the drain (5). Allow the fluid to drain into the container.
4. Tighten the drain (5) by hand pressure only.
5. Hold the element (2) and remove the screw (1). Remove the element and the glass bowl (3) from the base. Discard the old element.
6. Clean the glass bowl (4). Clean the bottom cover (6).
7. Install the new O-ring seal. Install the bottom cover onto the new element. Install the assembly onto the base.
8. Install the screw (1) and tighten the screw to a torque of 8 N·m (6 lb ft).
9. Remove the container and dispose of the fuel safely.
10. Open the fuel supply valve.

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

i02211066

Fuel System Primary Filter/Water Separator - Drain

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE
The water separator is not a filter. The water separator separates water from the fuel. The engine should never be allowed to run with the water separator more than half full. Engine damage may result.

NOTICE
The water separator is under suction during normal engine operation. Ensure that the drain valve is tightened securely to help prevent air from entering the fuel system.

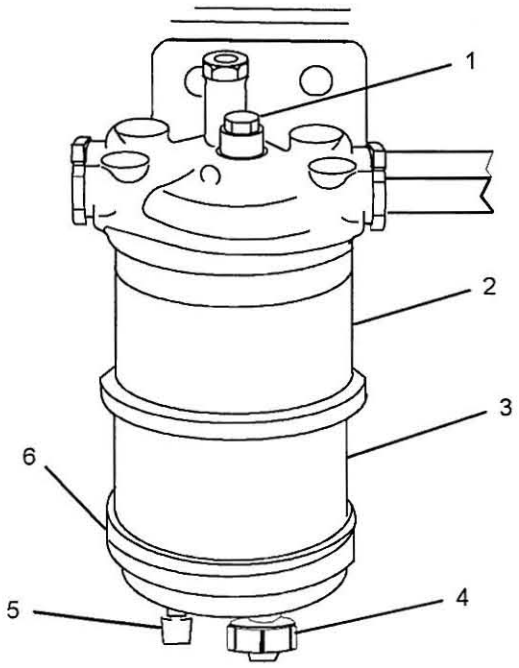

Illustration 46 g01118416

(1) Screw
(2) Element
(3) Glass bowl
(4) Sensor connection
(5) Drain
(6) Bottom cover

1. Place a suitable container below the water separator.

2. Open the drain (5). Allow the fluid to drain into the container.

3. When clean fuel drains from the water separator close the drain (5). Tighten the drain by hand pressure only. Dispose of the drained fluid correctly.

i02469473

Fuel System Secondary Filter - Replace

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

Element filter

Turn the valves for the fuel lines (if equipped) to the OFF position before performing this maintenance. Place a tray under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel immediately.

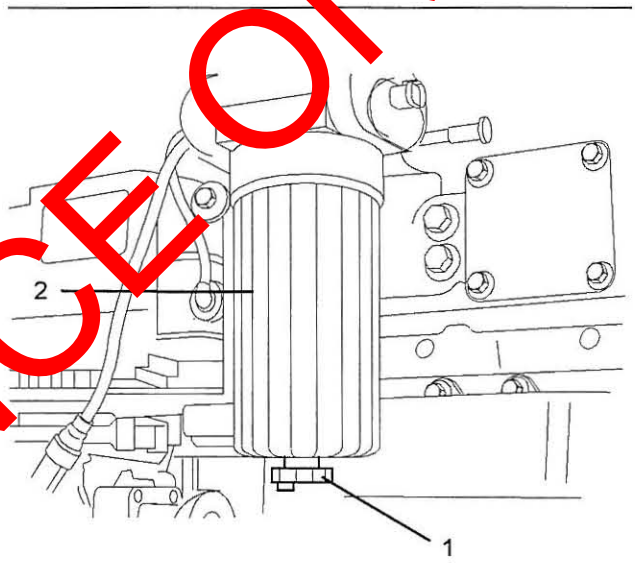

Illustration 47 g01010637

(1) Drain
(2) Filter bowl

1. Close the valves for the fuel lines (if equipped).

2. Clean the outside of the fuel filter assembly. Open the fuel drain (1) and drain the fuel into a suitable container.

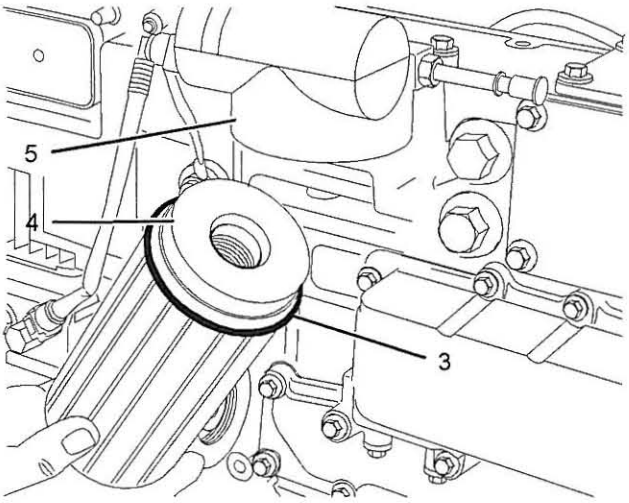

Illustration 48 g01010595

(3) O ring seal
(4) Element
(5) Filter head

3. Remove the filter bowl (2) from the filter head (5). Press on the element (4). Rotate the element counterclockwise in order to release the element for the filter bowl and remove the element from the bowl. Discard the used element.

4. Remove the O ring (3) from the filter bowl and clean the filter bowl. Check that the threads of the filter bowl are not damaged.

5. Install a new O ring seal (3) to the filter bowl (2).

6. Locate a new filter element (4) into the filter bowl. Press on the element and rotate the element clockwise in order to lock the element into the filter bowl.

7. Install the filter bowl (4) into the top of the filter head (5).

8. Tighten the filter bowl by hand until the filter bowl contacts the filter head. Rotate the filter bowl through 360 degrees.

Note: Do not use a tool to tighten the filter bowl.

9. Open the valves for the fuel lines (if equipped).

Spin-on filter

Turn the valves for the fuel lines (if equipped) to the OFF position before performing this maintenance. Place a tray under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel immediately.

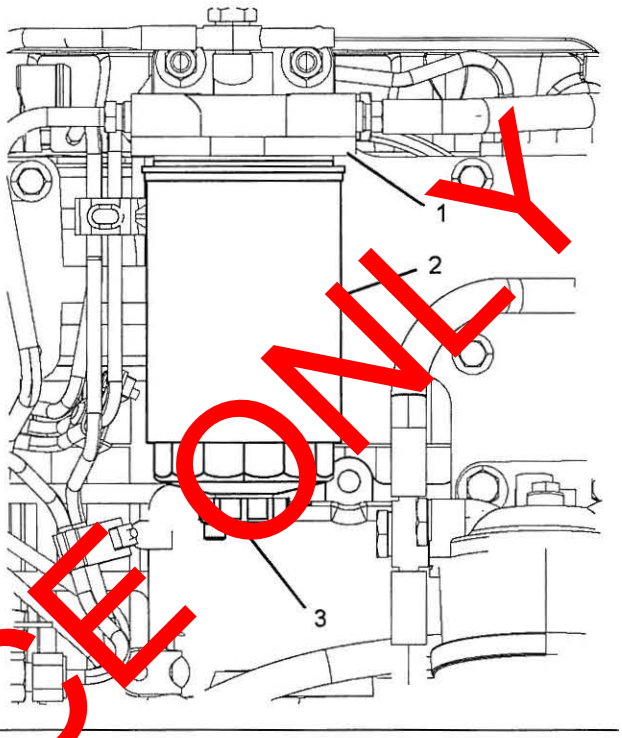

Illustration 49 g01121396

(1) Filter Head
(2) Spin-on filter
(3) Drain

1. Clean the outside of the fuel filter assembly. Open the fuel drain (3) and drain the fuel into a suitable container.

2. Use a suitable tool in order to remove the spin-on filter (2) from the filter head (1).

3. Ensure that the fuel drain (3) on the new spin-on filter is closed.

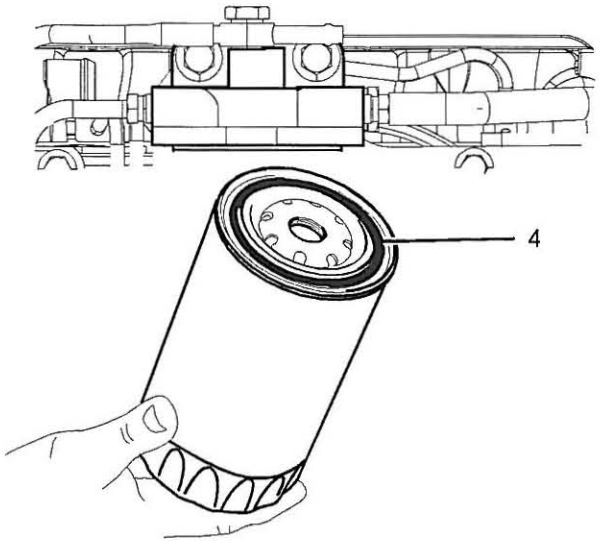

Illustration 50 g01121723

4. Lubricate the sealing ring (4) with clean fuel oil.

5. Install the spin-on filter (2) into the top of the filter head (1).

6. Tighten the spin-on filter by hand until the sealing ring contacts the filter head. Rotate the spin-on filter through 90 degrees.

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

i02335436

Fuel Tank Water and Sediment - Drain

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

Fuel Tank

Fuel quality is critical to the performance and to the service life of the engine. Water in the fuel can cause excessive wear to the fuel system.

Water can be introduced into the fuel tank when the fuel tank is being filled.

Condensation occurs during the heating and cooling of fuel. The condensation occurs as the fuel passes through the fuel system and the fuel returns to the fuel tank. This causes water to accumulate in fuel tanks. Draining the fuel tank regularly and obtaining fuel from reliable sources can help to eliminate water in the fuel.

Drain the Water and the Sediment

Fuel tanks should contain some provision for draining water and draining sediment from the bottom of the fuel tanks.

Open the drain valve on the bottom of the fuel tank in order to drain the water and the sediment. Close the drain valve.

Check the fuel daily. Allow five minutes after the fuel tank has been filled before draining water and sediment from the fuel tank.

Fill the fuel tank after operating the engine in order to drive out moist air. This will help prevent condensation. Do not fill the tank to the top. The fuel expands as the fuel gets warm. The tank may overflow.

Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe. Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Fuel Storage Tanks

Drain the water and the sediment from the fuel storage tank at the following intervals:

- Weekly
- Service intervals
- Refill of the tank

This will help prevent water or sediment from being pumped from the storage tank into the engine fuel tank.

If a bulk storage tank has been refilled or moved recently, allow adequate time for the sediment to settle before filling the engine fuel tank. Internal baffles in the bulk storage tank will also help trap sediment. Filtering fuel that is pumped from the storage tank helps to ensure the quality of the fuel. When possible, water separators should be used.

i02813964

Hoses and Clamps - Inspect/Replace

Inspect all hoses for leaks that are caused by the following conditions:

- Cracking
- Softness
- Loose clamps

Replace hoses that are cracked or soft. Tighten any loose clamps.

NOTICE
Do not bend or strike high pressure lines. Do not install bent or damaged lines, tubes or hoses. Repair any loose or damaged fuel and oil lines, tubes and hoses. Leaks can cause fires. Inspect all lines, tubes and hoses carefully. Tighten all connections to the recommended torque. Do not clip any other item to the high pressure lines.

Check for the following conditions:

- End fittings that are damaged or leaking
- Outer covering that is chafed or cut
- Exposed wire that is used for reinforcement
- Outer covering that is ballooning locally
- Flexible part of the hose that is kinked or crushed
- Armoring that is embedded in the outer covering

A constant torque hose clamp can be used in place of any standard hose clamp. Ensure that the constant torque hose clamp is the same size as the standard clamp.

Due to extreme temperature changes, the hose will harden. Hardening of the hoses will cause hose clamps to loosen. This can result in leaks. A constant torque hose clamp will help to prevent loose hose clamps.

Each installation application can be different. The differences depend on the following factors:

- Type of hose
- Type of fitting material
- Anticipated expansion and contraction of the hose
- Anticipated expansion and contraction of the fittings

Replace the Hoses and the Clamps

Refer to the OEM information for further information on removing and replacing fuel hoses (if equipped).

The coolant system and the hoses for the coolant system are not usually supplied by Perkins. The following text describes a typical method of replacing coolant hoses. Refer to the OEM information for further information on the coolant system and the hoses for the coolant system.

WARNING

Pressurized System Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine. Allow the engine to cool.
2. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

Note: Drain the coolant into a suitable, clean container. The coolant can be reused.

3. Drain the coolant from the cooling system to a level that is below the hose that is being replaced.
4. Remove the hose clamps.
5. Disconnect the old hose.
6. Replace the old hose with a new hose.
7. Install the hose clamps with a torque wrench.

Note: For the correct coolant, see this Operation and Maintenance Manual, “Fluid Recommendations”.

8. Refill the cooling system. Refer to the OEM information for further information on refilling the cooling system.
9. Clean the cooling system filler cap. Inspect the cooling system filler cap’s seals. Replace the cooling system filler cap if the seals are damaged. Install the cooling system filler cap.
10. Start the engine. Inspect the cooling system for leaks.

i02335774

Radiator - Clean

The radiator is not usually supplied by Perkins. The following text describes a typical cleaning procedure for the radiator. Refer to the OEM information for further information on cleaning the radiator.

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the radiator for these items: Damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the radiator, if necessary.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction to the fan's air flow. Hold the nozzle approximately 6 mm (0.25 inch) away from the radiator fins. Slowly move the air nozzle in a direction that is parallel with the radiator tube assembly. This will remove debris that is between the tubes.

Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

Use a degreaser and steam for removal of oil and grease. Clean both sides of the core. Wash the core with detergent and hot water. Thoroughly rinse the core with clean water.

If the radiator is blocked internally, refer to the OEM Manual for information regarding flushing the cooling system.

After cleaning the radiator, start the engine. Allow the engine to operate at low idle speed for three to five minutes. Accelerate the engine to high idle. This will help in the removal of debris and the drying of the core. Slowly reduce the engine speed to low idle and then stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a "comb". Inspect these items for good condition: Welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

i02335775

Severe Service Application - Check

Severe service is the application of an engine that exceeds the current published standards for that engine. Perkins maintains standards for the following engine parameters:

- Performance such as power range, speed range, and fuel consumption
- Fuel quality
- Operational Altitude
- Maintenance intervals
- Oil selection and maintenance
- Coolant type and maintenance
- Environmental qualities
- Installation
- The temperature of the fluid in the engine

Refer to the standards for the engine or consult your Perkins dealer or your Perkins distributor in order to determine if the engine is operating within the defined parameters.

Severe service operation can accelerate component wear. Engines that operate under severe conditions may need more frequent maintenance intervals in order to ensure maximum reliability and retention of full service life.

Due to individual applications, it is not possible to identify all of the factors which can contribute to severe service operation. Consult your Perkins dealer or your Perkins distributor for the unique maintenance that is necessary for the engine.

The operating environment, incorrect operating procedures and incorrect maintenance procedures can be factors which contribute to a severe service application.

Environmental Factors

Ambient temperatures – The engine may be exposed to extended operation in extremely cold environments or hot environments. Valve components can be damaged by carbon buildup if the engine is frequently started and stopped in very cold temperatures. Extremely hot intake air reduces engine performance.

Quality of the air – The engine may be exposed to extended operation in an environment that is dirty or dusty, unless the equipment is cleaned regularly. Mud, dirt and dust can encase components. Maintenance can be very difficult. The buildup can contain corrosive chemicals.

Buildup – Compounds, elements, corrosive chemicals and salt can damage some components.

Altitude – Problems can arise when the engine is operated at altitudes that are higher than the intended settings for that application. Necessary adjustments should be made.

Incorrect Operating Procedures

- Extended operation at low idle
- Frequent hot shutdowns
- Operating at excessive loads
- Operating at excessive speeds
- Operating outside the intended application

Incorrect Maintenance Procedures

- Extending the maintenance intervals
- Failure to use recommended fuel, lubricants and coolant/antifreeze

i02177969

Starting Motor - Inspect

Perkins recommends a scheduled inspection of the starting motor. If the starting motor fails, the engine may not start in an emergency situation.

Check the starting motor for correct operation. Check the electrical connections and clean the electrical connections. Refer to the Systems Operation, Testing and Adjusting Manual, "Electric Starting System - Test" for more information on the checking procedure and for specifications or consult your Perkins dealer or your Perkins distributor for assistance.

i02184788

Turbocharger - Inspect (If Equipped)

A regular visual inspection of the turbocharger is recommended. Any fumes from the crankcase are filtered through the air inlet system. Therefore, by-products from oil and from combustion can collect in the turbocharger compressor housing. Over time, this buildup can contribute to loss of engine power, increased black smoke and overall loss of engine efficiency.

If the turbocharger fails during engine operation, damage to the turbocharger compressor wheel and/or to the engine may occur. Damage to the turbocharger compressor wheel can cause additional damage to the pistons, the valves, and the cylinder head.

NOTICE
Turbocharger bearing failures can cause large quantities of oil to enter the air intake and exhaust systems. Loss of engine lubricant can result in serious engine damage.

Minor leakage of oil into a turbocharger under extended low idle operation should not cause problems as long as a turbocharger bearing failure has not occured.

When a turbocharger bearing failure is accompanied by a significant engine performance loss (exhaust smoke or engine rpm up at no load), do not continue engine operation until the turbocharger is renewed.

A visual inspection of the turbocharger can minimize unscheduled downtime. A visual inspection of the turbocharger can also reduce the chance for potential damage to other engine parts.

Removal and Installation

Note: The turbochargers that are supplied are nonserviceable.

For options regarding the removal, installation, and replacement, consult your Perkins dealer or your Perkins distributor. Refer to the Disassembly and Assembly Manual, "Turbocharger - Remove and Turbocharger - Install" for further information.

Inspecting

NOTICE
The compressor housing for the turbocharger must not be removed from the turbocharger for cleaning.

The actuator linkage is connected to the compressor housing. If the actuator linkage is moved or disturbed the engine may not comply with emmissions legislation.

1. Remove the pipe from the turbocharger exhaust outlet and remove the air intake pipe to the turbocharger. Visually inspect the piping for the presence of oil. Clean the interior of the pipes in order to prevent dirt from entering during reassembly.

2. Check for the presence of oil. If oil is leaking from the back side of the compressor wheel, there is a possibility of a failed turbocharger oil seal.

   The presence of oil may be the result of extended engine operation at low idle. The presence of oil may also be the result of a restriction of the line for the intake air (clogged air filters), which causes the turbocharger to slobber.

3. Inspect the bore of the housing of the turbine outlet for corrosion.

4. Fasten the air intake pipe and the exhaust outlet pipe to the turbocharger housing.

i02177973

Walk-Around Inspection

Inspect the Engine for Leaks and for Loose Connections

A walk-around inspection should only take a few minutes. When the time is taken to perform these checks, costly repairs and accidents can be avoided.

For maximum engine service life, make a thorough inspection of the engine compartment before starting the engine. Look for items such as oil leaks or coolant leaks, loose bolts, worn belts, loose connections and trash buildup. Make repairs, as needed:

- The guards must be in the correct place. Repair damaged guards or replace missing guards.

- Wipe all caps and plugs before the engine is serviced in order to reduce the chance of system contamination.

NOTICE
For any type of leak (coolant, lube, or fuel) clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

NOTICE
Accumulated grease and/or oil on an engine is a fire hazard. Remove the accumulated grease and oil. Refer to this Operation and Maintenance Manual, "Engine - Clean" for more information.

- Ensure that the cooling system hoses are correctly clamped and that the cooling system hoses are tight. Check for leaks. Check the condition of all pipes.

- Inspect the water pump for coolant leaks.

Note: The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and the parts contract.

Excessive coolant leakage may indicate the need to replace the water pump seal. For the removal of the water pump and the installation of water pump and/or seal, refer to the Disassembly and Assembly Manual, "Water Pump - Remove and Install" for more information or consult your Perkins dealer or your Perkins distributor.

- Inspect the lubrication system for leaks at the front crankshaft seal, the rear crankshaft seal, the oil pan, the oil filters and the rocker cover.

- Inspect the fuel system for leaks. Look for loose fuel line clamps and/or tie-wraps.

- Inspect the piping for the air intake system and the elbows for cracks and for loose clamps. Ensure that hoses and tubes are not contacting other hoses, tubes, wiring harnesses, etc.

- Inspect the alternator belts and any accessory drive belts for cracks, breaks or other damage.

Belts for multiple groove pulleys must be replaced as matched sets. If only one belt is replaced, the belt will carry more load than the belts that are not replaced. The older belts are stretched. The additional load on the new belt could cause the belt to break.

- Drain the water and the sediment from the fuel tank on a daily basis in order to ensure that only clean fuel enters the fuel system.
- Inspect the wiring and the wiring harnesses for loose connections and for worn wires or frayed wires.
- Inspect the ground strap for a good connection and for good condition.
- Disconnect any battery chargers that are not protected against the current drain of the starting motor. Check the condition and the electrolyte level of the batteries, unless the engine is equipped with a maintenance free battery.
- Check the condition of the gauges. Replace any gauges that are cracked. Replace any gauge that can not be calibrated.

i01907756

Water Pump - Inspect

A failed water pump may cause sev[illegible] engine overheating problems that could result in the following conditions:

- Cracks in the cylinder head
- A piston seizure
- Other potential damage to the engine

Note: The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and parts contract.

Visually inspect the water pump for leaks. Renew the water pump seal or the water pump if there is an excessive leakage of coolant. Refer to the Disassembly and Assembly Manual, "Water Pump - Remove and Install" for the disassembly and assembly procedure.

Warranty Section

Warranty Information

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Emissions Warranty Information

This engine may be certified to comply with exhaust emission standards and gaseous emission standards that are prescribed by the law at the time of manufacture, and this engine may be covered by an Emissions Warranty. Consult your authorized Perkins dealer or your authorized Perkins distributor in order to determine if your engine is emissions certified and if your engine is subject to an Emissions Warranty.

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Product and Dealer Information

Note: For product identification plate locations, see the section "Product Identification Information" in the Operation and Maintenance Manual.

Delivery Date: _____

Product Information

Model: _____

Product Identification Number: _____

Engine Serial Number: _____

Transmission Serial Number: _____

Generator Serial Number: _____

Attachment Serial Numbers: _____

Attachment Information: _____

Customer Equipment Number: _____

Dealer Equipment Number: _____

Dealer Information

Name: _____ Branch: _____

Address: _____

_____

_____

	Dealer Contact	Phone Number	Hours
Sales:	_____	_____	_____
Parts:	_____	_____	_____
Service:	_____	_____	_____

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Perkins®

SENR9777-03
December 2004

Systems Operation Testing and Adjusting

1103 and 1104C Engines

DC (Engine)
DD (Engine)
DJ (Engine)
DK (Engine)
RE (Engine)
RG (Engine)
RJ (Engine)
RR (Engine)
RS (Engine)
DF (Engine)
DG (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 have the most current information available.

⚠ WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

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

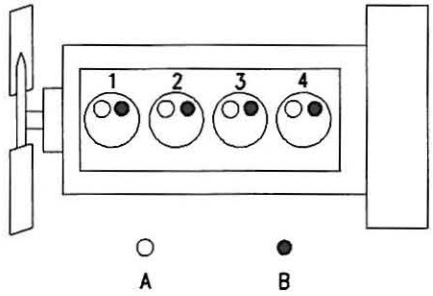

Illustration 1 g00984281

1104 example of the layout of the valves

(A) Inlet valve
(B) Exhaust valve

1104 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 in³)

Compression ratio

Naturally aspirated 19.25:1

Turbocharged 18.23:1

Number of cylinders 4

Cylinder arrangement ..... In-line

Firing order 1, 3, 4, 2

1104 Engine Specification

Genset

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 in³)

Compression ratio

Naturally aspirated 19.25:1

Turbocharged 1104A engines 17.2:1

Turbocharged 1104C engines 18.23:1

Number of cylinders 4

Cylinder arrangement ..... In-line

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

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.

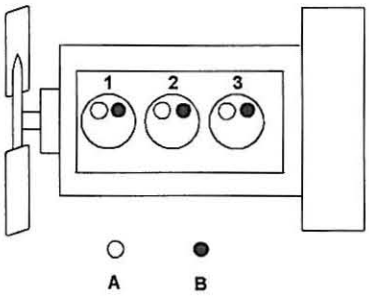

Illustration 2 g01116461

1103 example of the layout of the valves

(A) Inlet valve
(B) Exhaust valve

1103 Engine Specification

Industrial

Type ..... Three cylinder and four stroke

Type of combustion ..... Direct injection

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

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

Displacement ..... 3.3 L (201 in^3)

Compression ratio

Naturally aspirated 19.25:1

Turbocharged 18.23:1

Number of cylinders 3

Cylinder arrangement ..... In-line

Firing order 1, 2, 3

1103 Engine Specification

Genset

Type ..... Three cylinder and four stroke

Type of combustion ..... Direct injection

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

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

Displacement ..... 3.3 L (201 in^3)

Compression ratio

Naturally aspirated ..... 19.

Turbocharged 1103A engines 17.2:1

Turbocharged 1103C engines 18.23:

Number of cylinders 3

Cylinder arrangement ..... In-line

Firing order 1, 2, 3

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

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.

i01958097

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 1104 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 1103 engine crankshaft has four main journals. End play is controlled by thrust washers that are located on both sides of the number three 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.

1104 Engine Model Views

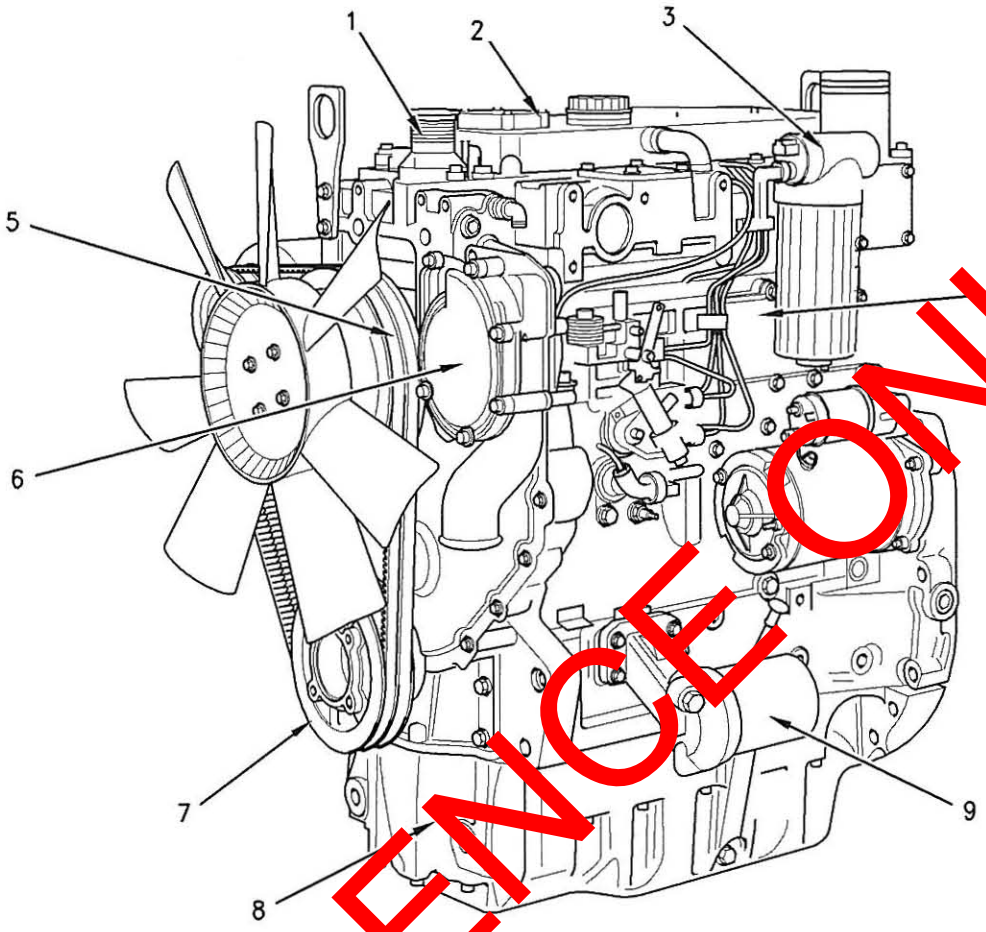

Illustration 3 g00993373

(1) Water temperature regulator housing
(2) Valve mechanism cover
(3) Fuel transfer pump and fuel filter
(4) Engine oil cooler
(5) Fan drive
(6) Water pump
(7) Crankshaft pulley
(8) Oil pan
(9) Engine oil filter

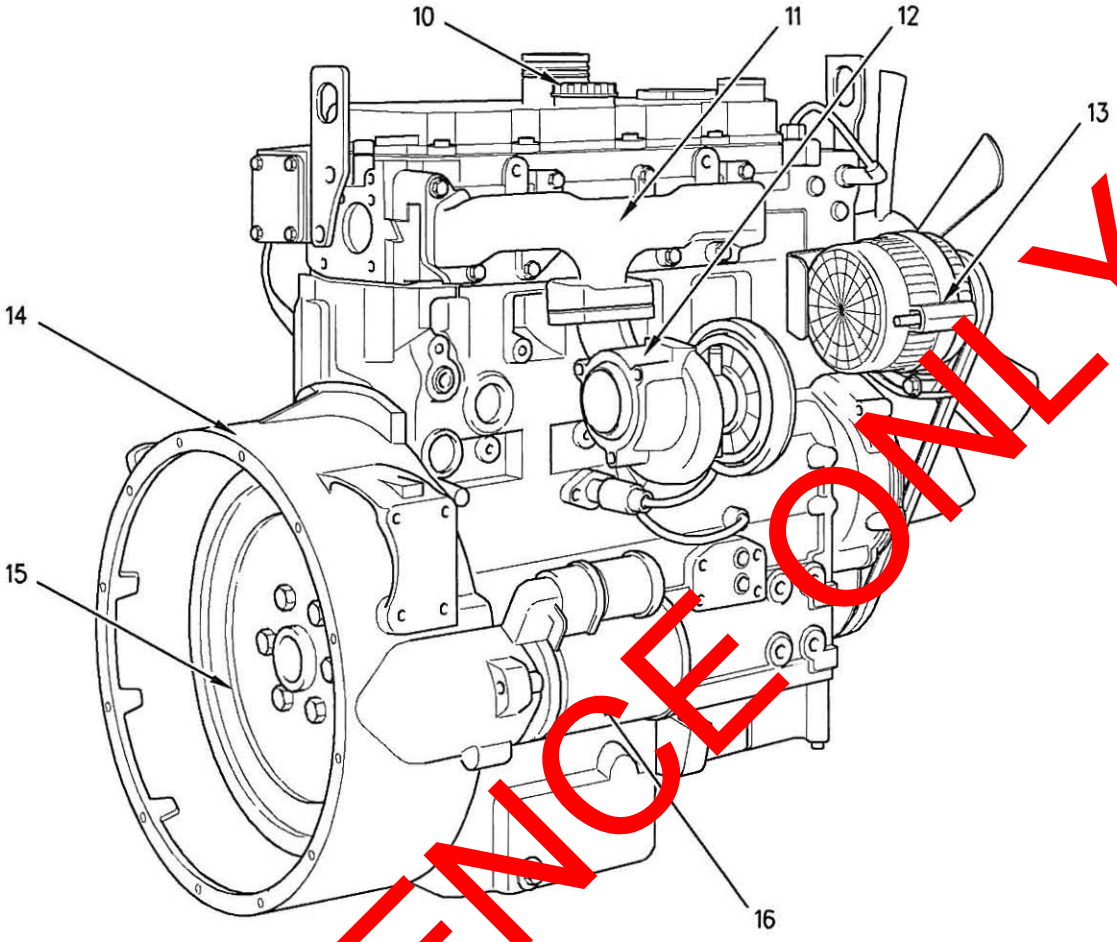

Illustration 4 g00928546

(10) Engine oil filler cap
(11) Exhaust manifold
(12) Turbocharger
(13) Alternator
(14) Flywheel housing
(15) Flywheel
(16) Starter motor

1103 Engine Model Views

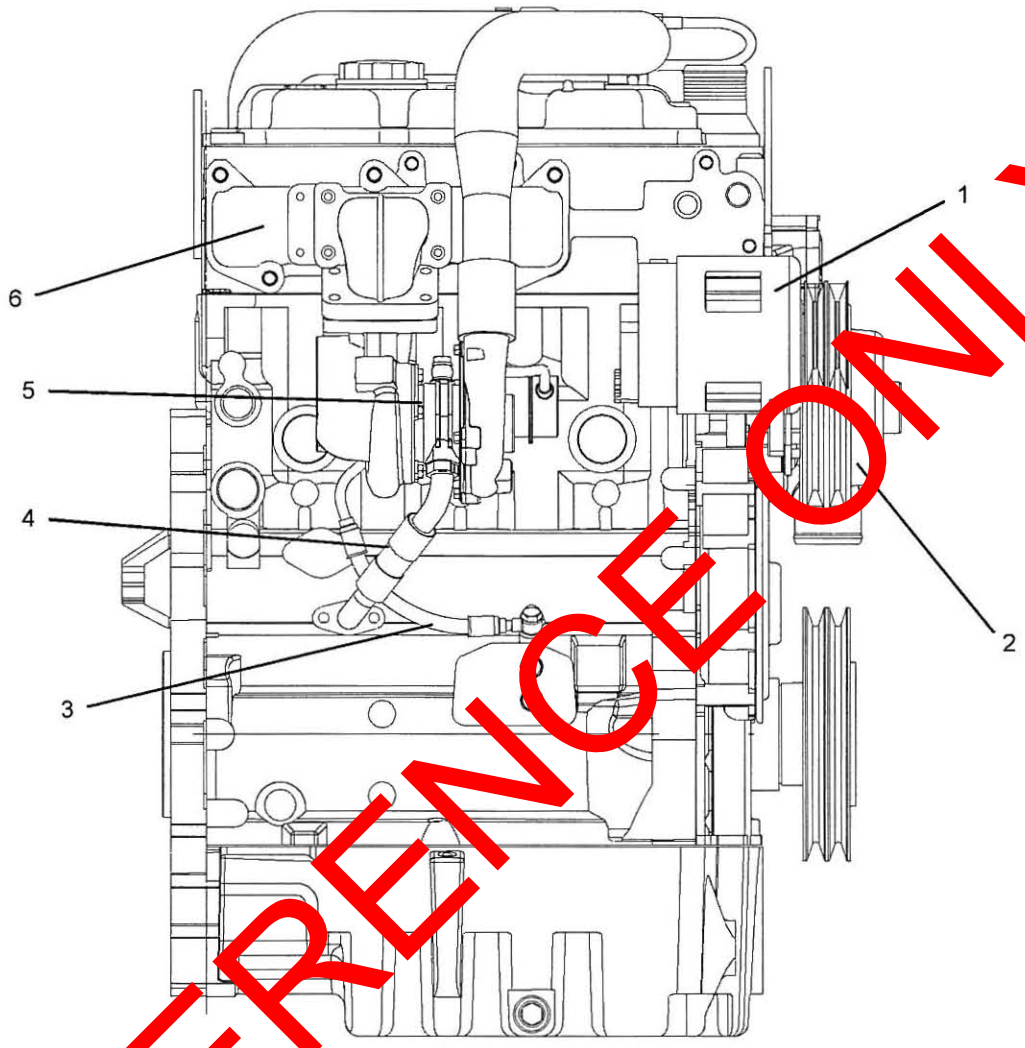

Illustration 5 g01011348

(1) Alternator
(2) Fan pulley
(3) Turbocharger oil supply
(4) Turbocharger oil drain
(5) Turbocharger
(6) Exhaust manifold

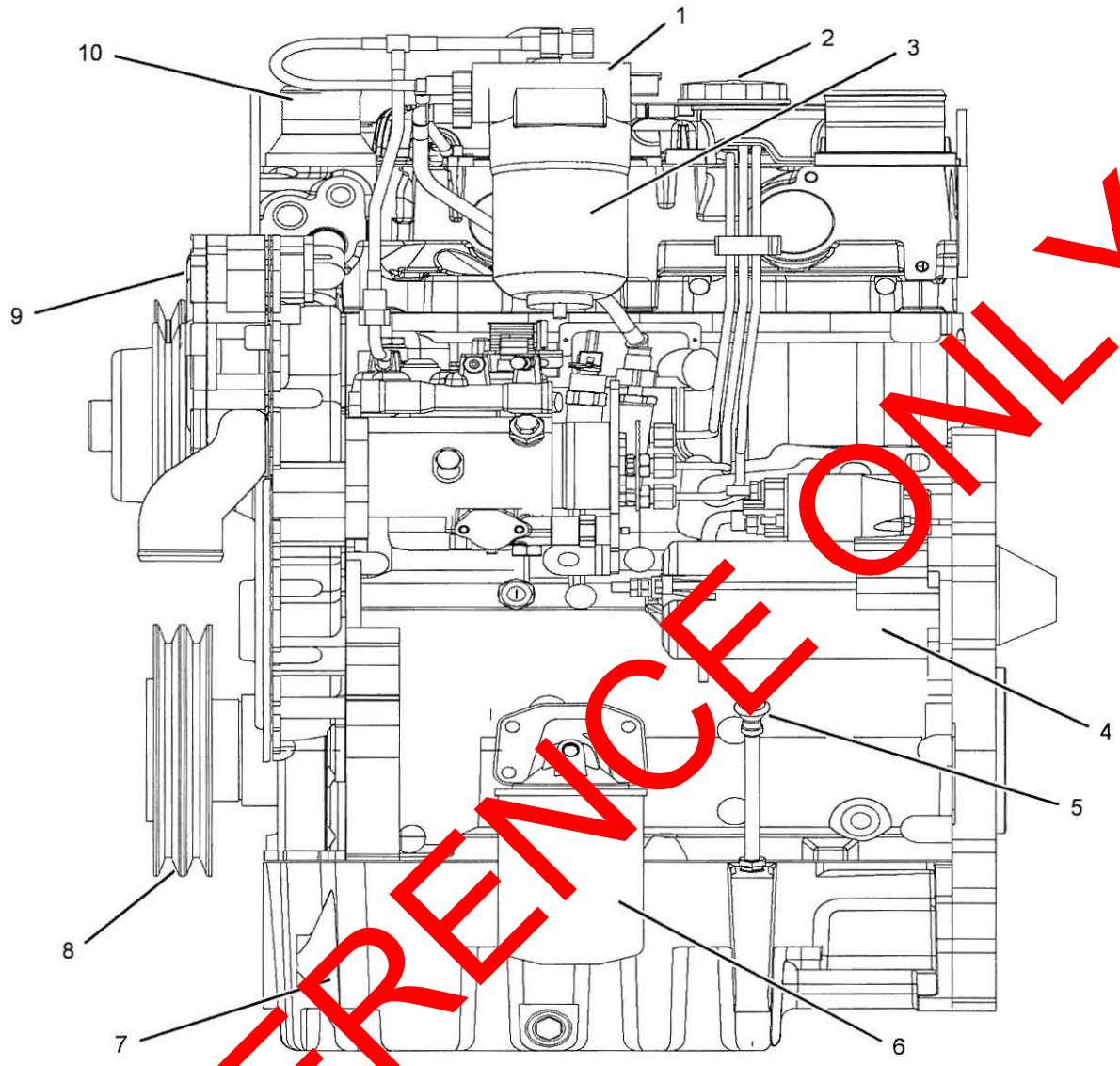

Illustration 6 g01011349

(1) Fuel transfer pump
(2) Oil filler cap
(3) Fuel filter
(4) Starter motor
(5) Dipstick
(6) Oil filter
(7) Oil pan
(8) Crankshaft pulley
(9) Water pump
(10) Water temperature regulator housing

i02211831

Fuel System

The Delphi DP210 or the Delphi DPG fuel injection pump is installed on the 1104 engine and the 1103 engine. The Delphi STP fuel injection pump is installed on the 1103 engine only. The Delphi DPA or the Bosch EPVE fuel injection pump is installed on the 1104 engine only.

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 length. 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 DP210, DPA, DPG and STP fuel injection pumps 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 DP210 fuel injection pump has a boost control. The Delphi DP210, DPA, DPG and STP fuel injection pumps have an engine stop solenoid and a feature that vents air from the pump.

The Delphi DP210 and STP fuel injection pumps have 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

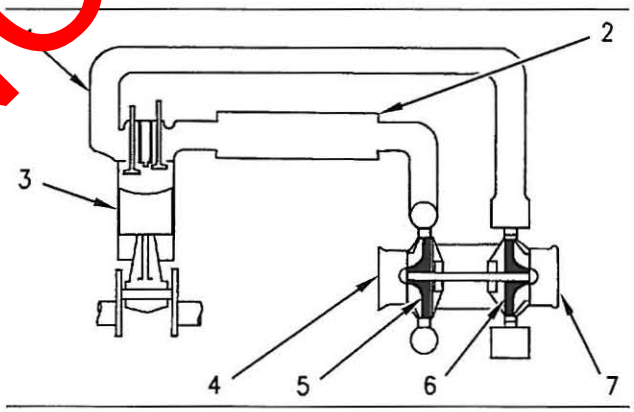

Illustration 7 g00281646

Air inlet and exhaust system (typical example)

(1) Exhaust manifold
(2) Intake manifold
(3) Engine cylinders
(4) Air intake
(5) Turbocharger compressor wheel
(6) Turbocharger turbine wheel
(7) Exhaust outlet

Engines which are naturally aspirated pull outside air through an air cleaner directly into the inlet manifold (2). The air flows from the intake manifold to the engine cylinders (3). The fuel is mixed with the air in the engine cylinders. After the fuel combustion occurs in the engine cylinder, 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 turbocharger compressor wheel (5). Then, the turbocharger compressor wheel compresses the air. The air flows through the intake manifold (2) which 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. Then, the air is mixed with fuel from the fuel injectors.

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.

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 turn. Then, the exhaust gases flow through the exhaust outlet (7) of the turbocharger to the outside.

The air inlet system is also equipped with a crankcase ventilation system. The intake strokes of the pistons pull in atmospheric air to the crankcase.

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.

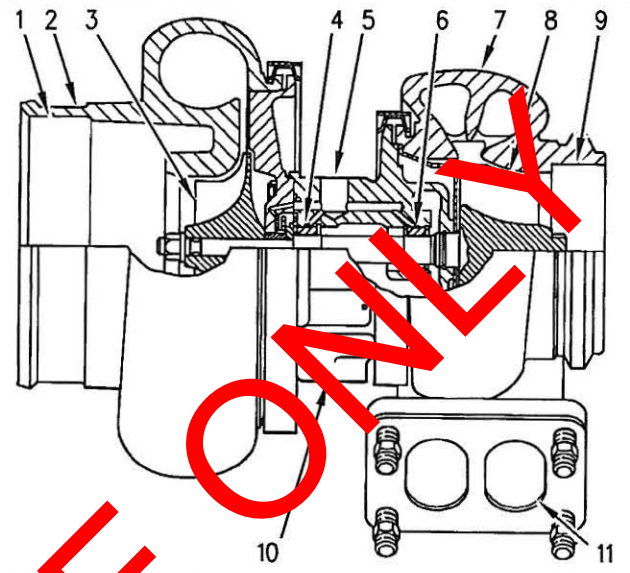

Illustration 8 g00302786

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 rpm. The compressor wheel is enclosed by 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. The wastegate is controlled by the boost pressure. This allows some of the exhaust to bypass the turbocharger at higher engine speeds. The wastegate is a type of valve that automatically opens at a preset level of boost pressure in order to allow exhaust gas to flow around the turbine. 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 the manifold 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. Steel 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. The exhaust valve guide has a counterbore in order to prevent the seizure of the valve stem. The seizure of the valve stem is caused by a buildup of carbon 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

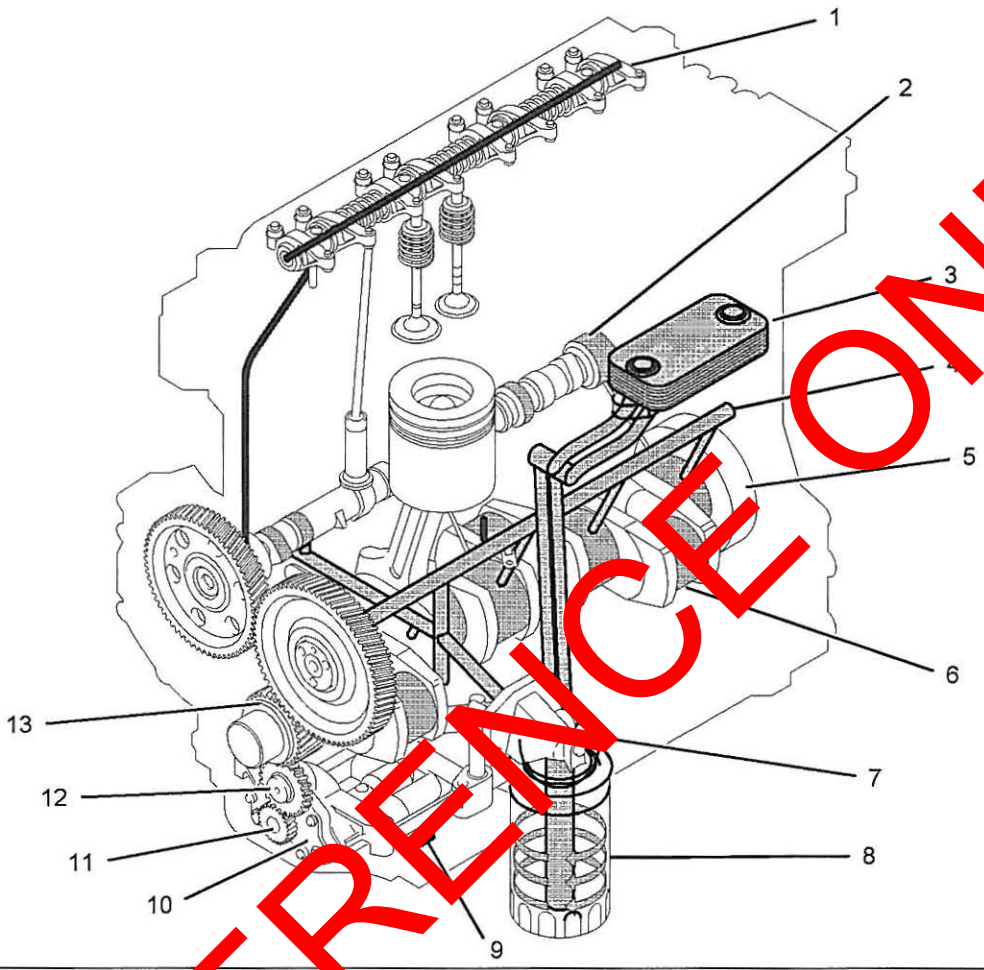

Illustration 9
g01009682

Flow diagram of the lubrication system for the 1104 engine

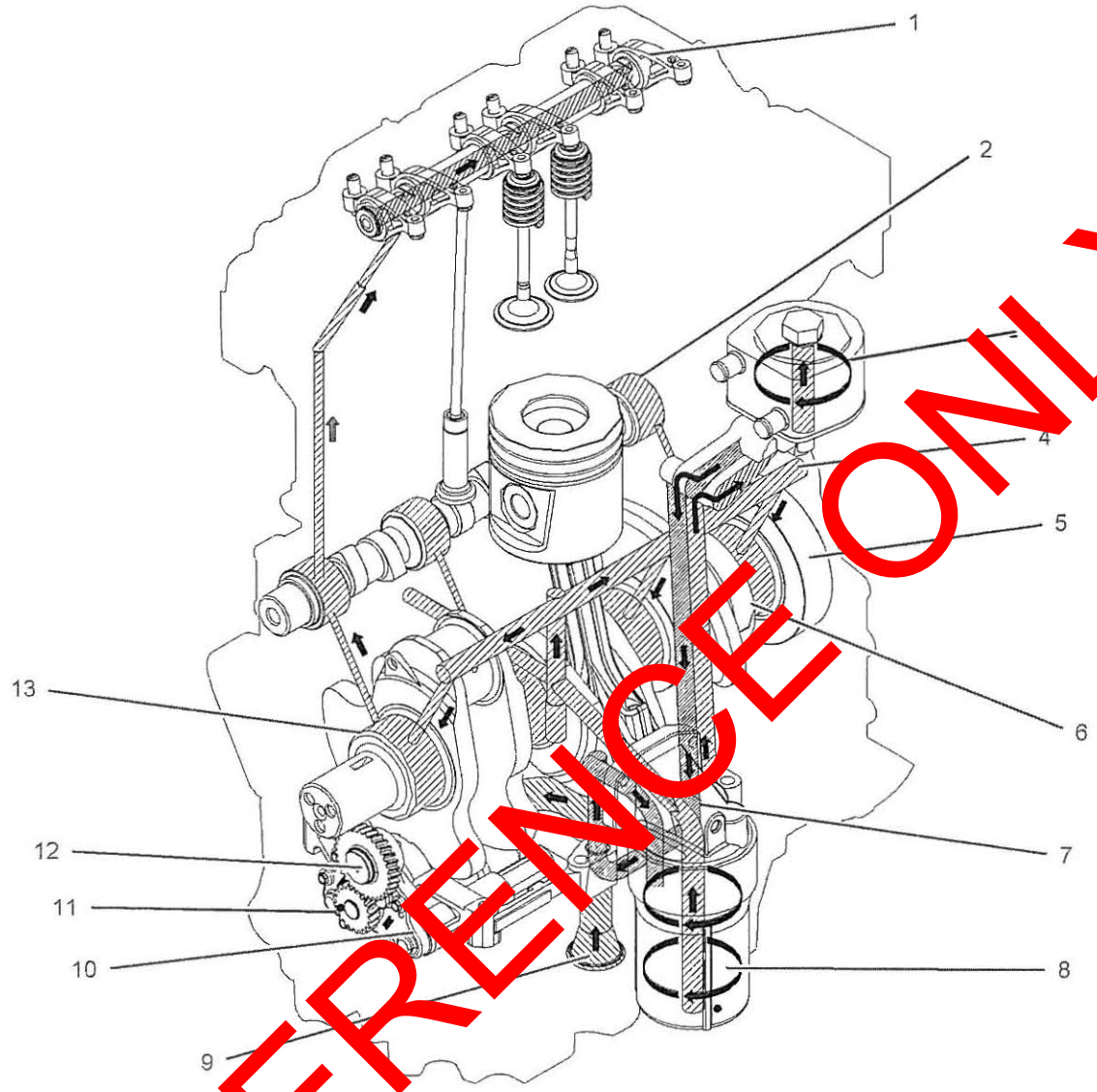

Illustration 10 g01016473

Flow diagram of the lubrication system for the 1103 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 the 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 1104 engine, or a modine oil cooler (3) for the 1103 engine. 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 second journal of the camshaft (2) 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

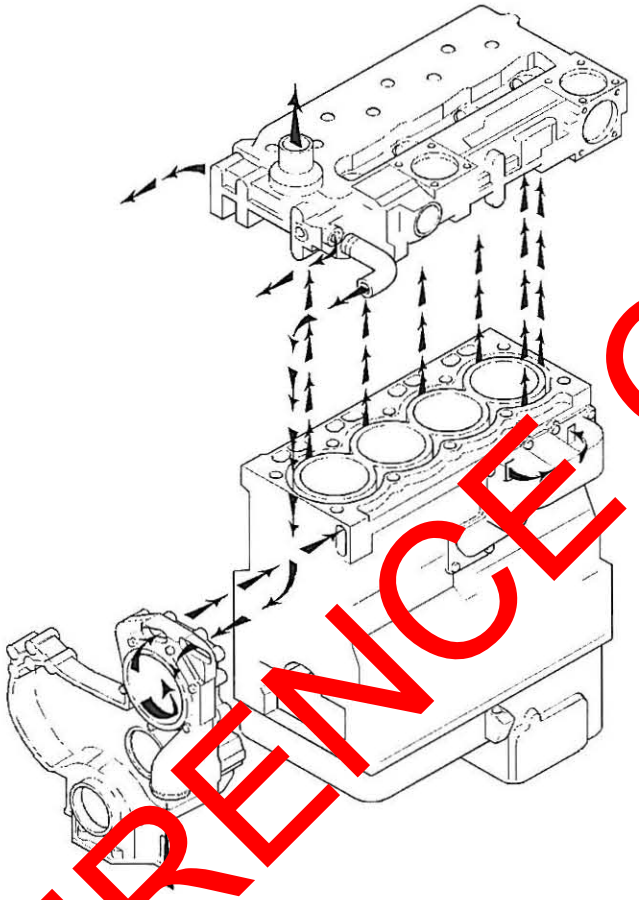

Illustration 11 g00985481

Flow diagram of the cooling system for the 1104 engine

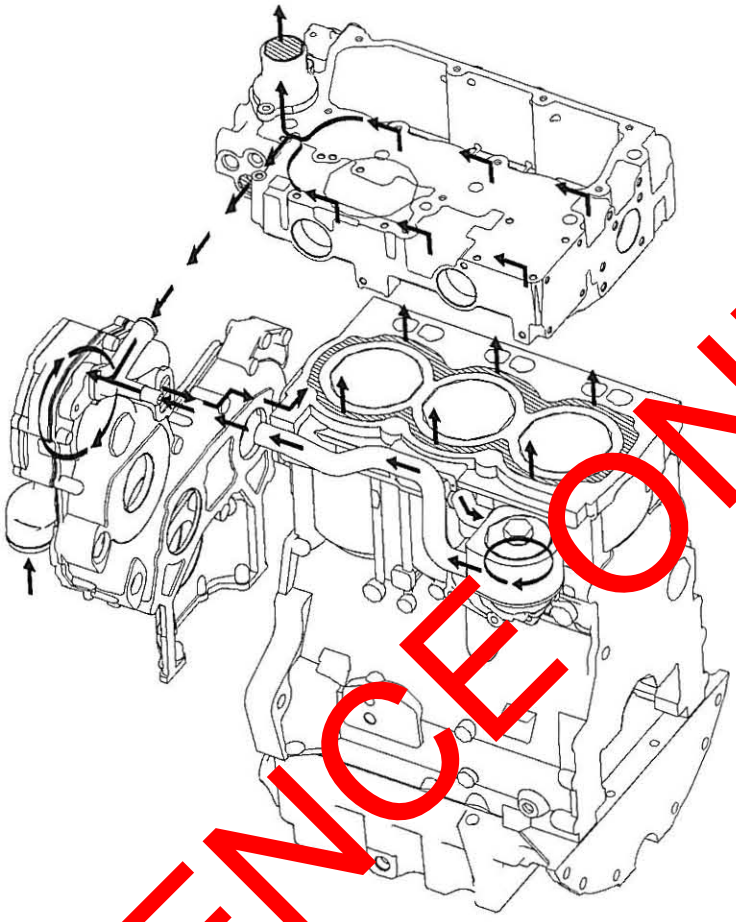

Illustration 12 g01016432

Flow diagram of the cooling system for the 1103 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.

1103 engines

From the rear of the cylinder block, some of the coolant passes into the modine oil cooler (if equipped). The modine oil cooler is located on the left side of the cylinder block. The coolant passes through the oil cooler before being returned through an external line to the inlet side of the water pump.

1104 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.

i02212837

Basic Engine

Cylinder Block and Cylinder Head

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

The cylinder block for the 1103 engine has three cylinders which are arranged in-line.

The cylinder block for the 1104 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.

The cylinder block for the 1103 engine has four main bearings which support the crankshaft. Thrust washers on both sides of the number three 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

Lip type 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.

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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

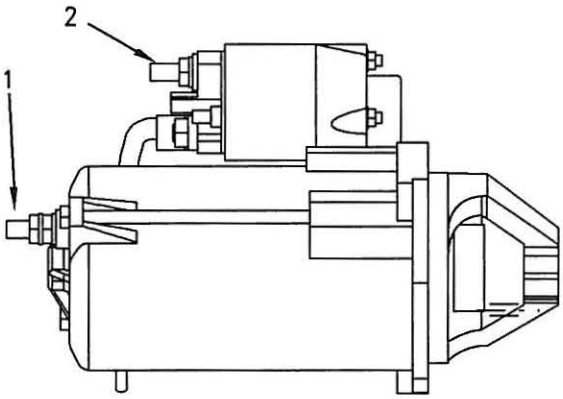


Illustration 13

12 Volt Starting Motor

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

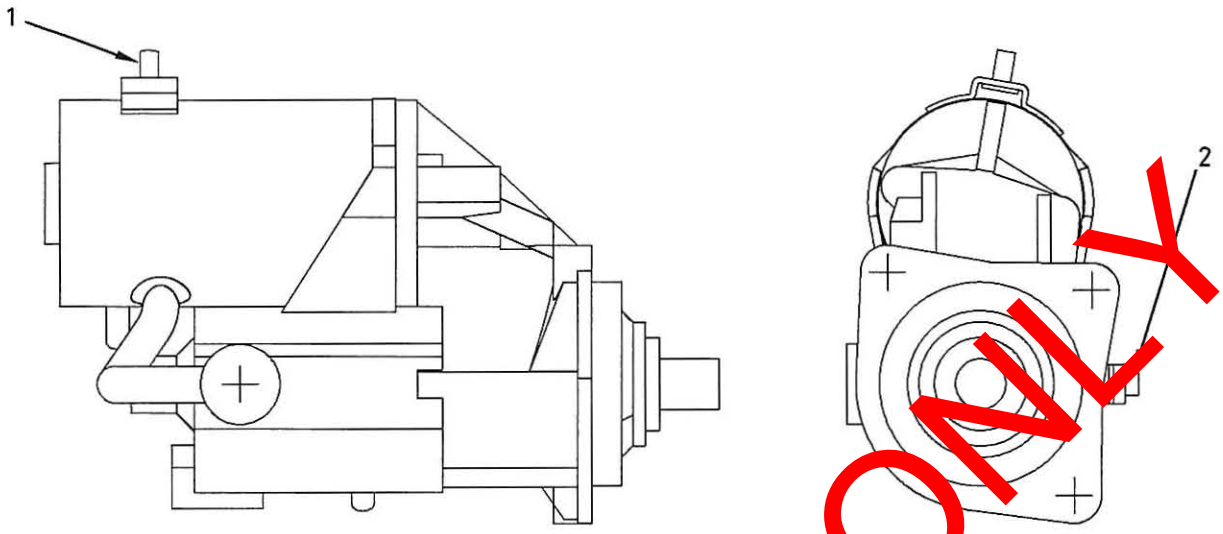


Illustration 14 g00956095

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

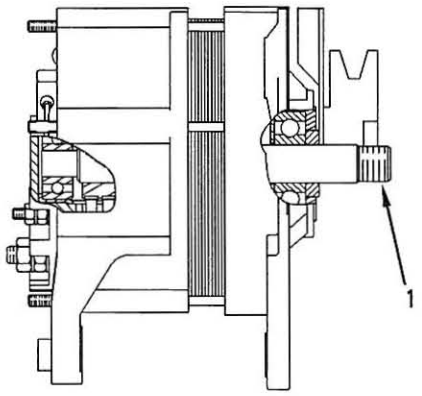


Illustration 15 g00303424

(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".

i01854200

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

   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.

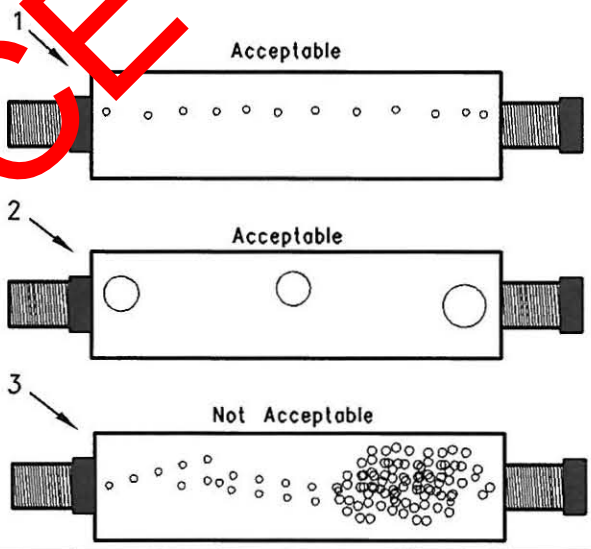


Illustration 16 g00578151

(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 not seen at the inlet to the fuel transfer pump, the air is entering the system after the fuel transfer pump. Refer to the Testing and Adjusting, "Fuel System - Prime".

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

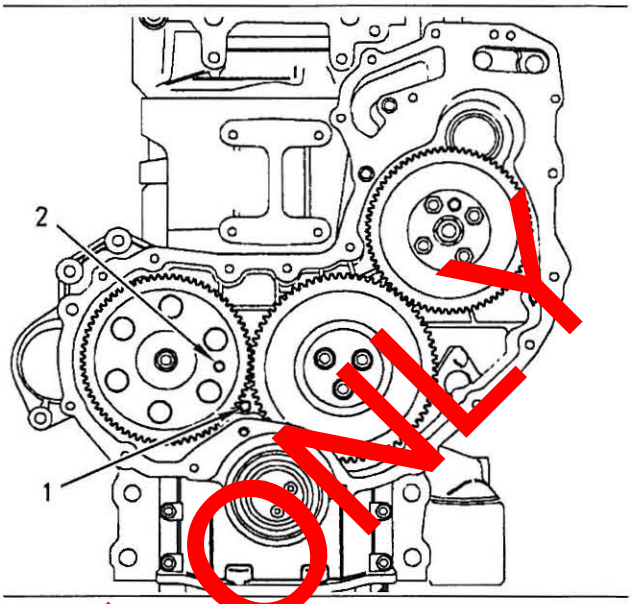


Illustration 17 g00923080

(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.

i02212983

Fuel Injection Pump Timing - Check

Delphi DP210, Delphi DPA, Delphi DPG and Delphi STP Fuel Injection Pumps

Note: The Delphi DP210, Delphi DPA, Delphi DPG and Delphi STP 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.

Note: The Delphi DPA fuel injection pump is only installed on the 1104 engine.

Delphi DP210, Delphi DPA, Delphi DPG and Delphi STP 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.

Bosch EPVE Fuel Injection Pump

Note: The Bosch EPVE fuel injection pump is only installed on the 1104 engine.

Table 2

Required Tools		
Part Number	Part Description	Qty
27610248	Bosch EPVE fuel injection pump timing adapter	1

1. Set the number one piston at the top center piston on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Piston" for the procedure.

2. Remove the high pressure fuel lines from the fuel injection pump.

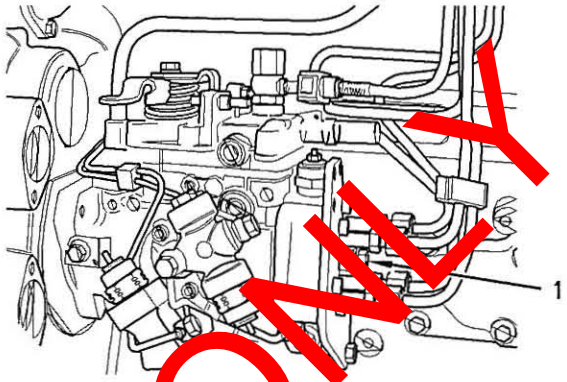


Illustration 18 g00988405

(1) Plug

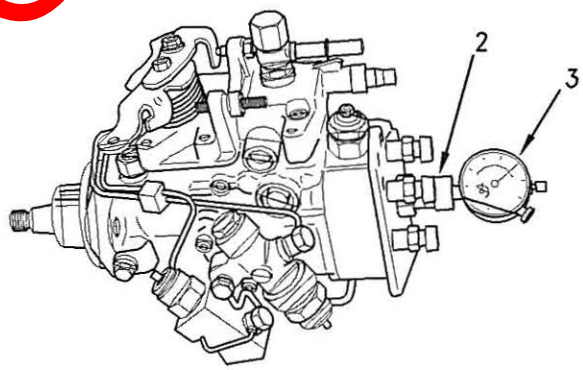


Illustration 19 g00988406

(2) Bosch EPVE fuel injection pump timing adapter
(3) Dial indicator

3. Remove the plug (1) and the washer from the rear of the fuel injection pump and install 27610248 fuel injection pump timing adapter (2). Install a suitable dial indicator (3) into 27610248 fuel injection pump timing adapter. Set the dial indicator to approximately 3 mm (0.1181 inch).

4. Rotate the crankshaft counterclockwise until the dial indicator (3) indicates that the plunger of the fuel injection pump is at the bottom of the stroke. Set the dial indicator (3) to zero.

5. Rotate the crankshaft clockwise, until the crankshaft timing pin can be pushed into the hole in the crankshaft web.

6. With the engine set at the Top Center Position for the No. 1 piston, check the reading on the dial indicator (3). Refer to Specifications, "Fuel Injection Pump" for the correct reading for the plunger.

7. If the fuel injection pump timing is correct remove the dial indicator (3). Remove 27610248 fuel injection pump timing adapter from the fuel injection pump. Install a new washer to the plug and install the plug in the back of the fuel injection pump. Refer to Specifications, "Fuel Injection Pump" for the correct torque.

8. Install the high pressure fuel lines on the fuel injection pump. Eliminate all air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

9. If the fuel injection pump timing is incorrect, refer to Testing and Adjusting, "Fuel Injection Pump Timing - Adjust".

i02213688

Fuel Injection Pump Timing - Adjust

Delphi DP210, Delphi DPA, Delphi DPG and Delphi STP Fuel Injection Pumps

The Delphi DP210, Delphi DPA, Delphi DPG and Delphi STP 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 can not be made to the fuel pump.

Bosch EPVE Fuel Injection Pump

Note: The Bosch EPVE fuel injection pump is only installed on the 1104 engine.

Table 3

Required Tools		
Part Number	**Part Description**	**Qty**
27610248	Bosch EPVE fuel injection pump timing adapter	1

Note: This procedure must only be carried out by a person with the correct training.

Note: Do not rotate the fuel injection pump if the fuel injection pump shaft is locked.

1. Set the number one piston at the top center on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Pistion" for the procedure.

2. Remove the rocker shaft. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods".

3. Remove the high pressure fuel lines from the fuel injection pump.

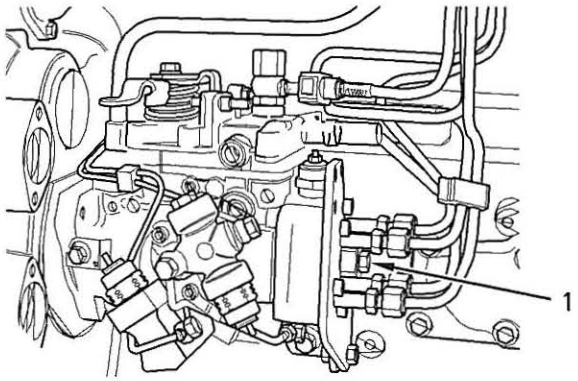


Illustration 20 g00996226

(1) Plug

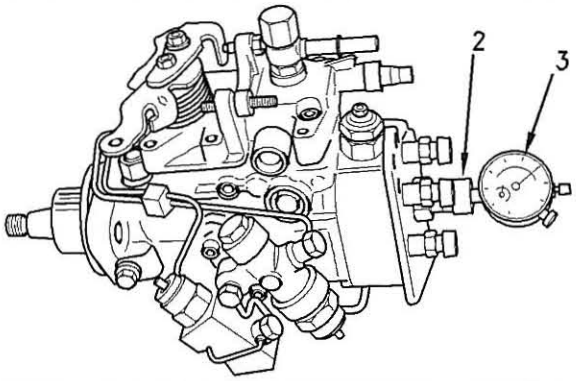


Illustration 21 g00996227

(2) Bosch EPVE fuel injection timing adapter
(3) Dial indicator

4. Remove the plug (1) and the washer from the rear of the fuel injection pump and install the 27610248 fuel injection pump timing adapter (2). Install a suitable dial indicator (3) into the 27610248 fuel injection pump timing adapter. Set the dial indicator to approximately 3 mm (0.1181 inch).

5. Ensure that the timing pins have been removed from the engine.

6. Rotate the crankshaft counterclockwise when the crankshaft is viewed from the front of the engine. Carefully rotate the crankshaft until the dial indicator (3) indicates that the plunger of the fuel injection pump is at the bottom. Set the dial indicator (3) to zero.

7. Rotate the crankshaft clockwise until the required lift on the plunger is achieved. Refer to Specifications, "Fuel Injection Pump" for the correct reading.

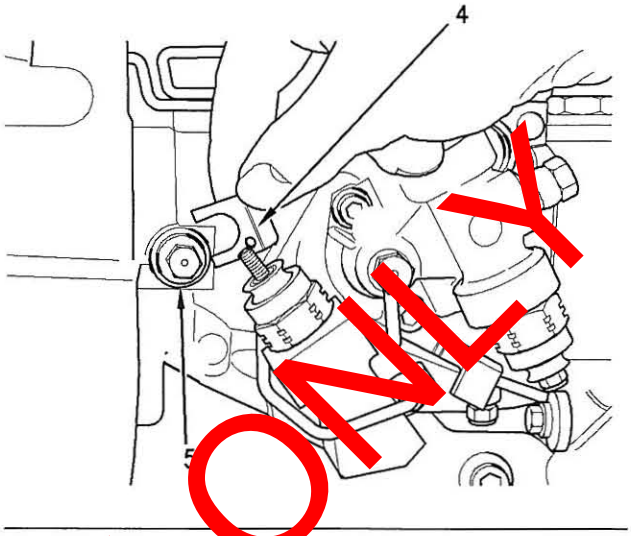


Illustration 22 g00996240

(4) Washer
(5) Locking screw

8. Lock the fuel injection pump shaft. In order to lock the shaft of the Bosch EPVE fuel injection pump, loosen the locking screw (5) and remove the washer (4). Tighten the locking screw to 31 N·m (23 lb ft). Ensure that the needle of the dial indicator has not moved.

9. Remove the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove and Install".

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

11. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection pump - Remove".

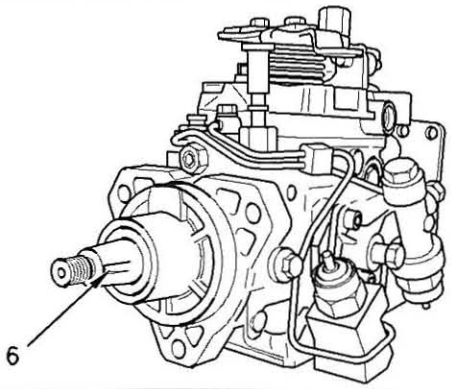


Illustration 23 g00996242

(6) Keyway

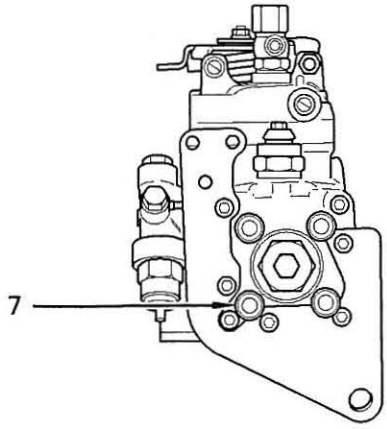


Illustration 24 g00996245
(7) Outlet

Note: A key should not be installed in the keyway (6).

Note: If the fuel injection pump is on the correct stroke, the keyway (6) is toward the outlet (7).

12. Set the number one piston at the top center piston on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Pistion" for the procedure.

13. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

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

15. Install the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove and Install".

16. Install a new washer to the plug and install the plug in the back of the fuel injection pump. Refer to Specifications, "Fuel Injection Pump" for the correct torque.

17. Install the rocker shaft. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods".

18. Install the high pressure fuel lines on the fuel injection pump. Eliminate all air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

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

i02214029

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 DP210, Delphi DPA, Delphi DPG and Delphi STP

The Delphi DP210, Delphi DPA, Delphi DPG and Delphi STP 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.

Bosch EVPE

The Bosch EPVE fuel injection pump will not eliminate air automatically from the fuel system. the following procedure must be used.

- Remove the valve mechanism cover.
- Turn the start switch to the RUN position for three minutes. Then return the start switch to the OFF position.
- Loosen the high pressure lines at the fuel injectors.
- Operate the starting motor until fuel free from air comes from the connections.
- Tighten the connections for the fuel injectors. Refer to Specifications, "Fuel Injection Lines".
- Operate the engine and check for leaks.
- Fit the valve mechanism cover.

i02214768

Fuel System Pressure - Test

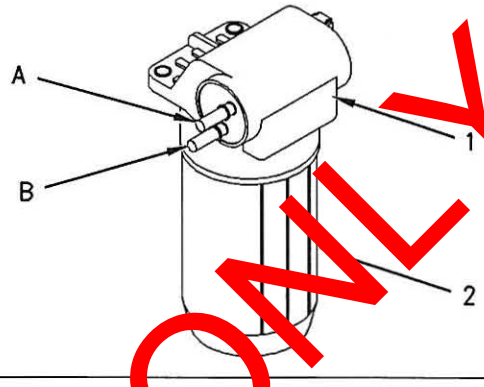


Illustration 25 g00928705

(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. Run the engine at idle for two minutes in order to remove any trapped air.

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

i01822825

Air Inlet and Exhaust System - Inspect

A general visual inspection should be made to 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 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.

i01935833

Wastegate - Test

⚠ 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.

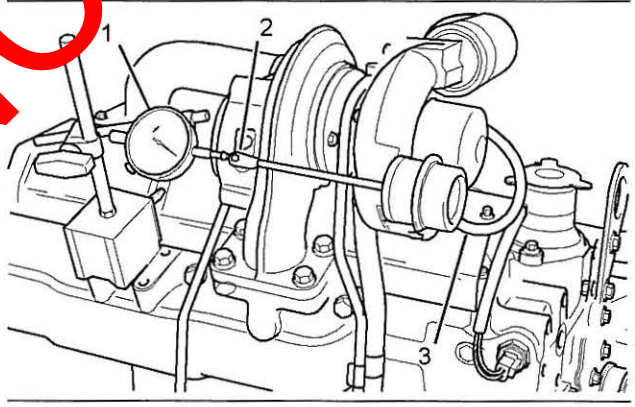


Illustration 26 g01009681

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

1. Use a suitable magnetic base dial indicator (1). Align the dial gauge to the actuator rod (2).
2. Remove the air hose to the actuator (3). Install an air line that can be adjusted in order to give the correct pressure.

Note: Do not exceed 205 kPa (30 psi) in order to check the actuator. Refer to the Specification, "Turbocharger" topic for information on the correct pressure setting for your actuator.

3. Carefully apply the air pressure until the air pressure has moved the rod 1 mm (0.0394 inch). Check that the air pressure is correct for your turbocharger.

4. For more information on installing a new turbocharger, contact your Perkins dealer or your Perkins distributor.

i01888954

Compression - Test

The cylinder compression test should only be used in order to compare the cylinders of an engine. 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.

i02214770

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. The temperature of the engine does not change the valve lash setting.

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

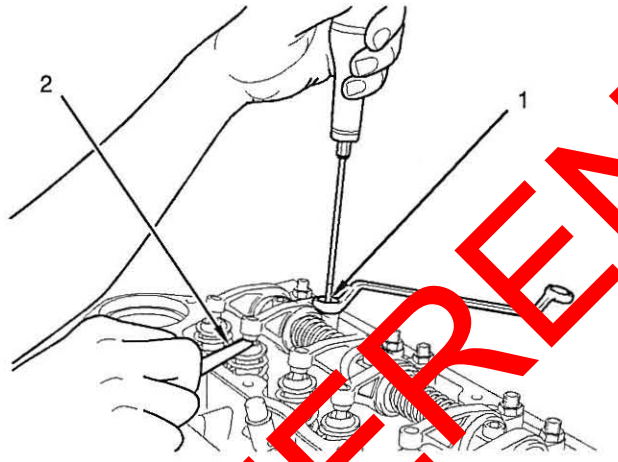


Illustration 27 g01016764

Setting the valve lash

(1) Adjustment screw
(2) Feeler gauge

Valve Lash Adjustment for the 1104 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 while adjustment screw (1) is being held from turning.

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 is 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”.

Valve Lash Adjustment for the 1103 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. 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 of No. 2 cylinder and the exhaust valve of No. 3 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 while adjustment screw (1) is being held from turning.

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 for No. 3 cylinder and the exhaust valve for No. 1 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. 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 for No. 1 cylinder and the exhaust valve for No. 2 cylinder.

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

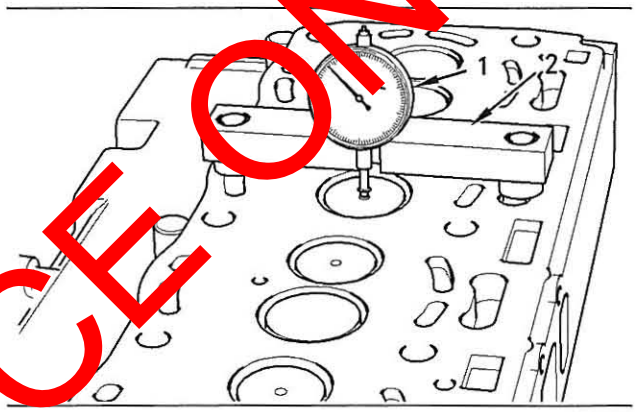
5. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i01889422

Valve Depth - Inspect

Table 4

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



g00983531

Illustration 28
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.

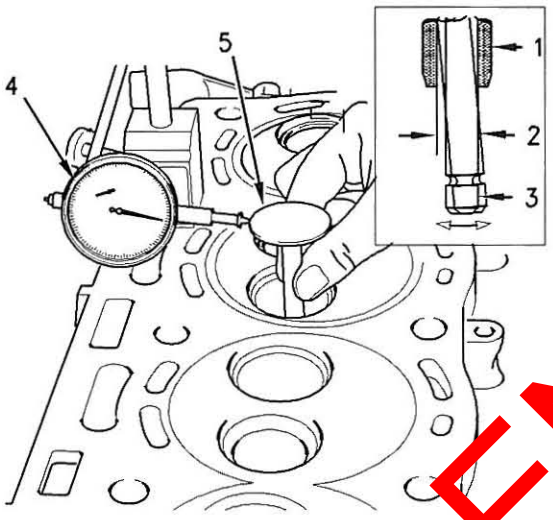
   If the valve depth below the cylinder head face exceeds the service limit, use a new valve to check the valve depth. If the valve depth still exceeds the service limit, renew the cylinder head or renew the valve seat inserts (if equipped). If the valve depth is within the service limit with a new valve, 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 29

(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 surface of the cylinder head.

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

i01893791

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 for clearances and torques.

Refer to the Specifications Module, "Engine Oil Pump".

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.

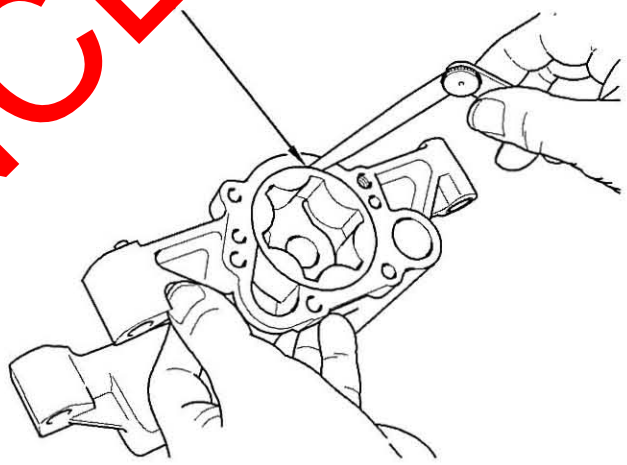


Illustration 30 g00985779

Clearance for the outer rotor body

(1) Measure the clearance of the outer rotor to the body.

3. Install the outer rotor. Measure the clearance of the outer rotor to the body (1).

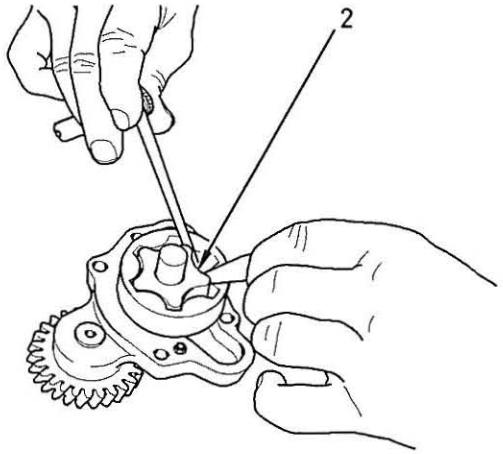


Illustration 31 g00985780

Clearance for the inner rotor

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

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

Illustration 32 g00989217

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. Refer to Disassembly and Assembly, “Engine Oil Pump - Install”.

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.

i01794028

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

i01892576

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. 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.

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. 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 combustible 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 33. 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.

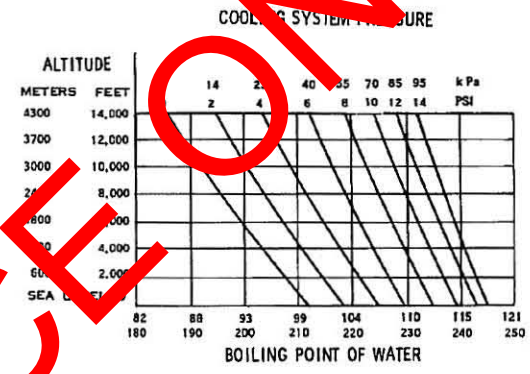


Illustration 33 g00286266

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.

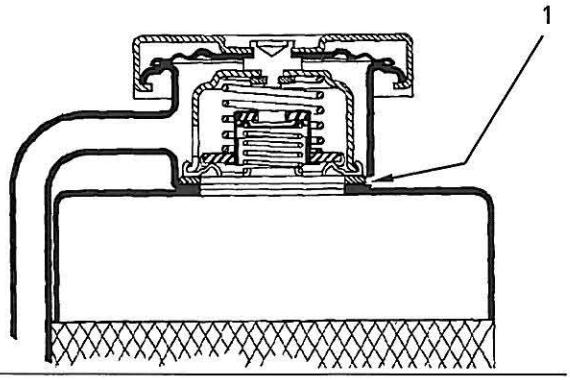


Illustration 34 g00296067

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 to 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.

i01956505

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 1104 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.

Modine oil cooler for the 1103 engine

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

1. Place a container under the modine oil cooler in order to collect any engine oil or coolant that drains from the modine oil cooler.
2. Refer to Disassembly and Assembly, "Engine Oil Cooler - Remove" for removal of the engine oil cooler.
3. Thoroughly clean the outside of the cooler plates with a suitable cleaning fluid.

⚠ 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. Thoroughly clean the inside of the cooler plates with clean water.

   Dry the cooling plate with low pressure air. Flush the inside of the cooling plate with clean lubricating oil.
5. Install the modine oil cooler. Refer to Disassembly and Assembly, "Engine Oil Cooler - Install".
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 3 g00905732

(1) Feeler gaug
(2) Pi ton ring
(3) iston grooves

2. Place 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

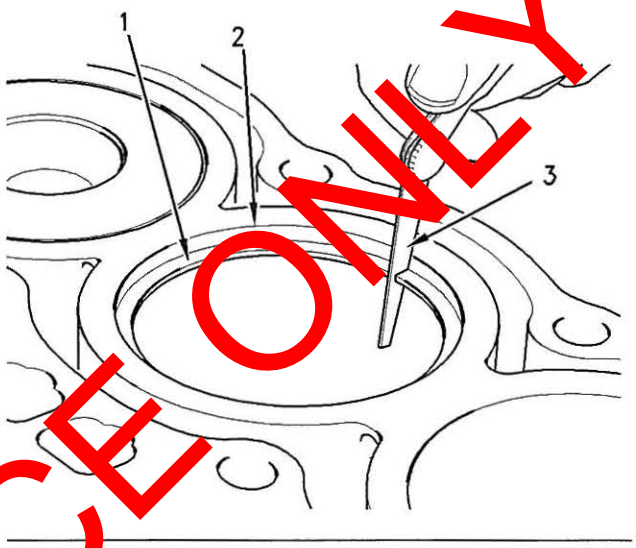


Illustration 36 g00983549

(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.

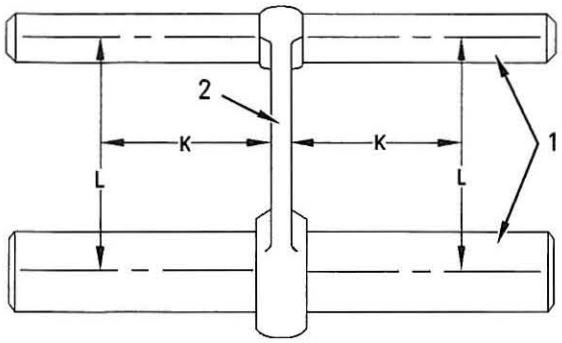
Note: The coil spring must be removed from the oil control ring before the gap of the oil control ring is measured.

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 37

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.

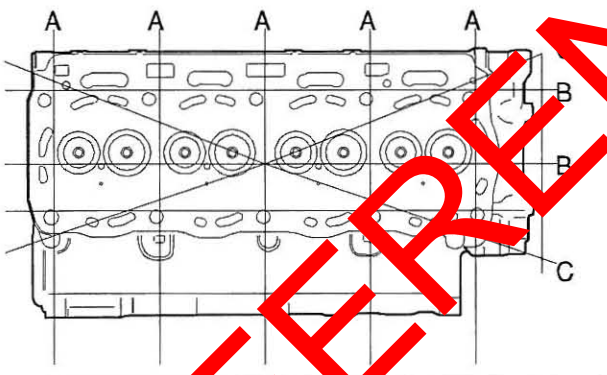
3. The top deck of the cylinder block must not be machined. This will affect the piston height above the cylinder block.

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”.

i01905914

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 38

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.

Remachining 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 (4.61 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 5

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.

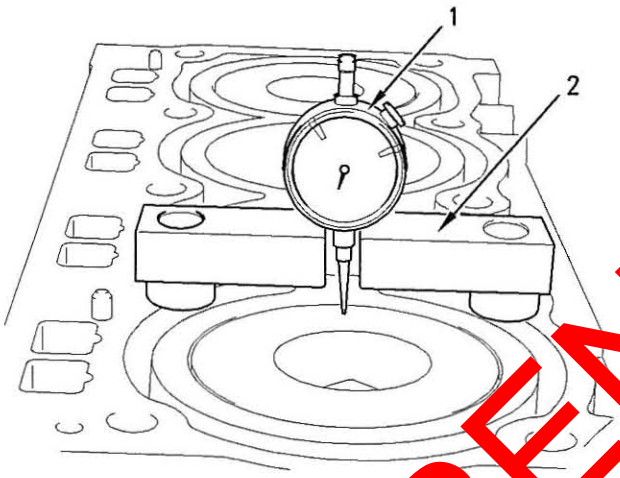


Illustration 39 g00983585

(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

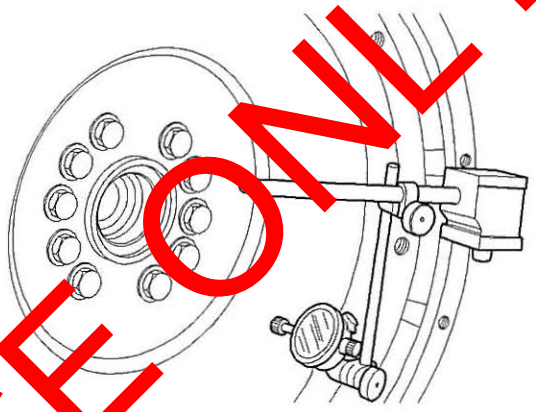


Illustration 40 g00987751

1. Install the dial indicator. Refer to Illustration 40.
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

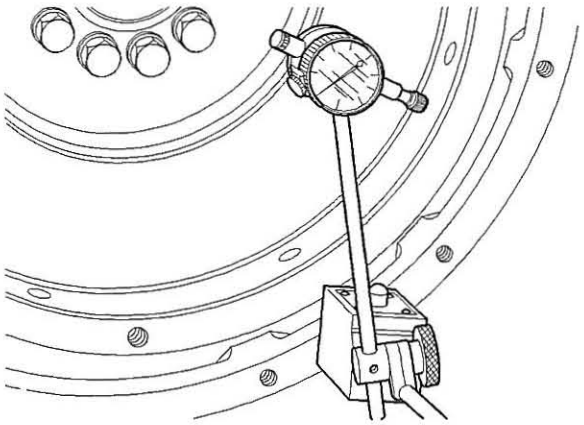
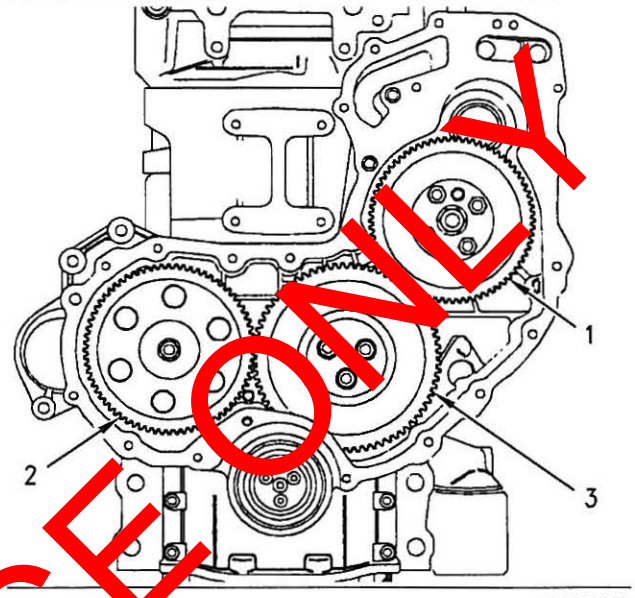


Illustration 41 g00987752

1. Install the dial indicator. Refer to Illustration 41.
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).

i01958093

Gear Group - Inspect



g00918708

Illustration 42
(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

i01899123

Alternator - Test

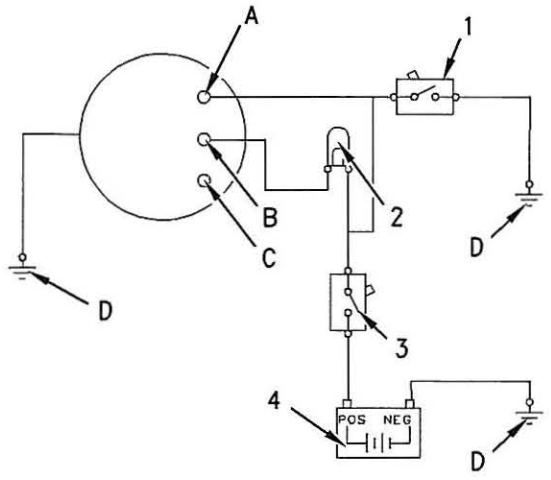


Illustration 43 g00931045

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 filament 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.

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.

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 6

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 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 7

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 7 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 6, then go to Step 2.

   b. The battery voltage is less than the voltage in Table 6.

      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 6.
- 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 6, 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 6. 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 7.

   b. Voltage drops are equal to the voltage drops that are given in Table 7 or the voltage drops are less than the voltage drops that are given in Table 7. 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 7. 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 8

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

Table 9

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.

i01955101

V-Belt - Test

Table 10

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 belt that is farthest from the engine.			

(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

1. Check the belts for wear and check the belts for damage. Belts must always be changed as a pair.

2. Fit a suitable Burroughs gauge at the center of the longest free length of the belt and check the tension on both belts. Check and adjust the tension on the tightest belt. To adjust the belt tension, see Disassembly and Assembly Manual, “Alternator - Install”.

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Specifications

1103 and 1104E Engines

DC (Engine)
DD (Engine)
DJ (Engine)
DK (Engine)
RE (Engine)
RG (Engine)
RJ (Engine)
RR (Engine)
RS (Engine)
DF (Engine)
DG (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 have the most current information available.

⚠ WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

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

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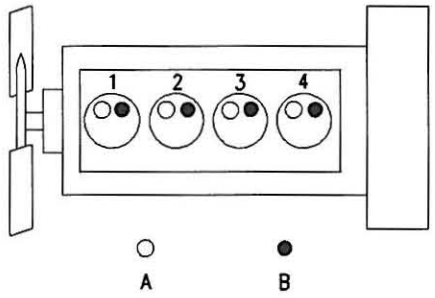
Engine Design

Four Cylinder Engine



g00984281

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 in³)

Cylinder arrangement ..... In-line

Type of combustion ..... Direct injection

Compression ratio

Naturally aspirated engines 19.3:1
Turbocharged engines 18.2:1
Turbocharged engines 17.2:1

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)

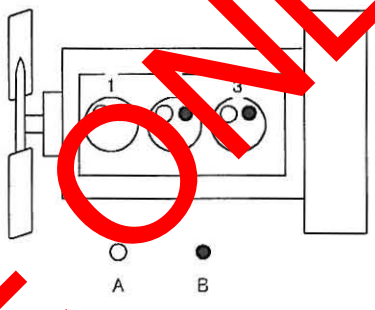
Firing order 1, 3, 4, 2

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.

Three Cylinder Engine



g01014247

Illustration 2

Cylinder and valve location

(A) Inlet valve
(B) Exhaust valve

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

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

Displacement ..... 3.3 L (201 in³)

Cylinder arrangement ..... In-line

Type of combustion ..... Direct injection

Compression ratio

Naturally aspirated engines 19.3:1
Turbocharged engines 18.2:1
Turbocharged engines 17.2:1

Number of cylinders 3

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, 2, 3

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.

i01914111

Fuel Injection Lines

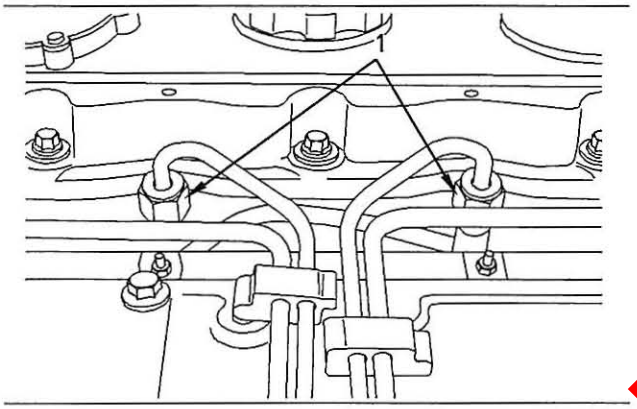


Illustration 3 g00923498

A typical fuel line

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

Note: Tighten the union nuts at the fuel injection pump to the following torque.30 N·m (22 lb ft)

i02199305

Fuel Injection Pump (Delphi DP210 DP310 and DPG fuel injection pumps)

Delphi DP210

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.

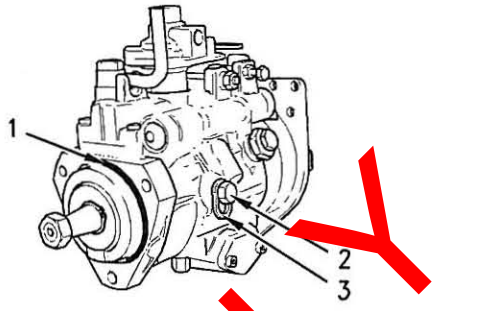


Illustration 4 g00922601

The Delphi DP 210 fuel injection pump

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)

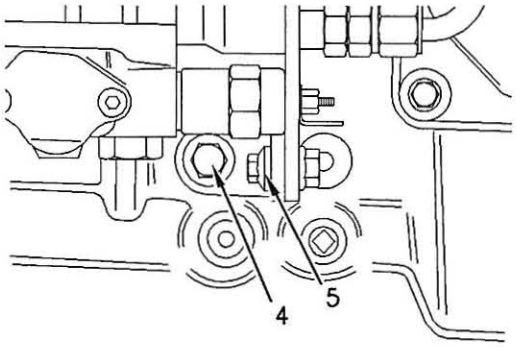


Illustration 5 g00986531

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)

Delphi DPA

The DPA injection pump has a support bracket that is similar to the DP 210 injection pump.

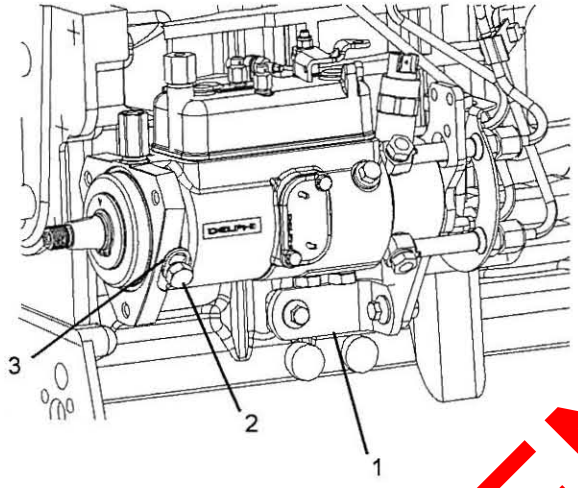


Illustration 6

(1) Support bracket
(2) Locking screw
(3) Washer

Note: The torque for the locking screw on the Delphi STP fuel injection pump and the Delphi DPA and DPG fuel injection pump is equal. The support bracket is larger on the Delphi DPA fuel injection pump. The torque for the mounting bolts on the support bracket for both fuel injection pumps is equal.

Delphi DPG

The DPG injection pump is only installed on engines that operate at a fixed speed. The support bracket is not installed on this injection pump.

i02074846

Fuel Injection Pump (Bosch EPVE for the 1104 engines only)

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 properly timing the engine and locking the shaft, the fuel injection pump will need to be timed by trained personnel.

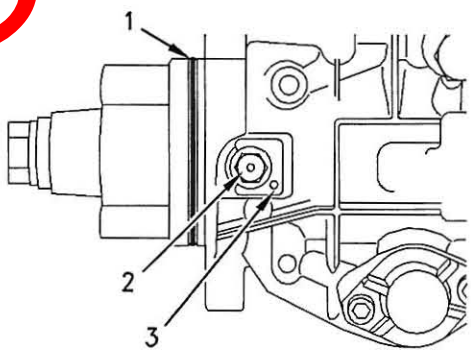


Illustration 7 g00986530

Bosch EPVE fuel injection pump

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) Spacer

Locking the shaft

Remove spacer (3) before locking screw (2) is tightened to the following torque. ..... 31 N·m (23 lb ft)

Unlocking the shaft

Loosen the bolt and place spacer (3) behind locking screw (2). Tighten the bolt to the following torque. ..... 12 N·m (9 lb ft)

The lift of the ER fuel injection pump plunger ..... 1.55 mm (0.0610 inch)

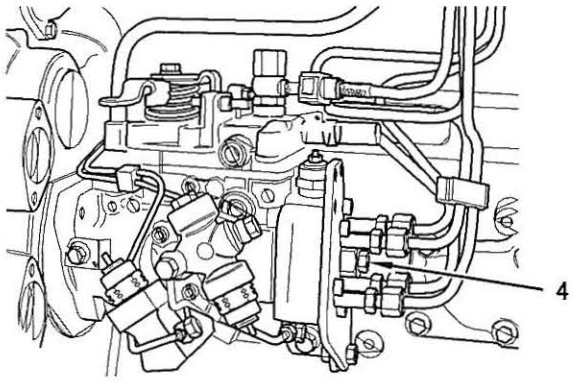


Illustration 8 g00988408
Installed EVEP fuel injection pump

(4) Tighten the plug for the fuel injection pump plunger to the following torque. ..... 29 N·m (21 lb ft)

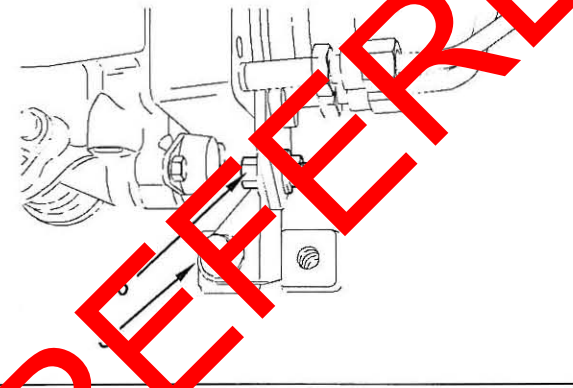


Illustration g00986295
Support bracket

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 (5) and then tighten the nut and the bolt (6). Tighten the bolt (5).

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

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

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

i02074902

Fuel Injection Pump (Delphi STP)

Note: Before the fuel injection pump is removed from the engine the fuel injection pump shaft must be locked. Position the engine to TDC 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 is removed prior to correctly timing the engine and locking the shaft, the fuel injection pump will need to be timed by trained personnel.

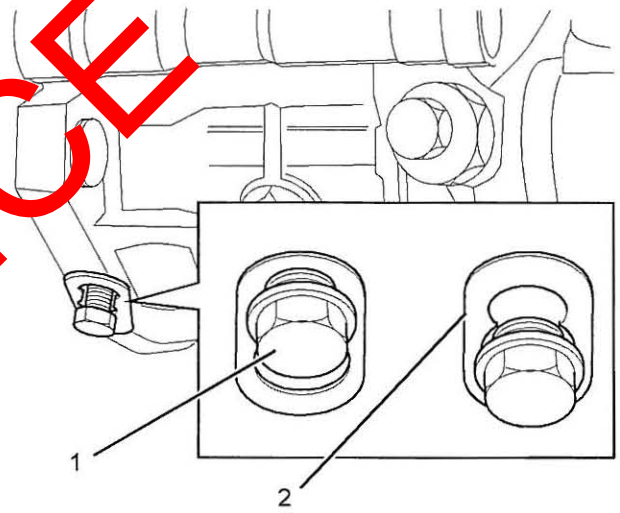


Illustration 10 g01061708
The Delphi STP fuel injection pump

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

(1) Locking screw

(2) Washer

Locking the shaft

Loosen locking screw (1) and move the washer (2) to the locked position. Tighten the bolt to the following torque. ..... 13 N·m (10 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)

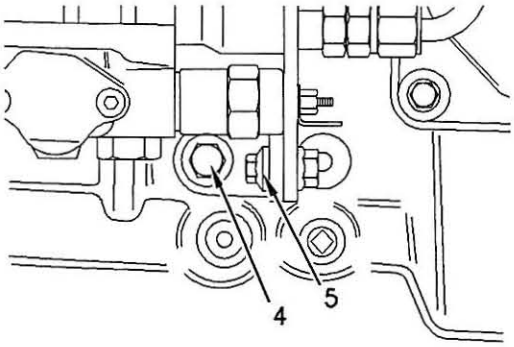


Illustration 11 g00986531

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 f housing to the following torque. ..... 25 N·m (18 lb ft)

i02207945

Fuel Injectors

Illustration 12 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)

i01957629

Fuel Transfer Pump

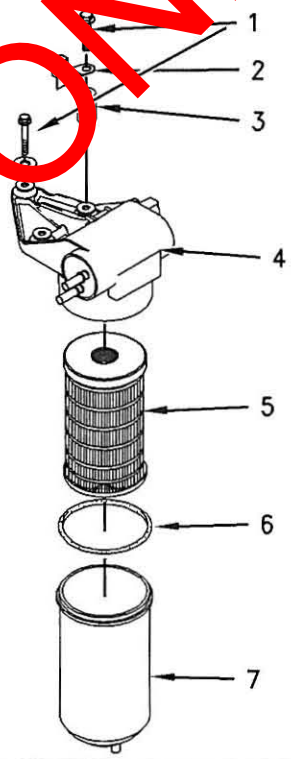


Illustration 13 g00986823

(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.

i01714153

Lifter Group

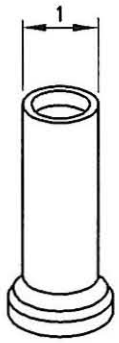


Illustration 14 g00629433

(1) Diameter of the lifter body .... 18.99 to 19.01 mm (0.7475 to 0.7485 inch)

Clearance of the lifter in the cylinder block bore ..... 0.04 to 0.09 mm (0.0015 to 0.0037 inch)

i01892700

Rocker Shaft

Note: The rocker shaft assembly for the 3 cylinder engine and the rocker shaft assembly for the 4 cylinder engine use the same components. The exception is the length of the rocker shaft.

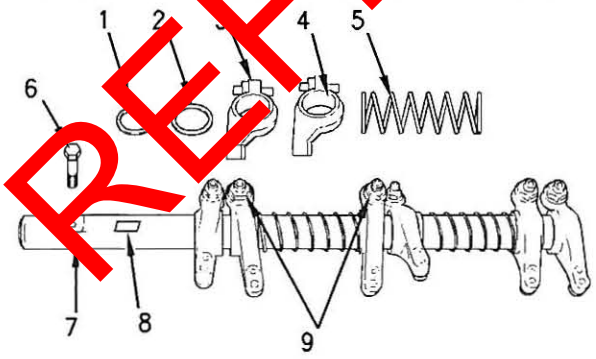


Illustration 15 g00985174

The rocker shaft

Note: In order to install the rocker shaft assembly, the tool 27610227 Spacing Toolis required.

(1) Snap ring

(2) Washer

(3) Rocker arm

(4) Rocker arm bore

Diameter of the rocker arm bore for the bushing ..... 25.01 to 25.05 mm (0.9847 to 0.9862 inch)

Rocker arm bushing

Clearance between the rocker arm bushing and the rocker shaft ..... 0.04 to 0.09 mm (0.0016 to 0.0035 inch)

Maximum permissible clearance between the rocker arm bushing 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 .. 24.96 to 24.99 mm (0.9827 to 0.9839 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)

i01948695

Valve Mechanism Cover

The Cover for the Four Cylinder Engine

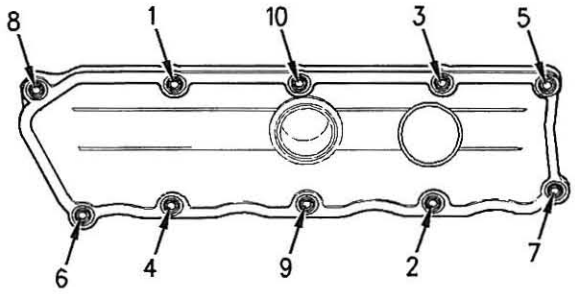


Illustration 16 g00908011

Cover

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

The Cover for the Three Cylinder Engine

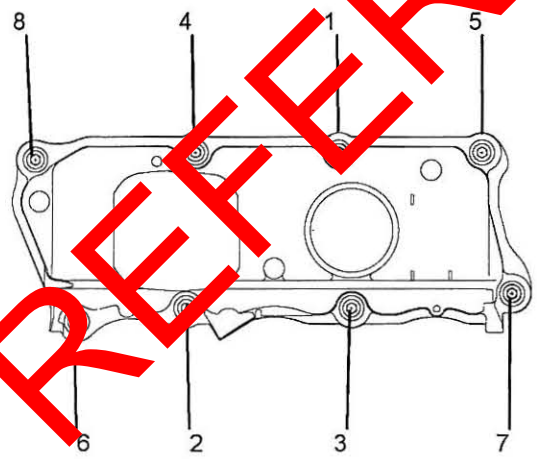


Illustration 17 g01018519

Cover

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

i01958092

Cylinder Head Valves

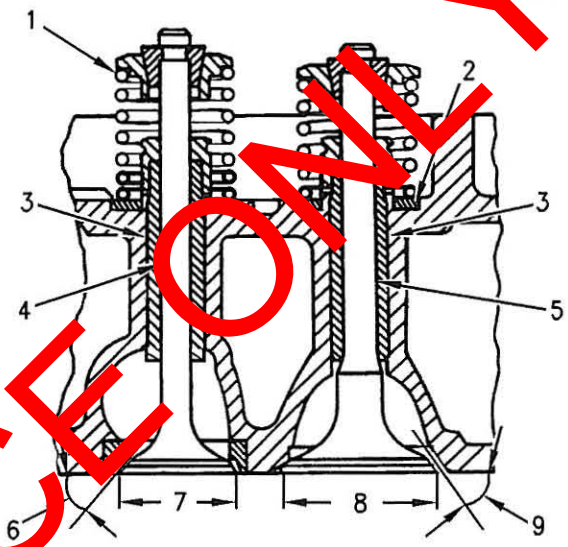


Illustration 18 g00294082

Cross section of cylinder head

(1) Valve spring

Naturally aspirated engines

The installed length of the valve springs ..... 33.5 mm (1.318 inch)

The load for the installed valve springs ..... 254 N (57.1 lb)

Turbocharged engines

The installed length of the valve springs ..... 34.5 mm (1.358 inch)

The load for the installed valve spring ..... 229 N (51.4 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 exhaust valve guide ..... 13.034 to 13.047 mm (0.5131 to 0.5137 inch)

Outside diameter of the inlet 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 the Disassembly and Assembly Manual 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 0.840 mm (0.0016 to 0.033 inch)

Overall length of the exhaust valve ..... 128.92 to 129.37 mm (5.075 to 5.093 inch)

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

Naturally aspirated engines ..... 0.53 to 0.81 mm (0.021 to 0.032 inch)

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

Turbocharged engine ..... 1.53 to 1.81 mm (0.060 to 0.071 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 ..... 128.92 to 129.37 mm (5.075 to 5.093 inch)

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

Naturally aspirated engines ..... 0.58 to 0.84 mm (0.023 to 0.033 inch)

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

Turbocharged engines ..... 1.58 to 1.84 mm (0.062 to 0.072 inch)

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

(6) Exhaust valve face angle from the vertical 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 ..... 46.20 to 46.45 mm (1.818 to 1.828 inch)

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

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

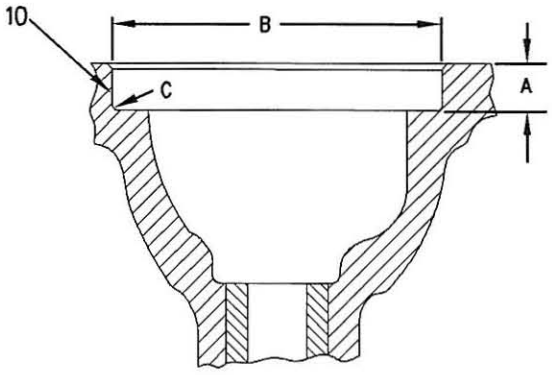


Illustration 19 g00809016
Recess for the valve seat insert

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

Recess for Inlet Valve Seat for Naturally Aspirated Engines

(A) .. 9.910 to 10.040 mm (0.3901 to 0.3952 inch)
(B) ..... 47.820 to 47.845 mm (1.8826 to 1.8836 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

Recess for Exhaust Valve Seat for Naturally Aspirated Engines

(A) .. 9.910 to 10.040 mm (0.3901 to 0.3952 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 Turbocharged Engines

(A) ..... 10.910 to 11.040 mm (0.4295 to 0.4346 inch)
(B) ..... 47.820 to 47.845 mm (1.8826 to 1.8836 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

Recess for Exhaust Valve Seat for Turbocharged Engines

(A) ..... 10.910 to 11.040 mm (0.4295 to 0.4346 inch)
(B) ..... 42.420 to 42.445 mm (1.6700 to 1.6710 inch)
(C) Maximum radius ..... 0.38 mm (0.015 inch)

i01899306

Cylinder Head

The maximum distortion of the cylinder head is g... in table 3.

Table 2

Required Tools		
Part Number	Part Description	Qty
21825607	Angle gauge	1

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

Four Cylinder engine

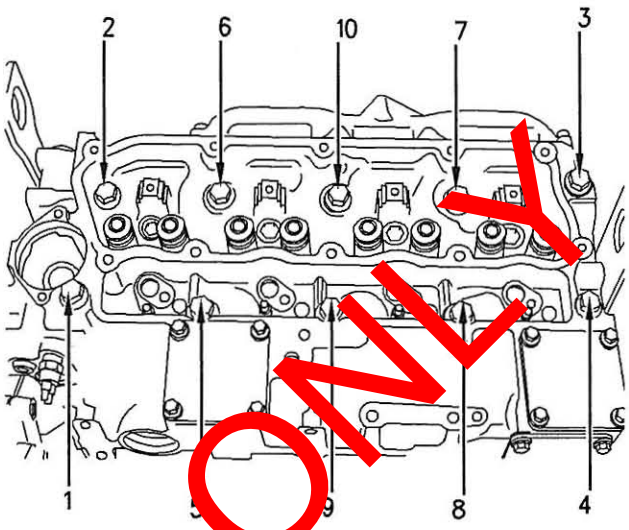


Illustration 20 g00987480

The tightening sequence

Three Cylinder engine

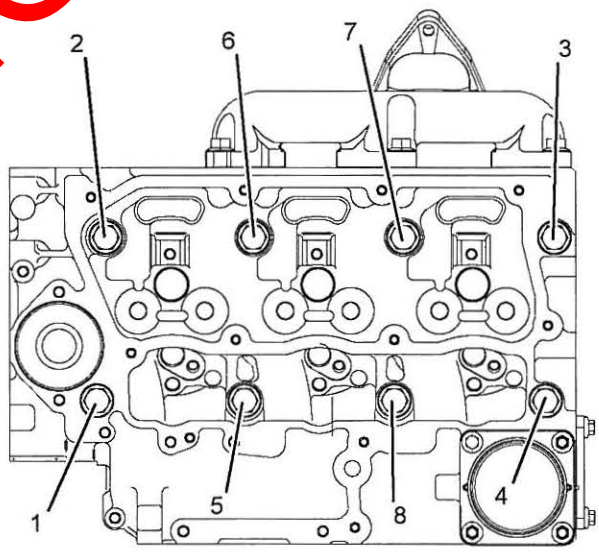


Illustration 21 g01017007

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)

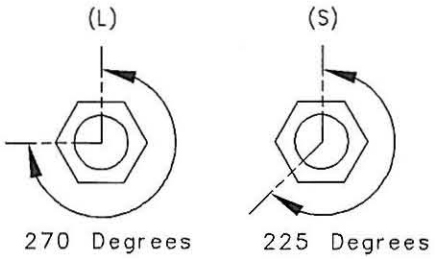


Illustration 22 g00905621

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 ..... 11[illegible].20 mm ([illegible].614 inch)

Note: The maximum distortion of the cylinder head is given in table 3.

Four Cylinder Engine

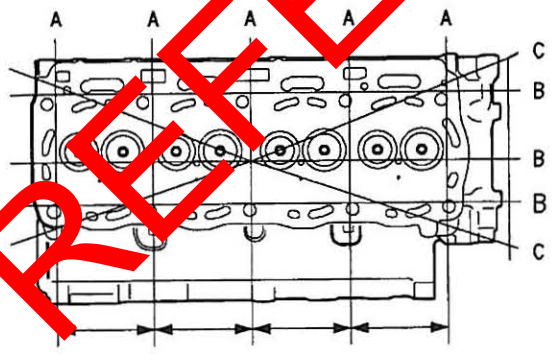


Illustration 23 g01006568

Three Cylinder Engine

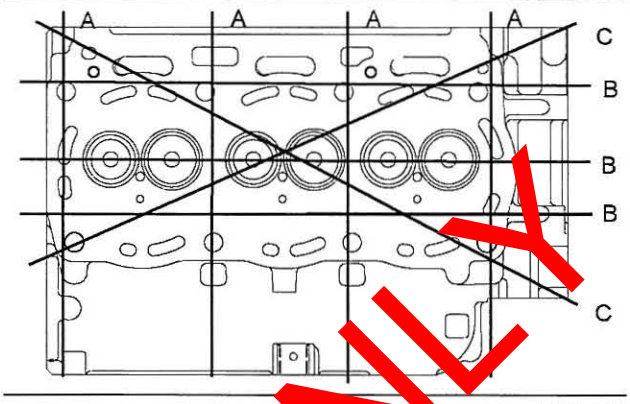


Illustration 24 g01017008

Table 3

Dimensi[illegible]	Maximum Permissible Distortion
Width (A)	0.03 mm (0.0018 inch)
L[illegible]gth (B)	0.05 mm (0.0019 inch)
Di[illegible]onal [illegible]ine (C)	0.05 mm (0.0019 inch)

i02224103

Turbocharger

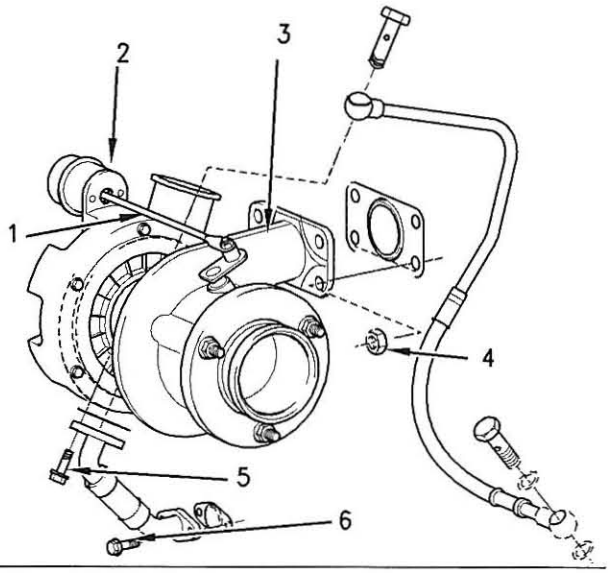


Illustration 25 g00991357

Typical turbocharger

(1) Actuator rod

(2) Actuator

(3) Turbocharger

(4) Tighten the nuts to the following torque. .. 47 N·m (34 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 waste gate ..... 205 kPa (30 psi)

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

Four Cylinder Engine

Table 4

The part number for the turbocharger	The pressure for the waste gate
2674A200	100 ± 5 kPa (14.5040 ± 0.7252 psi)
2674A201	110 ± 5 kPa (15.9544 ± 0.7252 psi)
2674A202	128 ± 5 kPa (18.5651 ± 0.7252 psi)
2674A209	100 ± 5 kPa (14.5040 ± 0.7252 psi)
2674A211	128 ± 5 kPa (18.5651 ± 0.725 psi)
2674A215	128 ± 5 kPa (18.5651 ± 0.725 psi)
2674A223	136 ± 5 kPa (19.72 ± psi)
2674A224	136 ± 5 Pa (19 254 ± 7252 psi)
2674A225	6 ± 5 kPa (4 ± 0.7252 psi)
2674A226	100 ± 5 kPa (14.5040 ± 0.7252 psi)
2674A22	128 ± 5 kPa (18.5651 ± 0.7252 psi)

Three Cylinder Engine

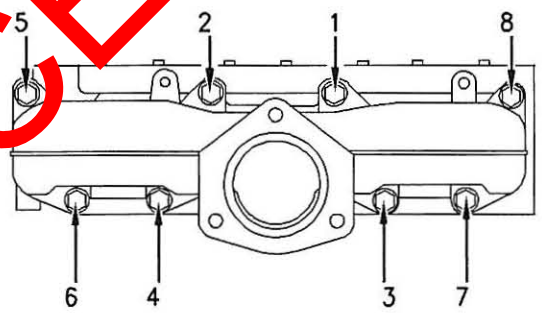
Table 5

The part number for the turbocharger	The pressure for the waste gate
2674A405	100 ± 3 kPa (14.5040 ± 0.4351 psi)
2674A421	100 ± 3 kPa (14.5040 ± 0.4351 psi)
2674A422	200 ± 3 kPa (29.0080 ± 0.4351 psi)

i01957427

Exhaust Manifold

Four Cylinder Engine



g00907527

Illustration 26

Tightening sequence

Note: The exhaust manifold must be aligned to the cylinder head. Refer to the Disassembly and Assembly manual.

Tighten the exhaust manifold bolts in the sequence that is shown in illustration 26 to the following torque. ..... 33 N·m (24 lb ft)

Three Cylinder Engine

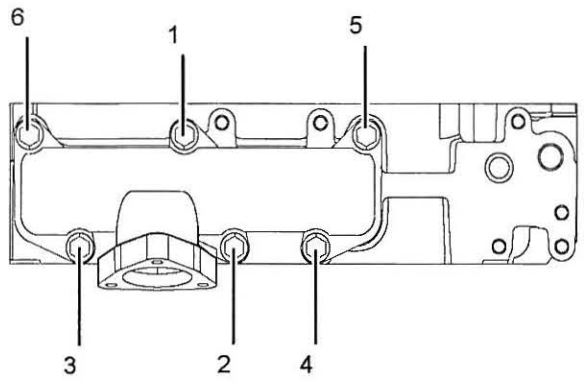


Illustration 27 g01017009

Note: The exhaust manifold must be aligned to the cylinder head. Refer to the Disassembly and Assembly manual.

Tighten the exhaust manifold bolts in the sequence that is shown illustration 27 to the following torque. ..... 33 N·m (24 lb ft)

i01956585

Camshaft

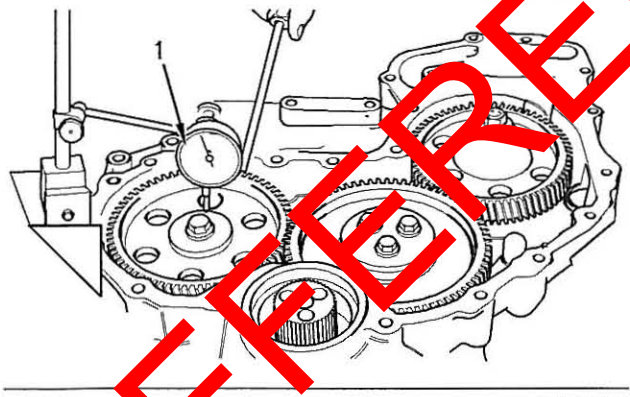


Illustration 28 g00987750

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)

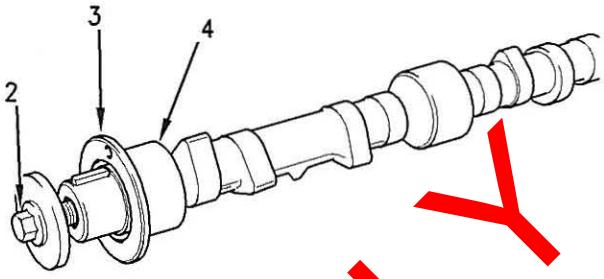


Illustration 29 g00976195

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 tables.

Table 6

1104 Diameters of Camshaft Journals	
Camshaft Journals	**Standard Diameter**
1	50.71 to 50.74 mm (1.9965 to 1.9975 inch)
2	50.46 to 50.48 mm (1.9865 to 1.9875 inch)
3	49.95 to 49.98 mm (1.9665 to 1.9675 inch)

Table 7

1103 Diameters of Camshaft Journals	
Camshaft Journals	**Standard Diameter**
1	50.71 to 50.74 mm (1.9965 to 1.9975 inch)
2	50.46 to 50.48 mm (1.9865 to 1.9875 inch)
3	50.46 to 50.48 mm (1.9865 to 1.9875 inch)
4	49.95 to 49.98 mm (1.9665 to 1.9675 inch)

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

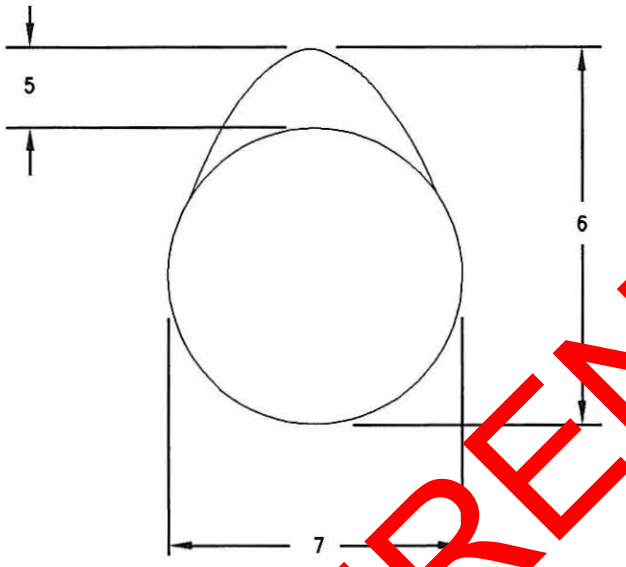


Illustration 30 g00629702

(5) Camshaft lobe lift

Naturally aspirated

Inlet lobe ..... 7.382 to 7.482 mm (0.2906 to 0.2946 inch)

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

Turbocharged

Inlet lobe ..... 7.031 to 7.130 mm (0.2768 to 0.2807 inch)

Exhaust lobe ..... 7.963 to 8.063 mm (0.3135 to 0.3174 inch)

(6) Camshaft lobe height

(7) Base circle

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

1. Measure the camshaft lobe height (6).
2. Measure the base circle (7).
3. Subtract the base circle that is found in Step 2 from the camshaft lobe height that is found in Step 1. The difference is the actual camshaft lobe lift.

Maximum permissible clearance between the actual lobe lift and the specified lobe lift of a new camshaft ..... 0.05 mm (0.0021 inch)

i01914527

Camshaft Bearings

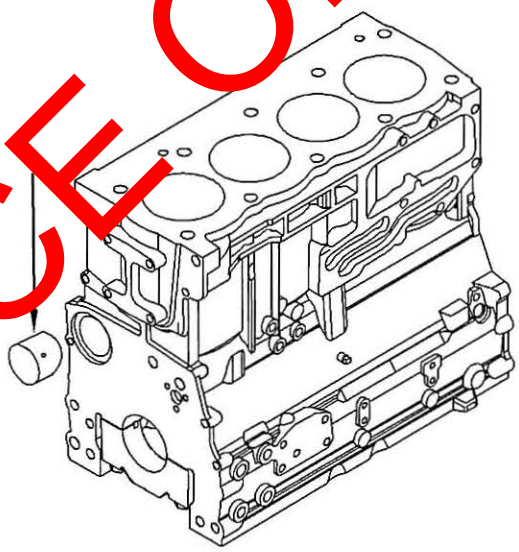


Illustration 31 g00997348

A typical four cylinder engine

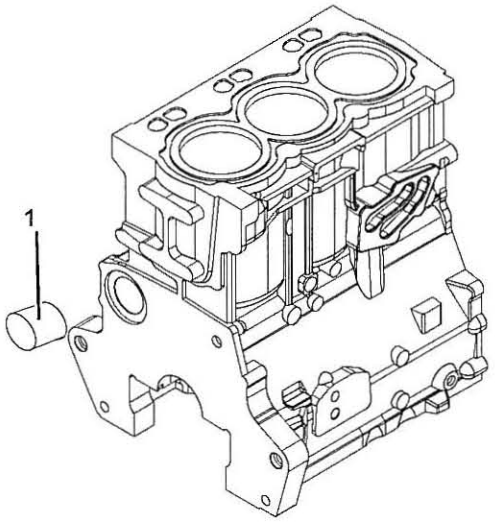


Illustration 32 g01017012

A three cylinder engine

(1) Camshaft bearing

The diameter for the installed camshaft bearing ..... 50.790 to 50.850 mm (1.9996 to 2.0020 inch)

i01958[illegible]

Engine Oil Filter

Spin-on Oil Filter

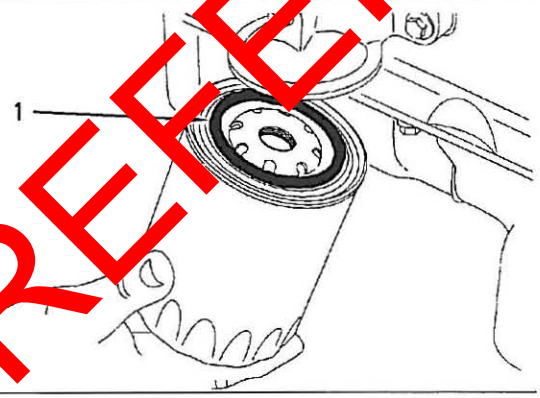


Illustration 33 g00915984

(1) Seal

Note: Lubricate the top of the seal with clean engine oil before installation.

Type ..... Full flow

Pressure to open engine oil filter bypass valve ..... 80 to 120 kPa (12 to 18 psi)

Replaceable Element

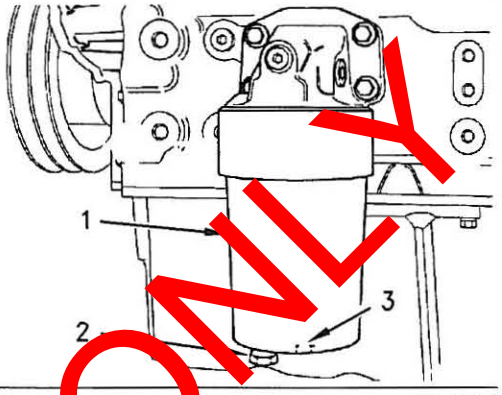


Illustration 34 g00915985

Note: Lubricate the seal on the oil filter housing with clean engine oil before installation.

Type ..... Full flow

Pressure to open engine oil filter bypass valve ..... 130 to 170 kPa (19 to 25 psi)

(1) Tighten the oil filter housing to the oil filter base to the following torque. ..... 25 N·m (18 lb ft)

(2) Tighten the drain plug on the oil filter housing to the following torque. ..... 12 N·m (9 lb ft)

Note: The horizontal filter as a drain plug in the filter head

(3) Recess for 1/2 inch square drive

i01957426

Engine Oil Pump

Four Cylinder Engines with Balancer Group

Type ..... Gear-driven differential rotor

Number of lobes

Inner rotor 6
Outer rotor 7

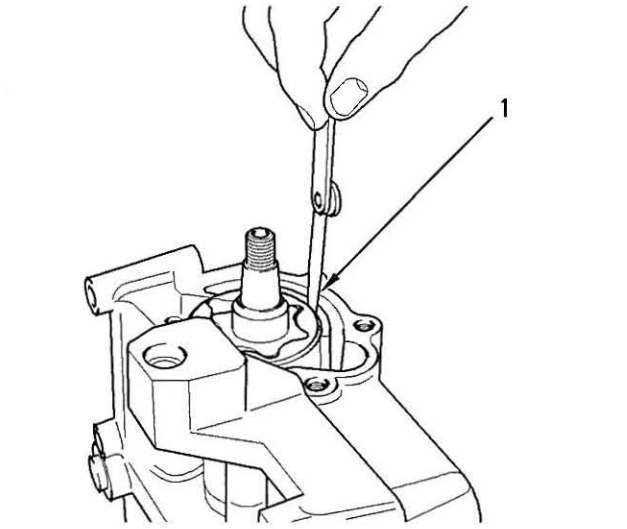


Illustration 35 g00989248

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 36 g00989236

Inner rotor

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

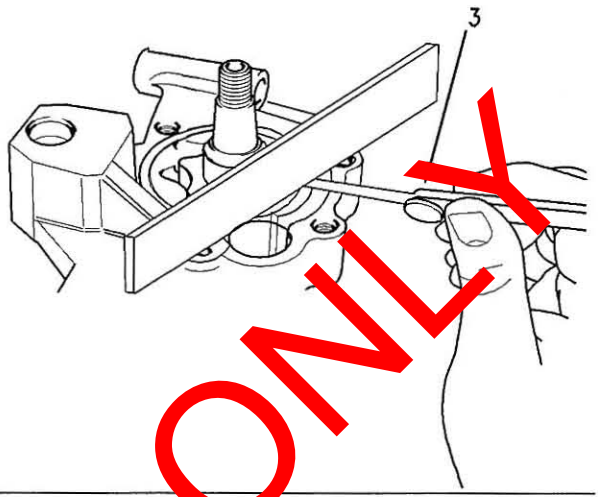


Illustration 37 g00989217

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 0.00 mm (0.0016 to 0.0043 inch)

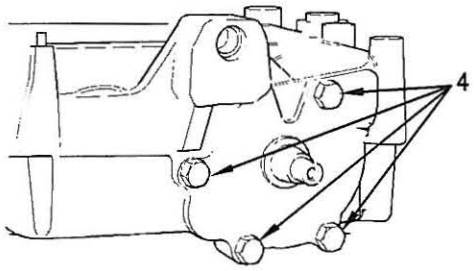


Illustration 38 g00938724

The end cover

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

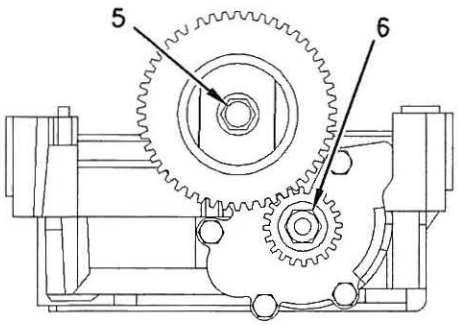


Illustration 39 g00989519
Idler gear and pump gear

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 Testing and Adjusting , "Finding Top Center Position for No. 1 Piston". Install the balancer. Refer to the Disassembly and Assembly manual. Install the gear for the oil pump and tighten the nut (6).

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

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

Four Cylinder and Three Cylinder Engines without Balancer Group

Type ..... Gear driven differential rotor

Number of lobes

Inner rotor 5
Outer rotor 6

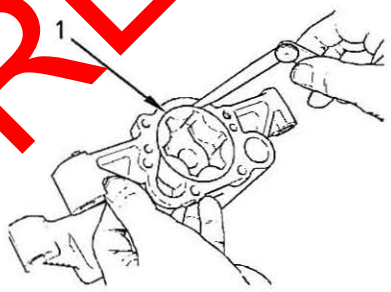


Illustration 40 g00938064
The oil pump

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

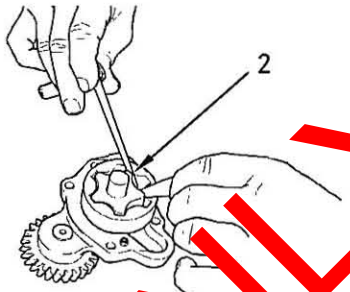


Illustration 41 g00938061
Checking the clearance

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

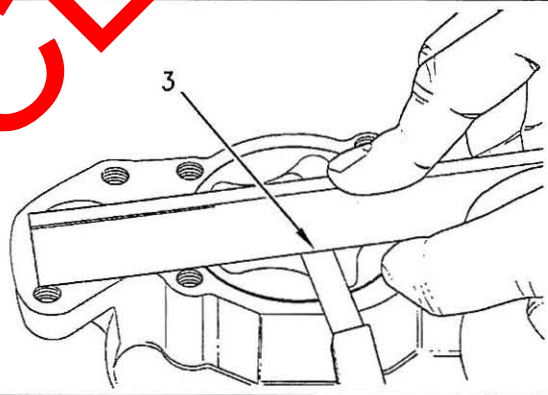


Illustration 42 g00938799
Checking the end play

(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. ..... 26 N·m (19 lb ft)

i01958104

Engine Oil Pressure

The minimum oil pressure at the maximum engine speed and at normal operating temperature is the following value. ..... 300 kPa (43 psi)

i01958107

Engine Oil Bypass Valve

Installed in the Oil Pump

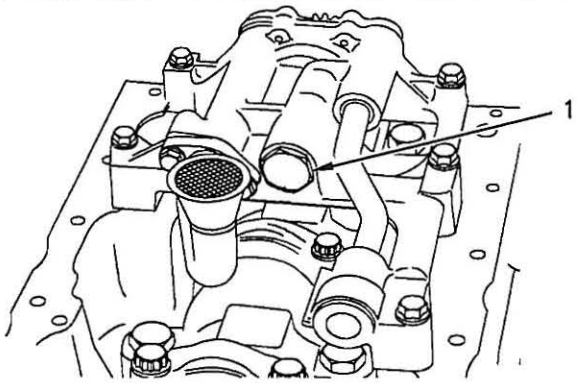


Illustration 43 g00919893
Typical engine oil pump

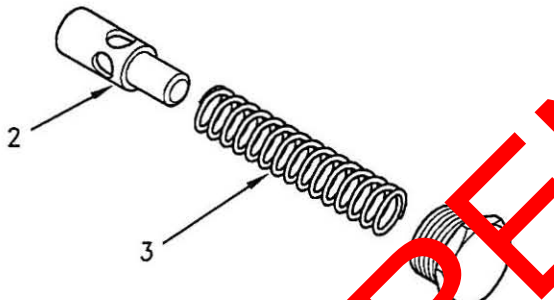


Illustration 44 g00921377
Relief valve and spring

(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)

Installed in the Balancer

1104 engines only

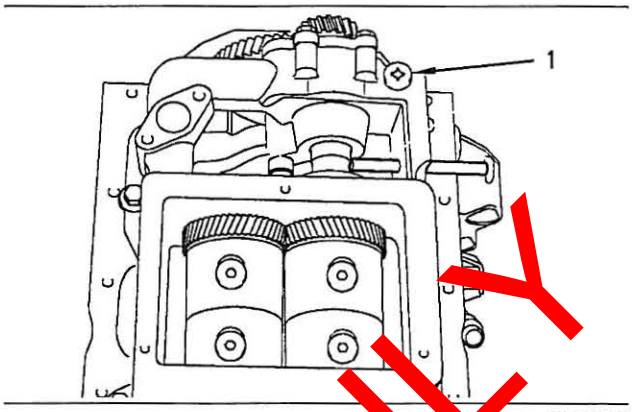


Illustration 45 g00919890
Plug

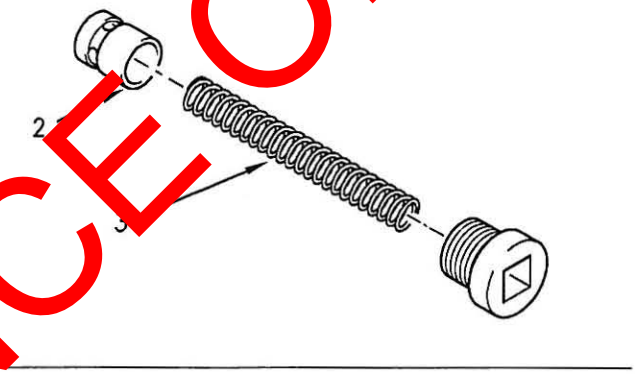


Illustration 46 g00921379
The relief valve for the balancer

(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)

i02242687

Engine Oil Pan

Front sealant

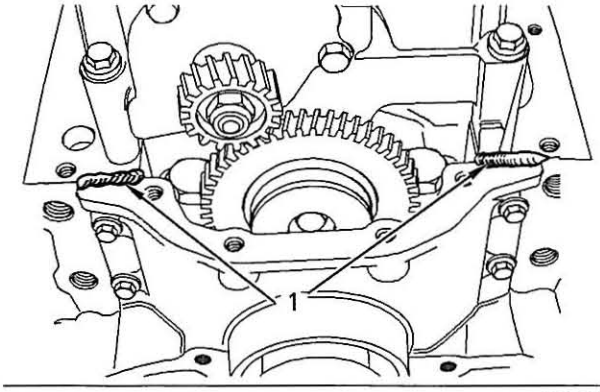


Illustration 47 g00990254

Applying sealant

(1) Apply 1861108 Powerpart silicone rubber sealant to the cylinder block and to the timing case.

Note: Apply a sealant bead of 3.5 mm (0.1378 inch) that is shown in illustration 47.

Rear sealant

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

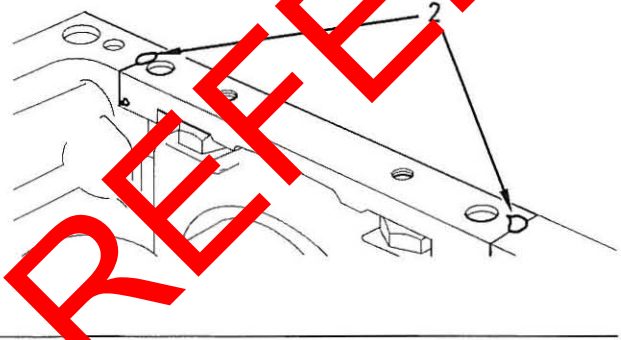


Illustration 48 g00990255

Applying sealant

(2) Apply 1861108 Powerpart silicone rubber sealant to the bridge. The sealant must not protrude more than 5 mm (0.1969 inch) above the bridge.

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

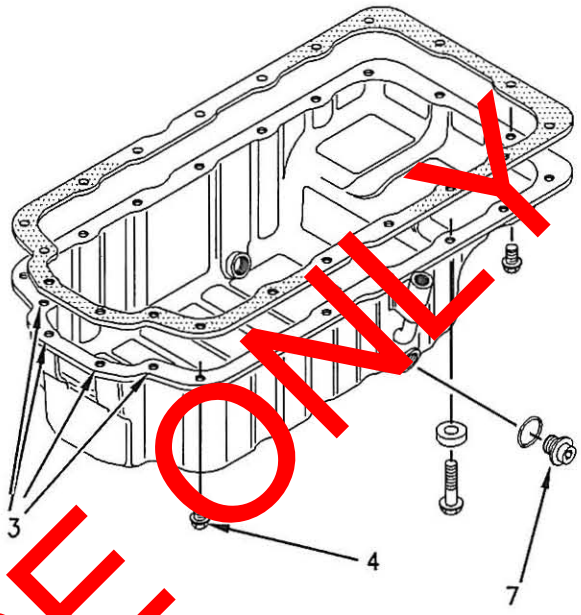


Illustration 49 g00990252

Typical oil pan

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

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

The cast iron oil pan

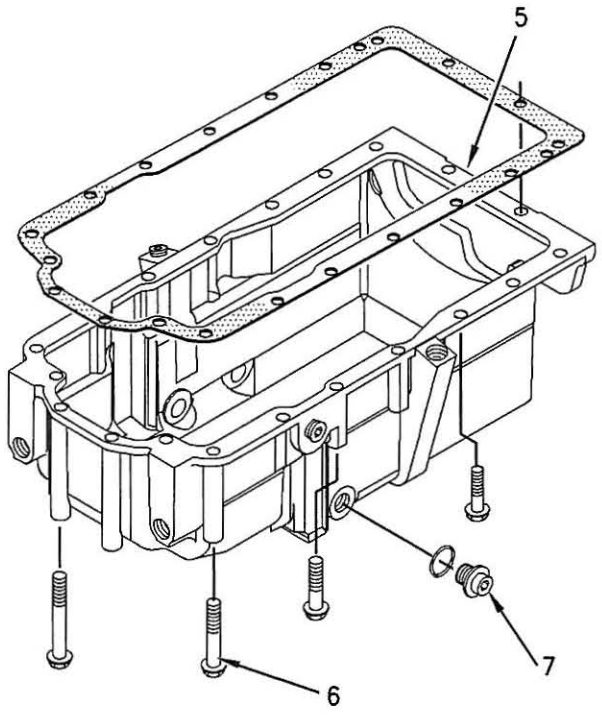


Illustration 50 g00990249
The cast iron oil pan

Note: The rear face of the cast iron oil pan (5) must be aligned to the rear face of the cylinder block.

(5) The maximum allowed value of the rear face misalignment. ..... 0.1 mm (0.0039 inch)

(6) Bolt

Tighten the front four bolts. Refer to illustration 49. Tighten the remaining bolts and the nuts that fasten the engine oil pan to the cylinder block to the following torque. ..... 22 N·m (16 lb ft)

Note: Thread sealant is applied to new bolts. In order to reuse the bolts, apply 21820117 Powerpart threadlocker and nutlock to the first three threads of the used bolts.

Note: The engine may be equipped with an oil drain plug or the engine may be equipped with a drain valve.

(7) Drain plug

Tighten the drain plug for the engine oil pan to the following torque. ..... 34 ± 5 N·m (25 ± 4 lb ft)

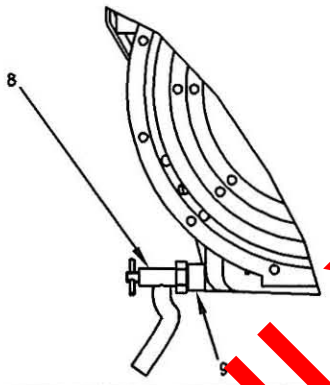


Illustration 51 g00990677
The drain valve

(8) Drain valve

Tighten the drain valve into the adapter to the following torque. ..... 34 ± 5 N·m (25 ± 4 lb ft)

(9) Adapter

Tighten the adapter into the engine oil pan to the following torque. ..... 34 ± 5 N·m (25 ± 4 lb ft)

i02224176

Crankcase Breather

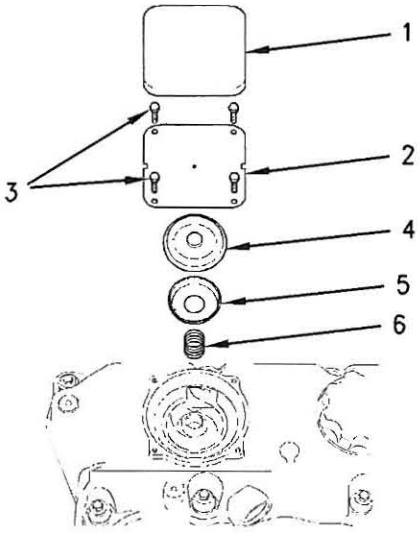


Illustration 52 g00926199
Breather valve

(1) Plastic cover

(2) Cover plate

(3) Screws

Tighten the screws for the cover plate with a plastic valve mechanism cover to the following torque. ..... 1.3 N·m (11.5 lb in)
Tighten the screws for the cover plate with a metal valve mechanism cover to the following torque. ..... 1.8 N·m (16 lb in)

(4) Diaphragm

(5) Cap

(6) Spring

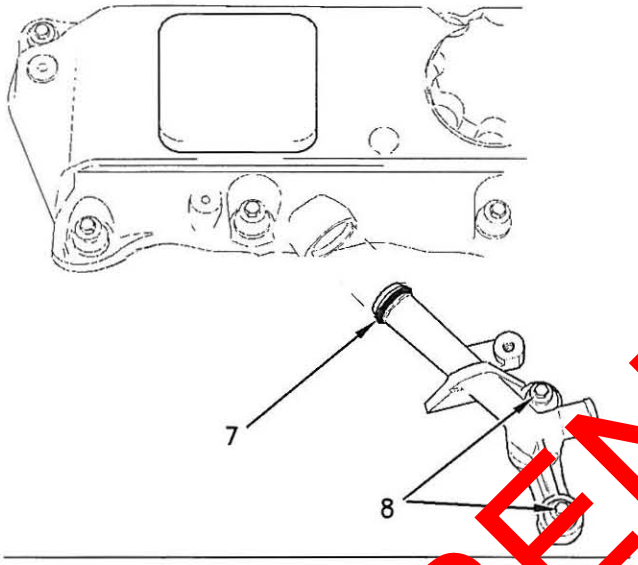


Illustration 53

(7) O-ring

Note: Apply 21820221 Powerpart red rubber grease 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)

Engine model DK and DJ

Note: These three cylinder engines do not have a breather valve in the valve mechanism cover.

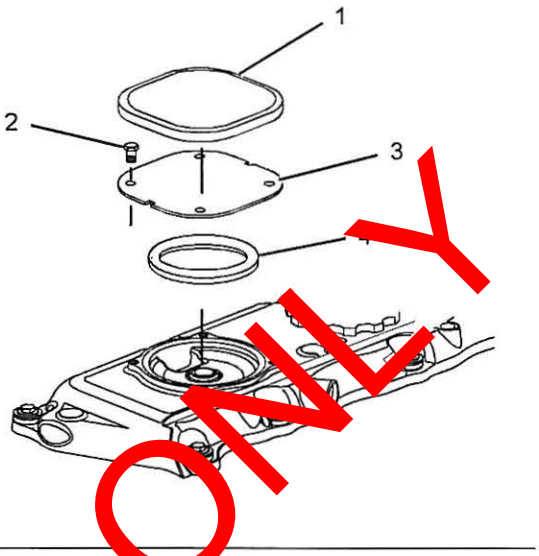


Illustration 54 g01121867

(1) Plastic cover
(2) Screw
(3) Cover plate
(4) Seal

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

i01914256

Water Temperature Regulator and Housing

Tighten the bolts (not shown) that fasten the housing to the following torque. ..... 22 N·m (16 lb ft)

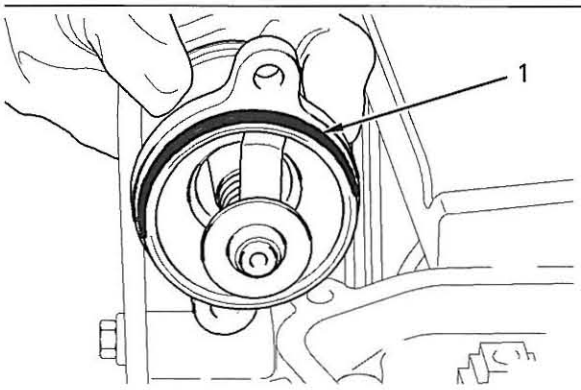


Illustration 55 g00997234

O ring

Note: Apply 21820221 Powerpart red rubber grease to the O-ring (1) in order to install the thermostat housing.

Water Temperature Regulator

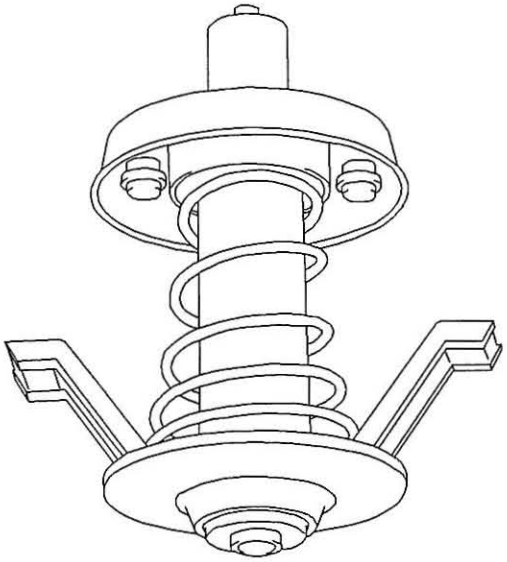


Illustration 56 g00906121

A typical water temperature regulator

Opening temperature ..... 79 ° to 84 °C (174 ° to 151 °F)

Full opening temperature ..... 93 °C (199 °F)

Minimum stroke at full open temperature ..... 10 mm (0.3937 inch)

i01904[illegible]3

Water Pump

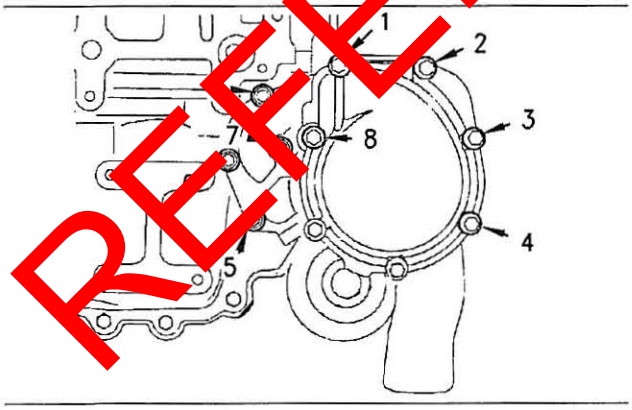


Illustration 57 g00915951

Tightening sequence

Note: Apply 21820117 Powerpart threadlock nutlock to the first three threads of the bolts before installation.

Tighten the nine bolts that secure the water pump to the front housing in the numerical sequence that is shown to the following torque. ..... 22 N·m (16 lb ft)

Note: Refer to the Disassembly and Assembly manual in order to service the water pump.

i01908154

Cylinder Block

Four Cylinder Engine

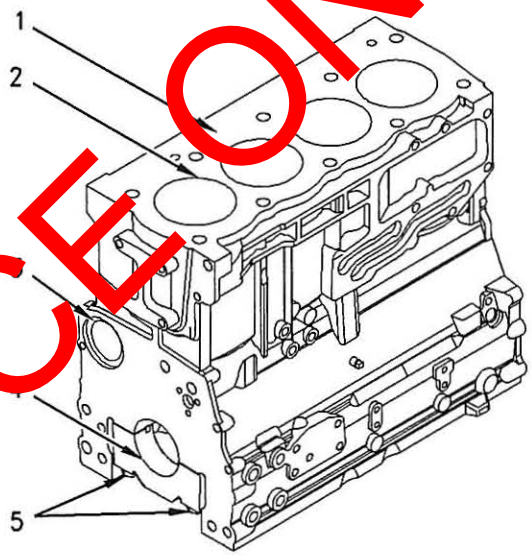


Illustration 58 g00924764

Cylinder block

(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 for the four cylinder engine

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 for the four cylinder engine

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 for the four cylinder engine

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)

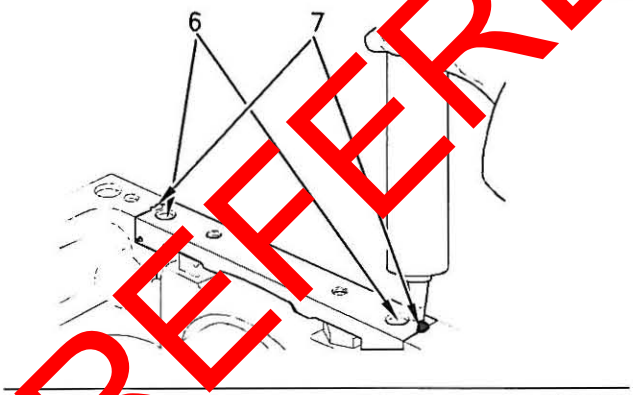


Illustration 59 g00938203

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 21826038 POWERPART Silicon Adhesive 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.

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)

Three Cylinder Engine

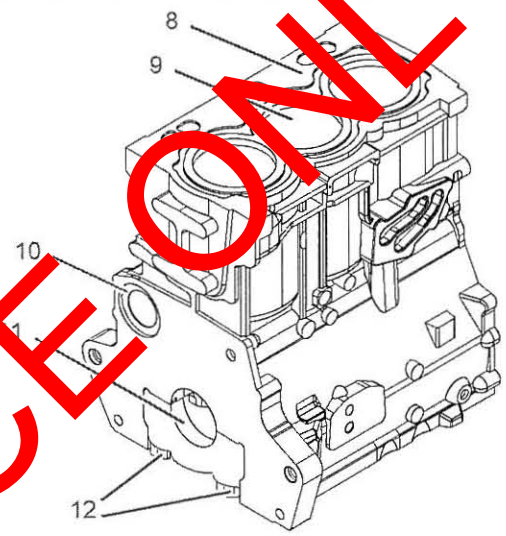


Illustration 60 g01018250

(8) Cylinder block

(9) 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)

(10) Camshaft bearings for the four cylinder engine

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 ..... 50.546 to 50.597 mm (1.9900 to 1.9920 inch)

Diameter of the bore in the cylinder block for the number 4 camshaft journal ..... 50.038 to 50.089 mm (1.9700 to 1.9720 inch)

(11) Main bearings for the three cylinder engine

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

(12) Main bearing cap bolts for the four cylinder and three cylinder engines

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)

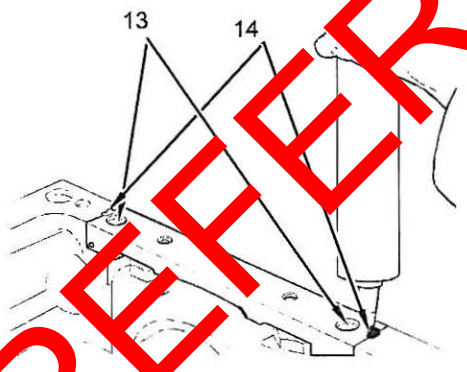


Illustration 61 g01018262

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 (13) 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 21826038 POWERPART Silicon Adhesive into groove (14) 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.

Total height of the cylinder block between the top and the bottom faces. ..... 441.173 to 441.274 mm (17.3692 to 17.3729 inch)

i01956920

Crankshaft

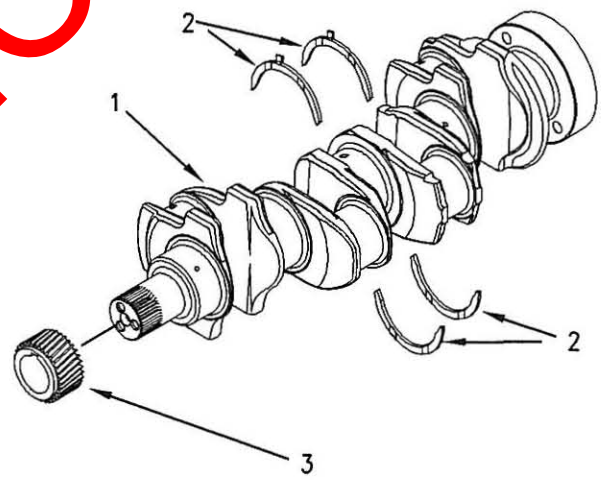


Illustration 62 g00992214

The crankshaft for the four cylinder engine

(1) Crankshaft for the four cylinder engine

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.

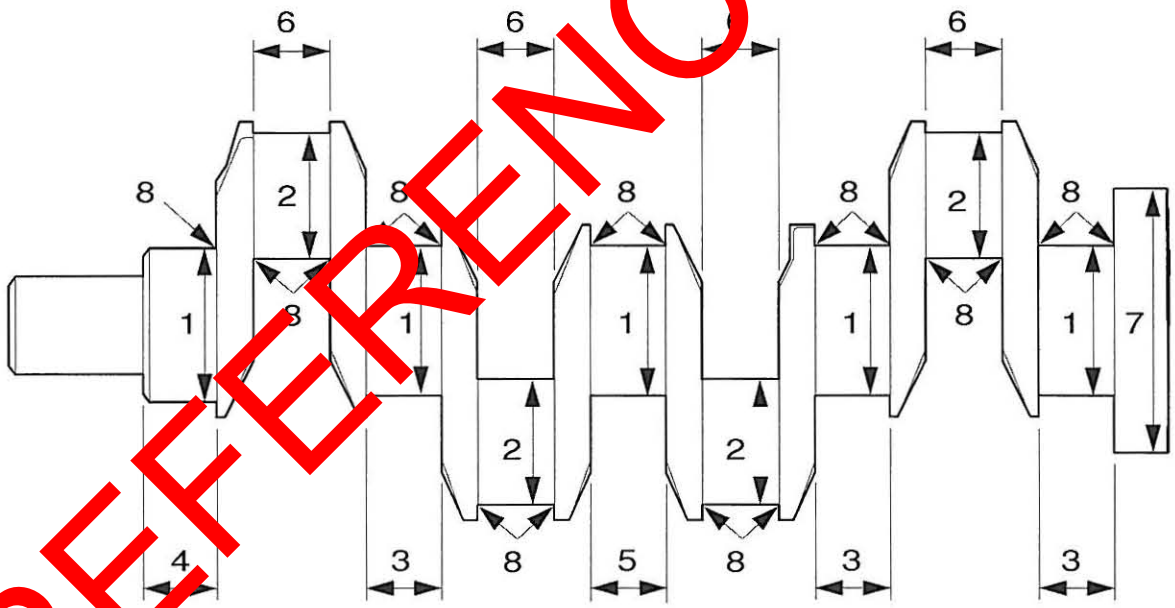


Illustration 63 g01017233
The 1104 engine crankshaft

Note: Refer to illustration 63 in order to use table 8.

The four cylinder engine.

Table 8

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	75.909 mm (2.9885 inch) to 75.930 mm (2.9894 inch)	75.649 mm (2.9783 inch) to 75.670 mm (2.9791 inch)	75.399 mm (2.9685 inch) to 75.420 mm (2.9693 inch)
2	63.220 mm (2.4890 inch) to 63.240 mm (2.4898 inch)	62.960 mm (2.4787 inch) to 62.982 mm (2.4796 inch)	62.708 mm (2.4688 inch) to 62.728 mm (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

Refer to table 9 for the maximum run out of the crankshaft journals.

The maximum difference in value between one crankshaft journal and the next crankshaft journal ..... 0.10 mm (0.0039 inch)

Table 9

Journal	Excessive run out
(1)	Mounting
(2)	0.08 mm (0.0031 inch)
(3)	0.13 mm (0.0051 inch)
(4)	0.08 mm (0.0031 inch)
(5)	Mounting

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

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

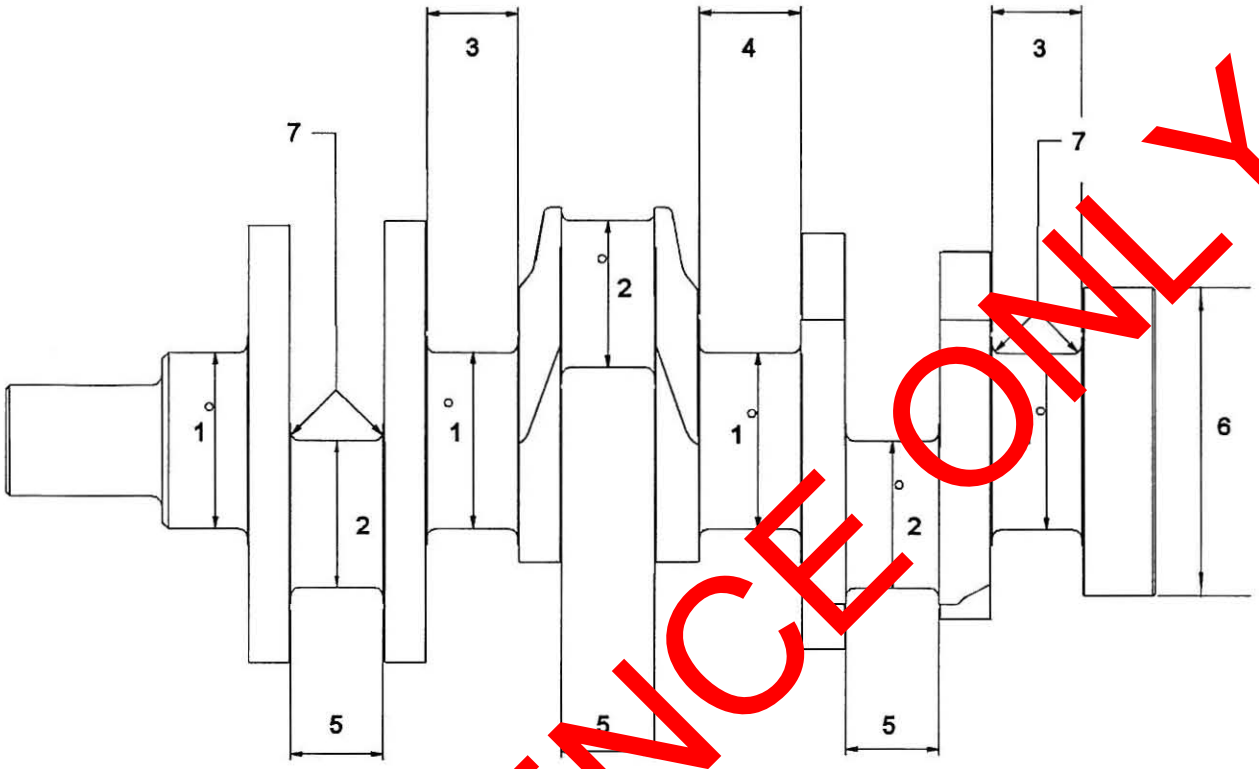


Illustration 64 g01017747

The crankshaft for the three cylinder engine

The crankshaft for the three Cylinder engine

Table 10

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	75.926 mm (2.9892 inch) to 75.905 mm (2.9884 inch)	75.672 mm (2.9792 inch) to 75.651 mm (2.9784 inch)	75.418 mm (2.9692 inch) to 75.397 mm (2.9684 inch)
2	63.236 mm (2.4896 inch) to 63.216 mm (2.4888 inch)	62.982 mm (2.4796 inch) to 62.962 mm (2.4788 inch)	62.728 mm (2.4696 inch) to 62.708 mm (2.4688 inch)
3	39.74 mm (1.5646 inch)maximum	N/A	N/A
4	44.68 mm (1.7591 inch)maximum	N/A	N/A
5	40.551 mm (1.5965 inch)maximum	N/A	N/A
6	133.17 mm (5.2429 inch) Do not machine this diameter.	N/A	N/A
7	3.68 mm (0.1449 inch) to 3.96 mm (0.1559 inch)	N/A	N/A

Refer to table 11 for the maximum run out of the crankshaft journals.

The maximum difference in value between one crankshaft journal and the next crankshaft journal ..... 0.10 mm (0.0039 inch)

Table 11

Journal	Excessive run out
(1)	Mounting Dia
(2)	0.051 mm (0.00[illegible] inch)
(3)	0.051 m[illegible] (0.[illegible]020 inch)
(4)	Moun[illegible]g Di[illegible]

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

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

i01958114

Crankshaft Seals

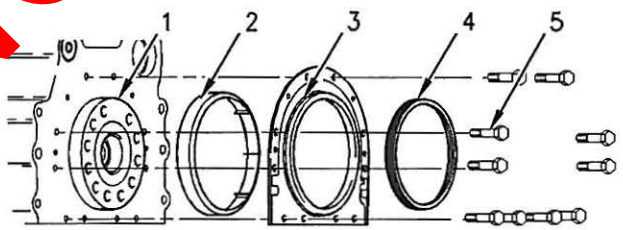


Illustration 65 g00915078

(1) Crankshaft

(2) Plastic sleeve

(3) Crankshaft seal

(4) Alignment tool

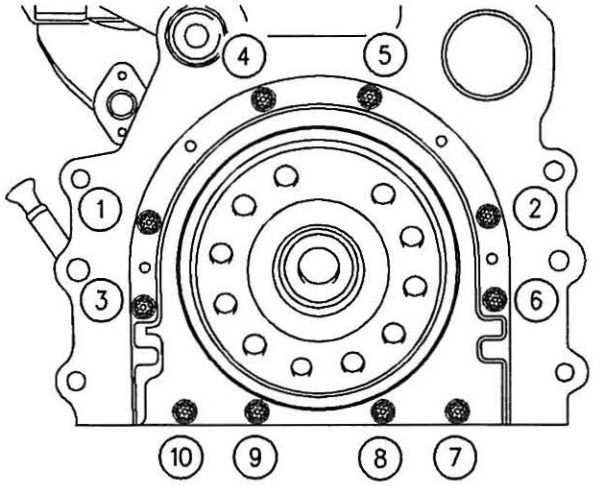


Illustration 66 g00915076

(5) Tighten bolts 1, 2, 3, 4, 5, 6, 7, and 10 in the sequence that is shown in Illustration 66 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 66 to the following torque. ..... 22 N·m (16 lb ft)

i01958141

Connecting Rod Bearing Journal

Refer to the Specifications Module, "Crankshaft" topic 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 the connecting rod bearing journals ..... 0.04 mm (0.0016 inch)

Width of the connecting rod bearing journals ... 40.35 to 40.42 mm (1.589 to 1.591 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 and radii ..... Ra 0.4 microns (16 µ inch)

i01958141

Main Bearing Journal

Refer to the Specifications module, "Crankshaft" topic 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 ..... 0.04 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)

i01958156

Connecting Rod

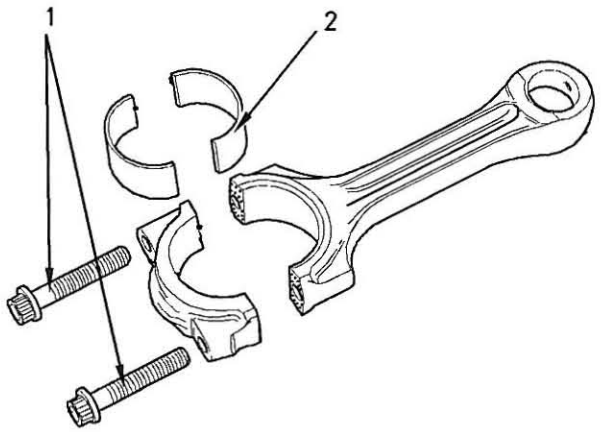


Illustration 67 g00907738

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

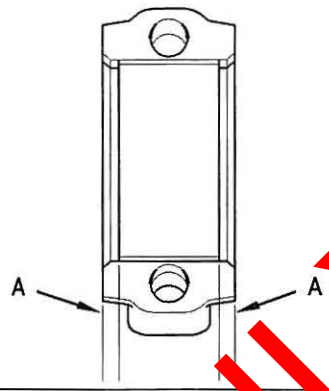


Illustration 68 g00995584

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 68. Refer to the Disassembly and Assembly manual for information on the alignment tool.

Table 12

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	31.55 to 31.88 mm (1.2405 to 1.255 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	0.030 to 0.081 mm (0.0012 to 0.0032 inch)

Table 13

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

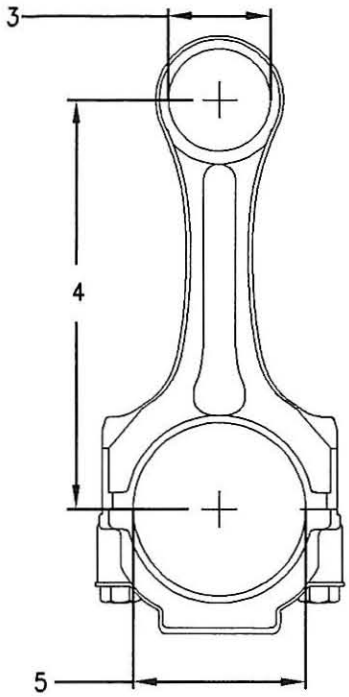


Illustration 69 g00907744

(3) Diameter of the parent bore for the piston pin ..... 43.01 to 43.04 mm (1.693 to 1.694 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 ..... 67.01 to 67.22 mm (2.6461 to 2.6465 inch)

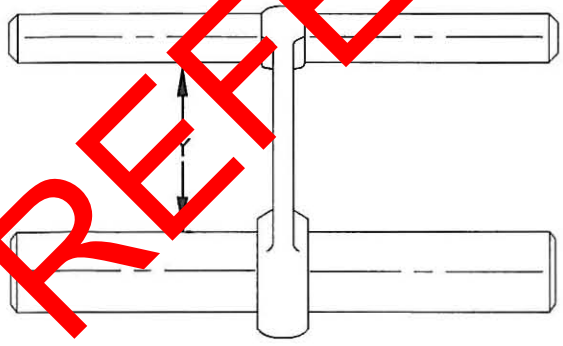


Illustration 70 g00915056

Connecting rods are color coded. The color code is a reference for the length (Y) of the connecting rod. Refer to table 14 for the different lengths of connecting rods.

Table 14

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		165.499 to 165.532 mm (6.5157 to 6.4961 inch)

i01958185

Piston and Rings

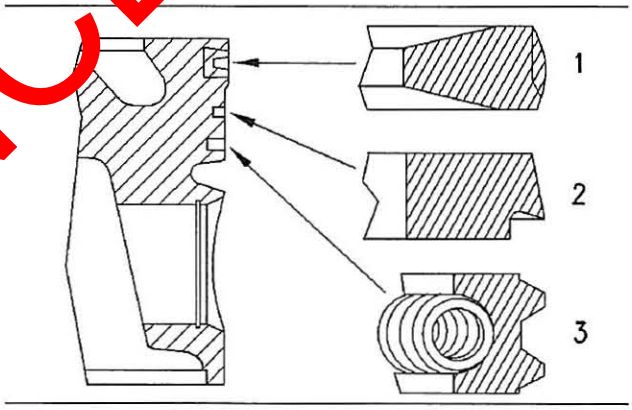


Illustration 71 g00888215

A typical example of a piston and rings

(1) Top compression ring

Naturally Aspirated

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

Width of the top compression ring ..... 2.475 to 2.49 mm (0.097 to 0.098 inch)

Clearance between the top compression ring and the piston groove ..... 0.09 to .15 mm (0.0035 to 0.0059 inch)

Ring gap ..... 0.30 to 0.55 mm (0.0118 to 0.0216 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 0.55 mm (0.0118 to 0.0216 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 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.

(2) Intermediate compression ring

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

Width of intermediate compression ring ..... 2.47 to 2.49 mm (0.097 to 0.098 inch)

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

Ring gap ..... 0.70 to 0.95 mm (0.0275 to 0.0374 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 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.

(3) Oil control ring

Shape of oil control ring ..... two-piece coil th... ...pring-loaded

Width of oil control ring .... 3.47 to 3.49 mm (0.13... to 0.1374 inch)

Clearance between the oil control ring and the groove in the pist... ....03 to 0.07 mm (0.00...1 to 0.0027 inch)

Ring gap ..... 0.30 to 0.55 mm (0.0118 to 0.0216 inch)

Note: A p... is u...ed in or...er to hold both ends of the spring of th... contr... ring in position. The ends of the ...prin... of t...e oi... control ring must be installed o...posite ...he end gap of the oil control ring.

Note: Ensure that the ring end gaps of the piston rings a... 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 ..... 80 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 0.1...24 inch)

Width of top groove in piston for the turbo...rged engine ..... Ta...ered

Width of second groove in pi...ton ... 2.54 t... 2.56 mm (0.100... to ...1008 inch)

Width of third groove in p...ton ..... 3.52 to 3.54 mm (0.1386 to 0.1394 inch)

Piston pin

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

Di...eter ... the bore for the piston pin ..... 39.703 to 39.709 mm (1.5631 to 1.5633 inch)

i01957425

Piston Cooling Jet

Note: The three cylinder naturally aspirated engine may have installed piston cooling jets as an option.

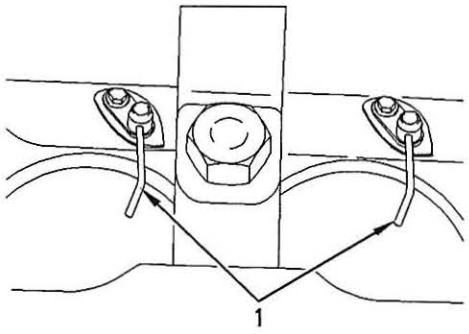


Illustration 72 g00942652

(1) Installed piston cooling jets

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

Piston Cooling Jet Alignment

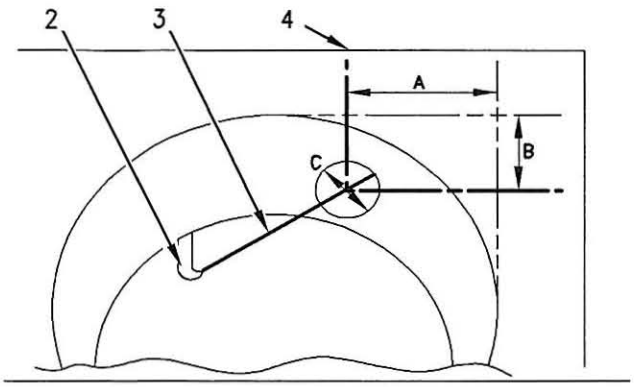


Illustration 73 g01006929

(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 55.25 mm (2.1752 inch) and dimension (B) is 14 mm (0.5512 inch). Dimension (A) and dimension (B) are tangent to the cylinder bore (4).

3. The position of the rod (3) must be within dimension (C). Dimension (C) is 14 mm (0.5512 inch).

i01957083

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)

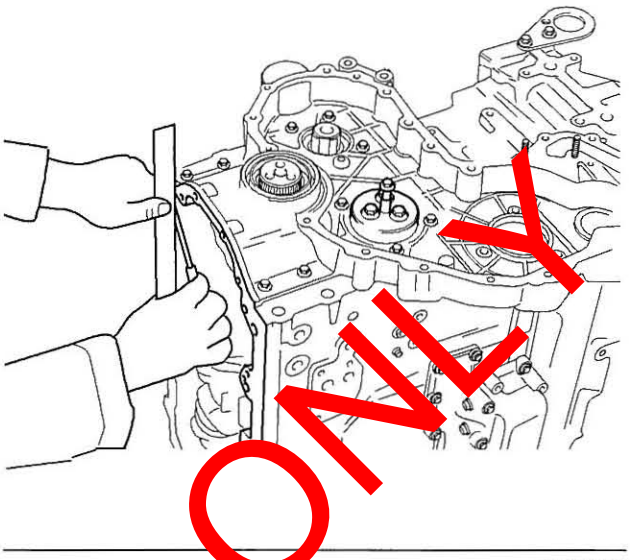


Illustration 74 g00995663

Alignment

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

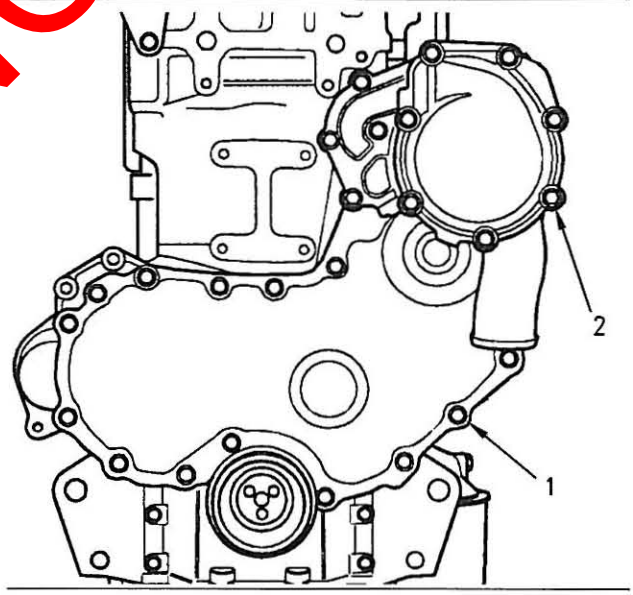


Illustration 75 g00918672

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.

i01912958

Gear Group (Front)

The 1104 mechanical engines use two types of fuel injection pumps. The fuel injection pump can be either a Delphi 210 fuel injection pump or a Bosch EPVE fuel injection pump.

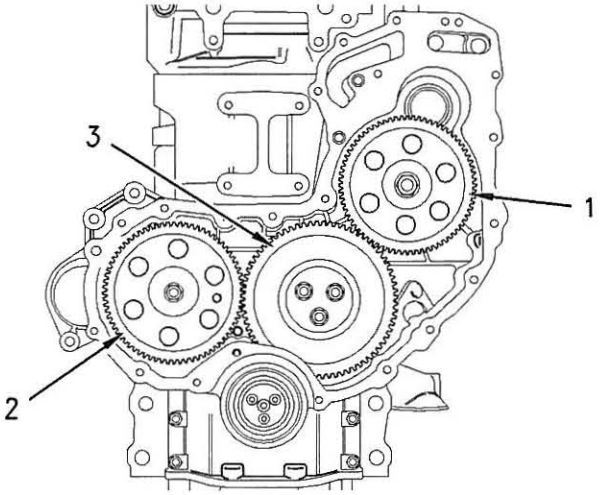


Illustration 76 g00995[illegible]6

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 the Specifications Module, "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 ..... 62.35 to 62.36 mm (2.8484 to 2.8488 inch)

Width of idler gear and split bushing 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 ..... 50.73 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

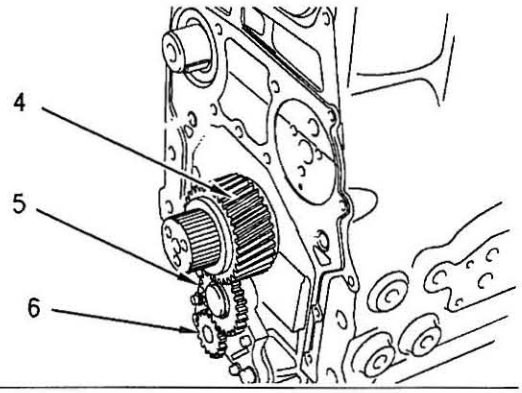


Illustration 77 g00996214

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 7

Backlash values

Backlash between the idler gear (3) and the oil pump drive gear (6) ..... 0.046 to 0.10[illegible] mm (0.[illegible] inch)

Backlash between the oil pump idler gear (5) and the crankshaft gear (1) ..... 0.095 to 0.160 mm (0.003[illegible] to 0.0063 inch)

Backlash between the idler gear (3) and the crankshaft gear (1) ..... 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

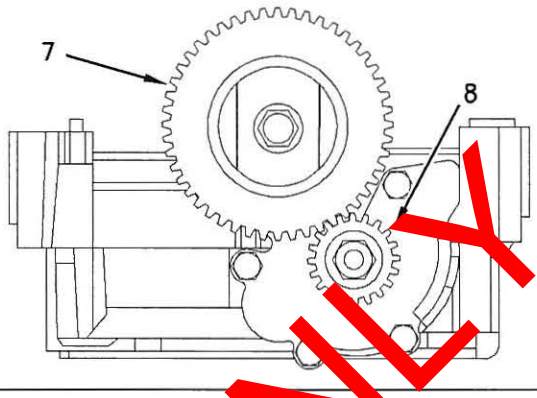


Illustration 78 g00996003
Balancer gears

(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)

i02234222

Flywheel

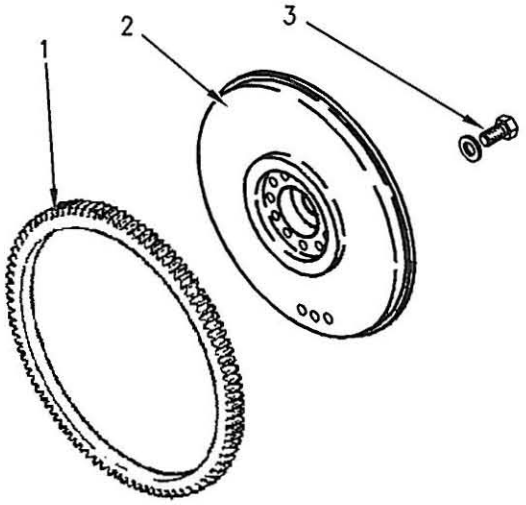


Illustration 79 g00584712

Standard flywheel

(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 bolt to the following torque. ..... 105 N·m (77 lb ft)

Non-standard flywheel

Note: A special flywheel is aligned to a dowel on the crankshaft.

i01957025

Flywheel Housing

Four cylinder

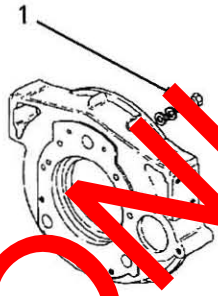


Illustration 80 g00631781

(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)

Three cylinder

The three cylinder engine is equipped with a back plate.

i02234223

Crankshaft Pulley

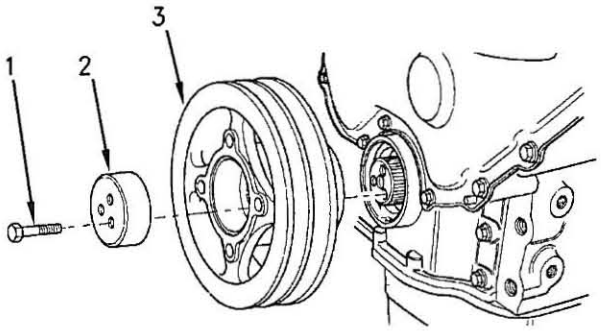


Illustration 81 g00915497

A standard pulley

Note: Lubricate the threads of the bolts with clean engine oil before installation.

(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) twice.

(2) Thrust block

(3) Crankshaft pulley

Non-standard pulley

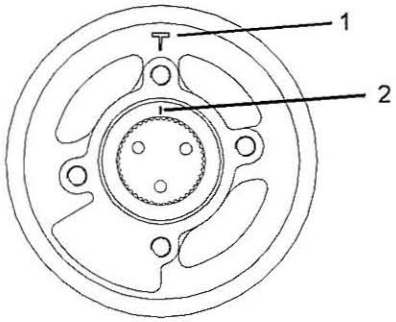


Illustration 82 g01126584

(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.

i01958344

Fan Drive

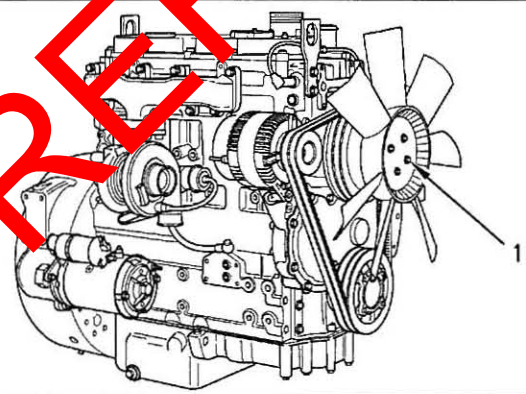


Illustration 83 g00926178

A typical fan drive

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

Tighten the bolts that secure the fan drive pulley to the hub to the following torque (not shown). .. 22 N·m (16 lb ft)

Fan drive housing

Tighten the bolts that secure the fan drive housing to the cylinder head to the following torque (not shown). ..... 44 N·m (32 lb ft)

Bearing bore for the housing .. 61.986 to 62.005 mm (2.4404 to 2.4411 inch)

Outer bearing diameter ..... 61.987 to 62.000 mm (2.4404 to 2.4409 inch)

Interference fit for the bearing ..... 0.014 to minus 0.018 mm (0.0006 to minus 0.0007 inch)

The outer diameter of the shaft .. 25.002 to 25.011 mm (0.9843 to 0.9847 inch)

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)

i01958367

Alternator

12 Volt and 24 Volt Alternator

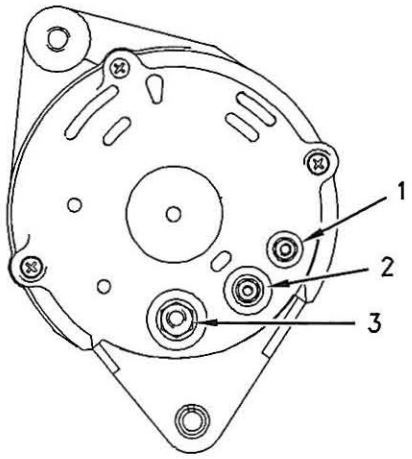


Illustration 84 g00959541

A typical alternator

(1) Tighten terminal nut "W" to the following torque. ..... 2 N·m (17 lb in)

(2) Tighten terminal nut "D+" to the following torque. ..... 4.3 N·m (38 lb in)

(3) Tighten terminal nut "B+" to the following torque. ..... 4.3 N·m (38 lb in)

Tighten the pulley nut (not shown) to the following torque. ..... 80 N·m (59 lb ft)

Alignment of the alternator pulley to the crankshaft pulley ..... ± 2.4 mm (± 0.0945 inch)

Rotation ..... clockwise

Polarity ..... Negative earth

V-Belt

Note: The V-belt must be checked by a gauge. Refer to the Testing and Adjusting, "V-Belt-Test" for the correct type of gauge in order to check the V-belt.

V-belt tension ..... 535 N (120 lb)

i01958653

Starter Motor

24 Volt Starter Motor

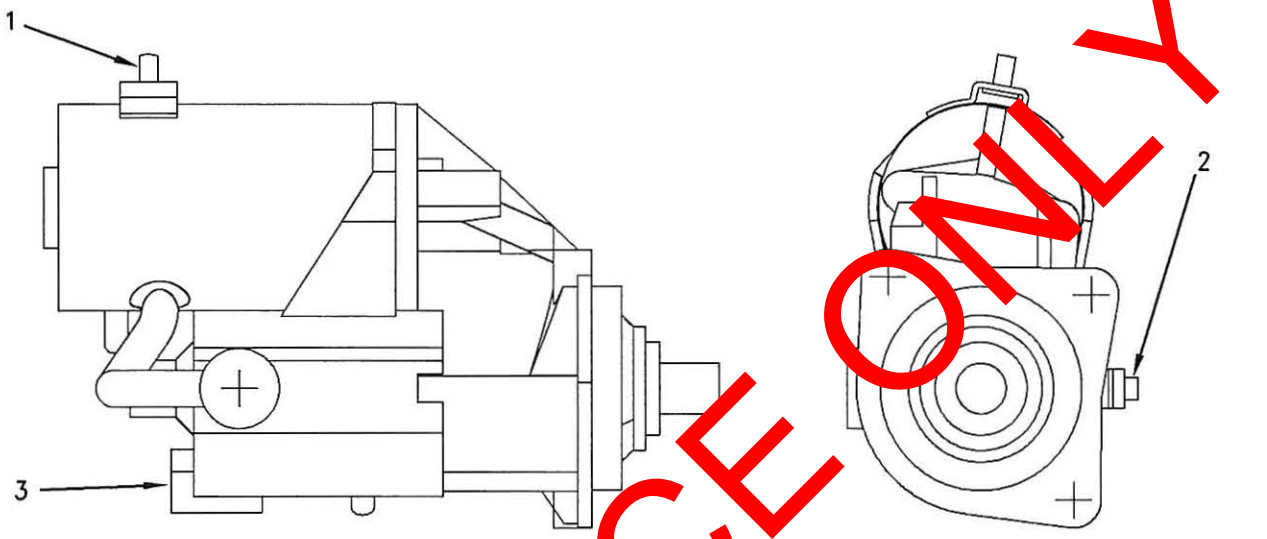


Illustration 85 g00974968

The 24 volt starter motor which shows the electrical connec

(1) Tighten the negative terminal nut to the following torque. ..... 15 N·m (11 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. ..... 3.5 N·m (31 lb in)

Rated voltage ..... 24 volts

Pull in voltage ..... 16 volts

12 Volt Starter Motor

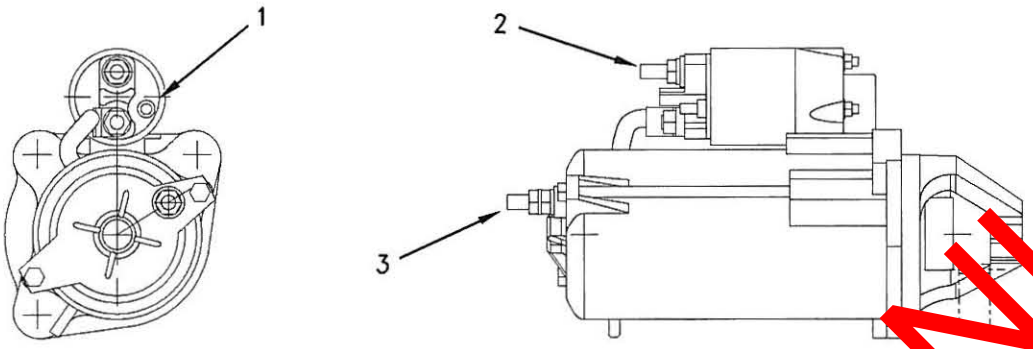


Illustration 86 g00977365

The 12 volt starter 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

Pull in voltage ..... 8 volts

i02248408

Glow Plugs

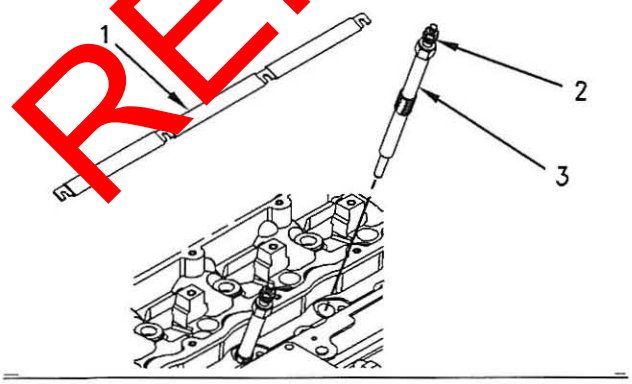


Illustration 87 g00955714

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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Disassembly and Assembly

1103 and 1104 Industrial Engines

DC (Engine)
DD (Engine)
DJ (Engine)
DK (Engine)
RE (Engine)
RG (Engine)
RJ (Engine)
RR (Engine)
RS (Engine)
DF (Engine)
DG (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 hav 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

i02219291

Fuel Priming Pump - Remove and Install

Removal procedure

There are two types of fuel priming pump. Type 1 is mounted above the starter motor. Type 1 is combined with the fuel filter. Type 2 is mounted below the starter motor. Type 2 is not combined with the fuel filter. Type 2 is used on 4 cylinder engines only.

Removal Procedure for Type 1

Start By:

a. Remove the assembly of the filter case and the fuel filter element. Refer to this Disassembly and Assembly Manual, "Fuel Filter Base - Remove and Install".

Note: There is an option for the three cylinder engine. The fuel priming pump and the fuel filter can be installed onto the application rather than onto the engine. If this is the case, refer to the appropriate installation manual that is supplied by the OEM for further information.

Note: Put identification marks on all fuel hose assemblies and on all tube assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies and plug all tube assemblies. This helps prevent fluid loss, and this helps to keep contaminants from entering the system.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

Dispose of all fluids according to local regulations and mandates.

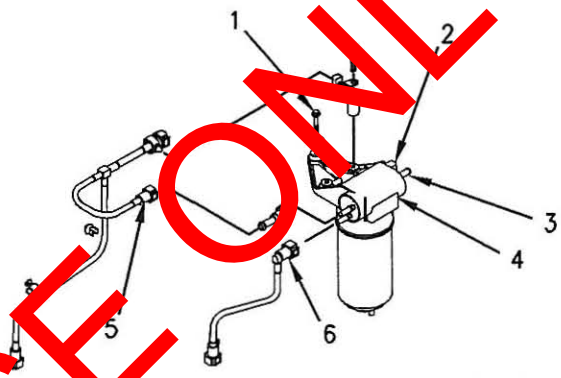

Illustration 1 g00952432
Typical example

1. Disconnect the tube assembly (5). Disconnect the tube assembly (6). Install dust covers onto the connectors for the fuel priming pump.
2. Disconnect the fuel return line from the connector (3). Install a dust cover to the connector (3).
3. Disconnect the harness assembly from the connector (2).
4. Support the fuel priming pump. Remove the three setscrews (1) and discard the rubber washers. Remove the fuel priming pump (4).

Removal Procedure for Type 2

Note: Put identification marks on the two fuel hose assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies . This helps prevent fluid loss, and this helps to keep contaminants from entering the system.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

Dispose of all fluids according to local regulations and mandates.

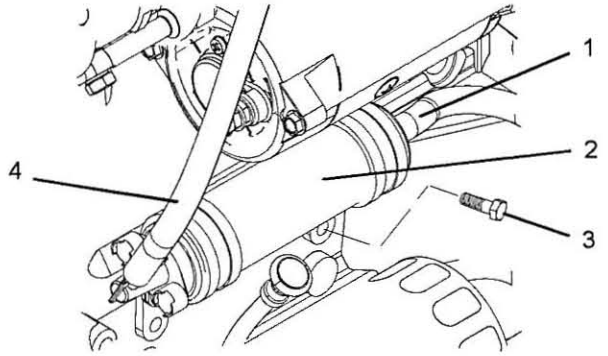

Illustration 2 g01121719

1. Disconnect the fuel hose assembly (1). Disconnect the fuel hose assembly (4). Install dust covers onto the connectors for the fuel priming pump.
2. Disconnect the harness assembly from the electrical connector on the fuel priming pump (2).
3. Support the fuel priming pump. Remove the two setscrews (3). Remove the fuel priming pump (2).

Installation Procedure

There are two types of fuel priming pump. Type 1 is mounted above the starter motor. Type 1 is combined with the fuel filter. Type 2 is mounted below the starter motor. Type 2 is not combined with the fuel filter. Type 2 is used on 4 cylinder engines only.

Installation Procedure for Type 1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

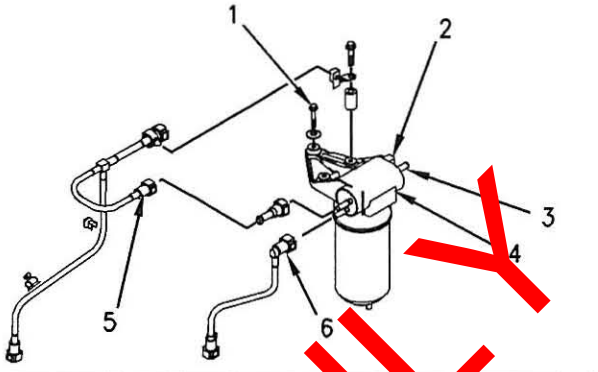

Illustration 3 g00952432
Typical example

1. Clean the external surfaces of the fuel priming pump (4). Position the fuel priming pump (4) and install the three setscrews (1) and new rubber washers.
2. Remove the dust covers from the fuel priming pump (4). Remove the plugs from the tube assemblies. Connect the tube assembly (5). Connect the tube assembly (6).
3. Connect the fuel return line to the connector (3).
4. Connect the harness assembly to the connector (2).
5. Remove the air from the fuel system. Refer to the Operations and Maintenance Manual, “Fuel System - Prime”.

Installation Procedure for Type 2

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

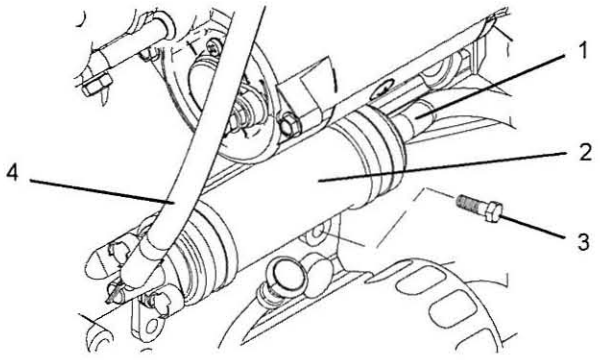

Illustration 4 g01121719

1. Clean the external surfaces of the fuel priming pump (2). Position the fuel priming pump (2) and install the two setscrews (3).

2. Remove the dust covers from the fuel priming pump. Remove the plugs from the fuel hose assemblies. Connect the fuel hose assembly (1). Connect the fuel hose assembly (4).

3. Connect the harness assembly to the electrical connector on the fuel priming pump (2).

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

i02224029

Fuel Filter Base - Remove and Install

Removal Procedure

There are two types of fuel filter. The element filter has a fuel filter element in a filter case. The element filter is combined with the fuel priming pump. The spin-on filter is self-contained. The spin-on filter is not combined with the fuel priming pump. The spin-on filter is used on 4 cylinder engines only.

Removal Procedure for the Element Filter

Note: There is an option for the three cylinder engine. The fuel filter and the fuel priming pump can be installed onto the application rather than onto the engine. If this is the case, refer to the appropriate OEM information as well to this text.

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 removal procedure is identical for the four cylinder and the three cylinder engines. The illustrations show the four cylinder engine.

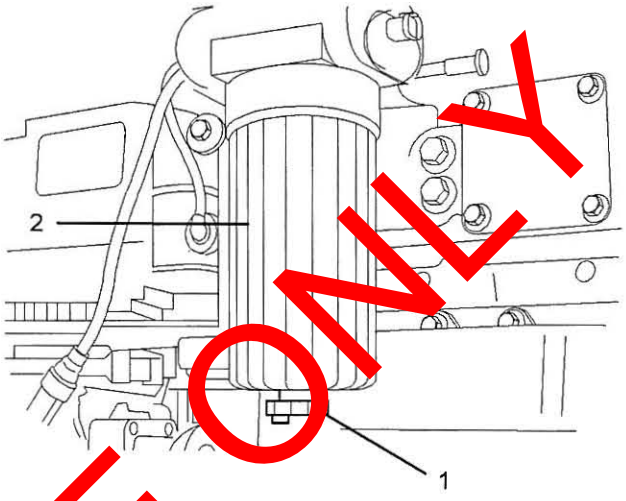

Illustration 5 g01010637
Typical example

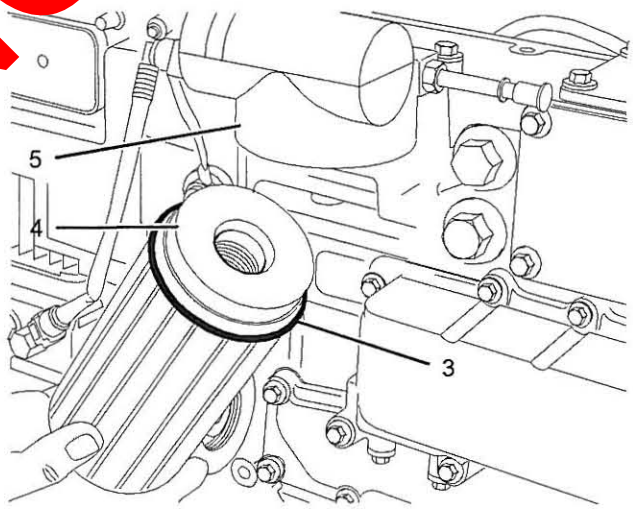

Illustration 6 g01010595
Typical example

1. Place a suitable container below the filter in order to collect the spilled fuel. Thoroughly clean the outside surfaces of the fuel filter. Open the drain (1) in order to drain the fuel from the filter.

2. Use a suitable strap wrench to loosen the filter case (2). Remove the filter case (2) from the filter head (5).

3. Push down against the spring pressure that is applied to the filter element (4). Rotate the filter element (4) counterclockwise in order to release the filter element from the filter case (2).

4. Discard the filter element (4) and the O-ring (3).

Removal Procedure for the Spin-on Filter

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.

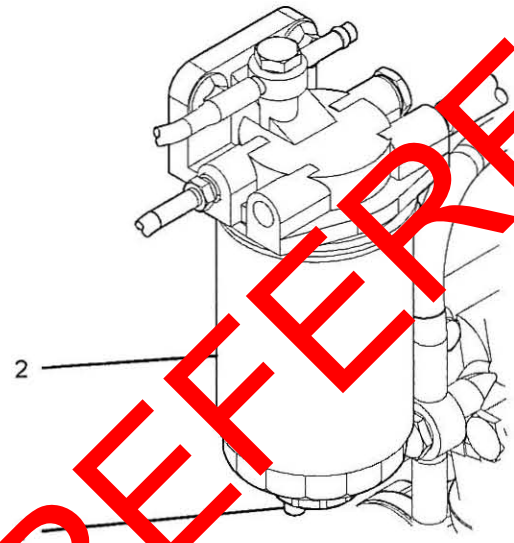

Illustration 7 g01121724

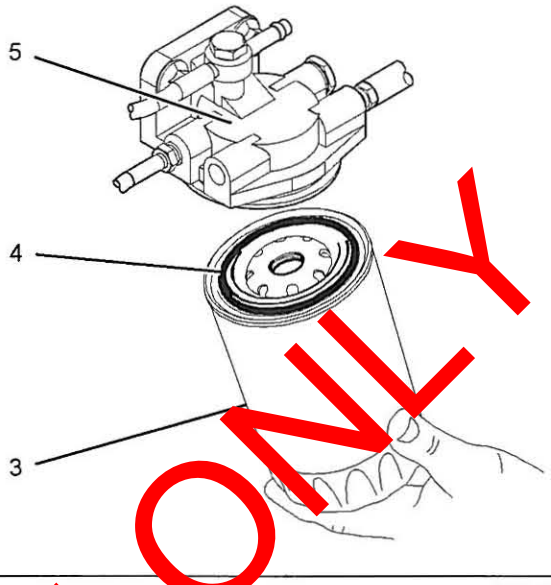

Illustration 8 g01121763

1. Turn the valves for the fuel lines (if equipped) to the OFF position before performing this maintenance. Place a tray under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel immediately.

2. Clean the outside of the fuel filter assembly. Open the fuel drain (1) and drain the fuel into a suitable container.

3. Use a suitable tool in order to remove the spin-on filter (2) from the filter head (5).

4. Discard the filter element (3) and the O-ring (4).

Installation Procedure

There are two types of fuel filter. The element filter has a fuel filter element in a filter case. The element filter is combined with the fuel priming pump. The spin-on filter is self-contained. The spin-on filter is not combined with the fuel priming pump.

Installation Procedure for the Element Filter

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

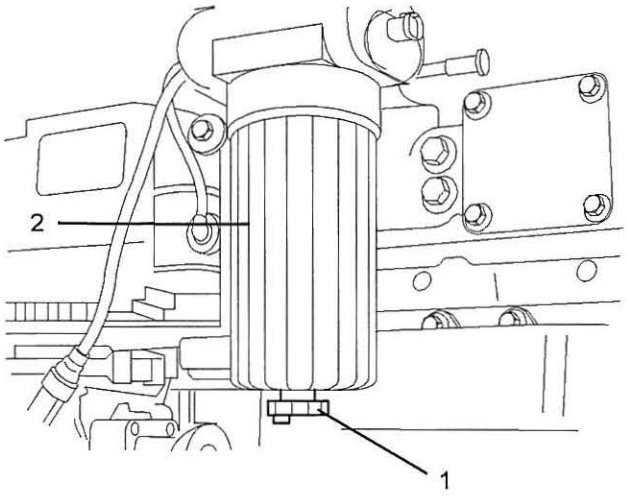

Illustration 9 g01010637
Typical example

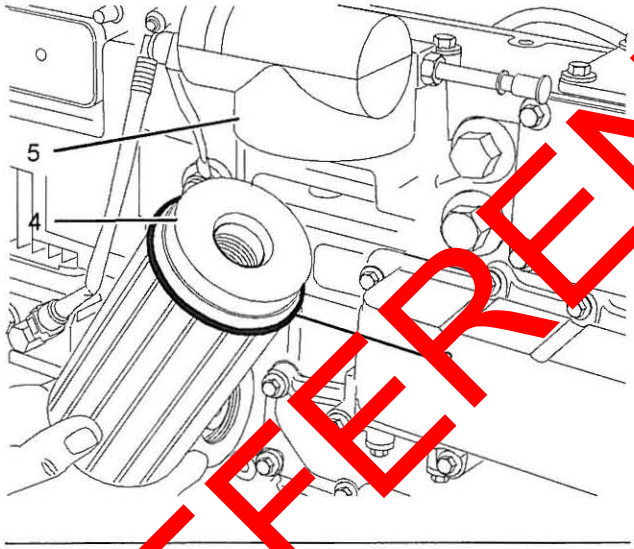

Illustration 10 g01010595
Typical example

1. Thoroughly clean the inside of the filter case (2) and thoroughly clean the lower face of the filter head (5).

2. Inspect the thread of a new filter element (4) in order to ensure that the thread is not damaged. Inspect the thread of the adapter in the filter head (5) in order to ensure that the thread is not damaged.

3. Inspect the condition of the spring and ensure that the spring is correctly located within the filter case (2).

4. Install the new filter element (4) into the filter case (2). Push the filter element against the spring pressure and rotate the filter element in a clockwise direction in order to secure the filter element within the filter case (2).

5. Lightly lubricate a new O-ring (3) with clean fuel oil. Install the new O-ring (3) into the recess within the filter case (2).

6. Close the drain (1).

7. Remove the air from the fuel system. Refer to the Operations and Maintenance Manual, "Fuel System - Prime". Remove the suitable container and dispose of the fuel that has drained as waste.

Installation Procedure for the Spin-on Filter

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

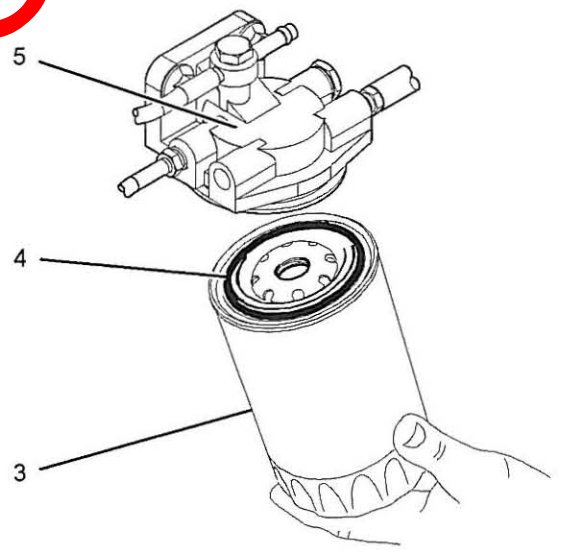

Illustration 11 g01121763

1. Thoroughly clean the lower face of the filter head (5).

2. Inspect the thread of a new filter element (3) in order to ensure that the thread is not damaged. Inspect the thread of the adapter in the filter head (5) in order to ensure that the thread is not damaged.

3. Lubricate the sealing ring (4) with clean fuel oil.

4. Install the spin-on filter (3) onto the filter head (5).

5. Tighten the spin-on filter by hand until the sealing ring contacts the filter head. Rotate the spin-on filter through 90 degrees.

6. Close the drain (1).

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

i02221357

Fuel Injection Lines - Remove

Removal Procedure

Start By:

a. If equipped, remove the cover for the fuel injectors. Refer to this Disassembly and Assembly Manual, "Fuel Injector Cover - 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: The removal procedure is identical for four cylinder and three cylinder engines. The illustration shows the four cylinder engine.

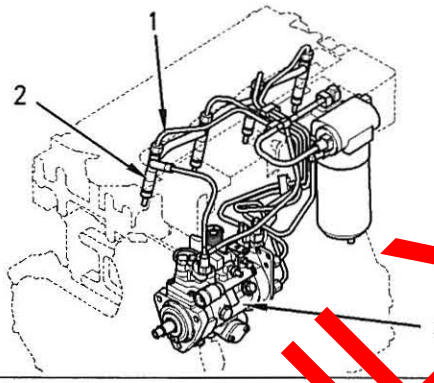

Illustration 12 g00955826
Typical example

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

2. Disconnect the fuel injection lines (1) at the fuel injection pump (3).

3. If necessary remove the clamps for the fuel injection lines or loosen the clamps for the fuel injection lines. Remove the fuel injection lines (1).

4. Install dust caps onto the ports of the fuel injectors and onto the ports of the fuel injection pump. Install dust caps onto both ends of the fuel injection lines.

i02221359

Fuel Injection Lines - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

Dispose of all fluids according to local regulations and mandates.

Note: The installation procedure is identical for the four cylinder and the three cylinder engines. The illustration shows the four cylinder engine.

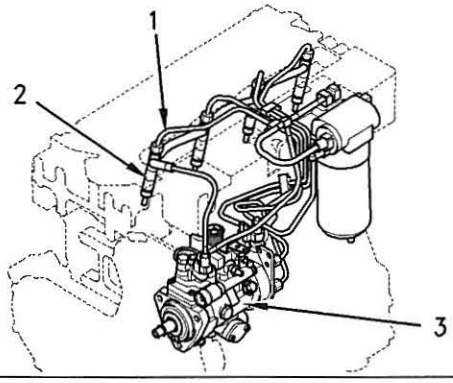

Illustration 13 g00955826

Typical example

1. Inspect the fuel injection lines (1) for wear and for damage. Replace any fuel injection line (1) that is worn or any fuel injection line that is damaged.

2. Loosely install the clamps for the fuel injection lines (1).

3. Remove the dust caps from the fuel injection pump (3) and from the fuel injectors (2). Remove the dust caps from the fuel injection lines (1).

4. Loosely connect the nuts at both ends of the fuel injection lines (1).

5. Ensure that each fuel injection line (1) does not contact any other fuel injection line or any other engine component. Tighten the fasteners for the clamps for the fuel injection lines (1). Check that the fuel injection lines (1) are still clear of other components.

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

7. Tighten the fuel injection lines (1) at the fuel injection pump to 30 N·m (22 lb ft).

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

END BY:

a. If equipped, install the cover for the fuel injectors. Refer to this Disassembly and Assembly Manual, "Fuel Injector Cover - Remove and Install".

i02221380

Fuel Injector Cover - Remove and Install (If Equipped)

Removal Procedure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The removal procedure is identical for the four cylinder and the three cylinder engines. The illustration shows the four cylinder engine.

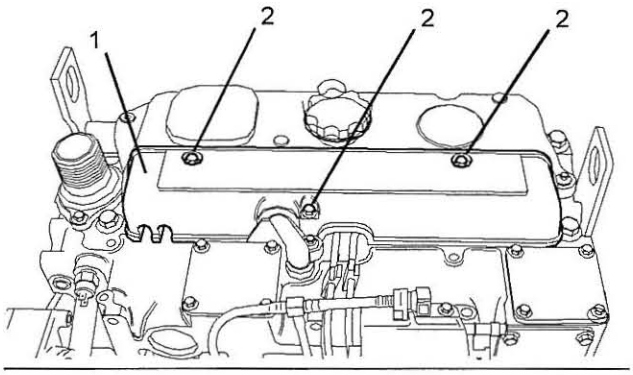

Illustration 14 g01011111

Typical example

1. Thoroughly clean all of the outer surfaces of the cover (1) for the fuel injectors.

2. Remove the setscrews (2) from the cover (1).

3. Remove the cover (1).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The installation procedure is identical for the four cylinder and the three cylinder engines. The illustration shows the four cylinder engine.

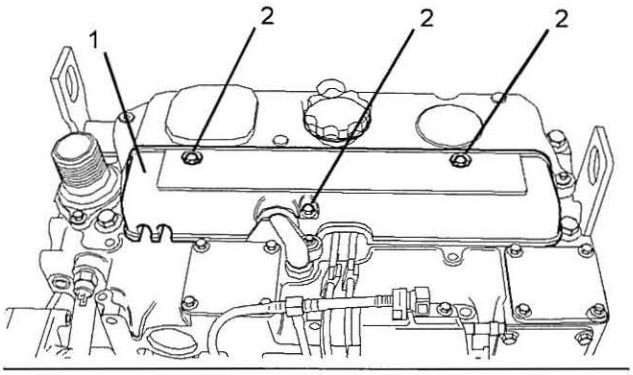

Illustration 15 g01011111
Typical example

1. Thoroughly clean all of the inner surfaces of the cover (1) for the fuel injectors.
2. Install the cover (1).
3. Install the setscrews (2) for the cover (1). Tighten the setscrews (2) to a torque of 9 N·m (7 lb ft).

i02216956

Fuel Injection Pump - Remove (Delphi DP210)

Removal Procedure

Start By:

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

b. Remove the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

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

Note: The removal procedure is identical for the four cylinder and the three cylinder engines. The illustrations show the four cylinder engine.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston".

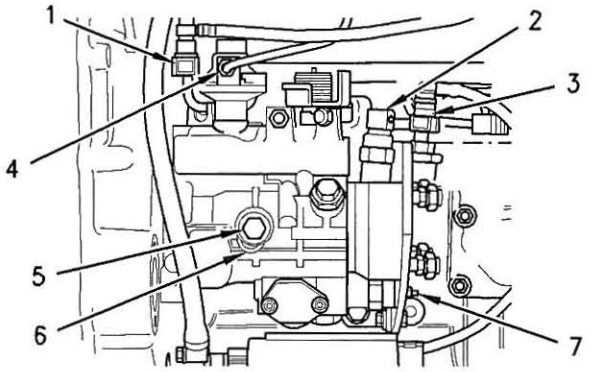

Illustration 16 g00956204
Typical example

2. Loosen the locking screw (5). Rotate the spacer (6) in order to allow the 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 the locking screw (5) to a torque of 17 N·m (13 lb ft).

Note: The 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.

Note: Put identification marks on all fuel hose assemblies and on all tube assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies and plug all tube assemblies with suitable plastic plugs. Also install dust caps on all of the connectors on the fuel injection pump. This helps prevent fluid loss, and this helps to keep contaminants from entering the system.

3. Disconnect the fuel return line (1). Disconnect the tube assembly (4) from the fuel injection pump.

4. Disconnect the fuel line (3).

5. Disconnect the harness assembly (2) from the timing advance solenoid (7).

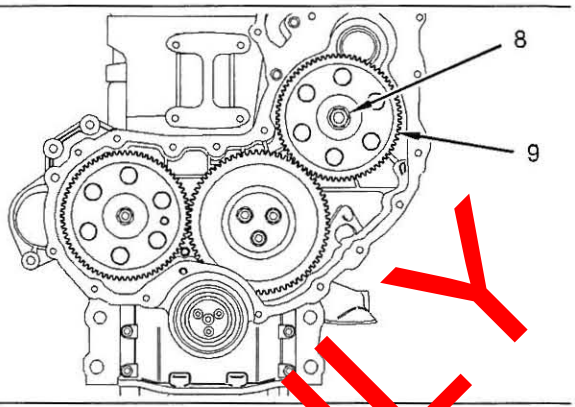

Illustration 17 g01011369
Typical example

6. Remove the nut (8) and the washer from the shaft of the fuel injection pump.

7. Use a suitable puller in order to remove the fuel injection pump gear (9).

Note: Do not pry the fuel injection pump gear (9) from the shaft of the fuel injection pump.

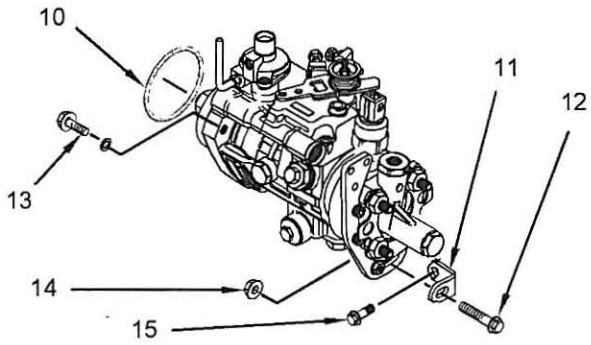

Illustration 18 g01062058
Typical example

Note: The two steps that follow are only required if the bracket (11) is installed on the fuel injection pump.

8. Remove the nut (14). Remove the bolt (12).

9. If necessary, remove the setscrew (15) and the bracket (11) from the cylinder block.

10. Remove the setscrews (13) in order to remove the fuel injection pump.

11. Remove the fuel injection pump from the front housing. Remove the O-ring (10) and discard the O-ring from the fuel injection pump.

i02075326

Fuel Injection Pump - Remove (Delphi STP)

Removal Procedure

Start By:

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

b. Remove the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Timing Top Center Position for No. 1 Piston".

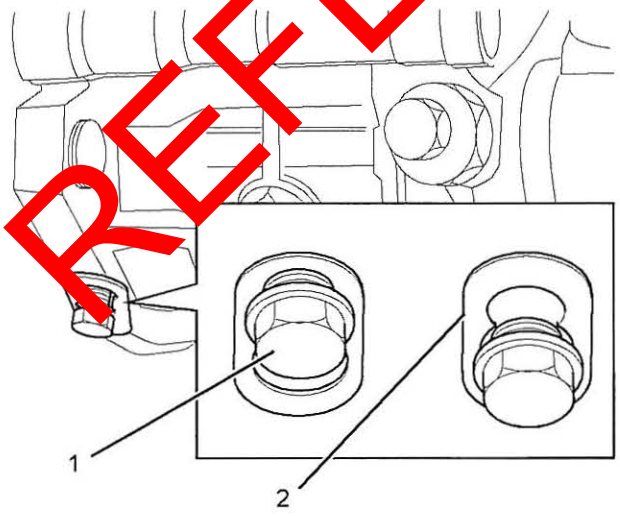

Illustration 19 g01061708

2. Loosen the locking screw (1). Rotate the spacer (2) in order to allow the locking screw (1) 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 the locking screw (1) to a torque of 13 N·m (9.6 lb ft).

Note: The locking screw (1) 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.

Note: Put identification marks on all fuel hose assemblies and on all tube assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies and plug all tube assemblies with suitable plastic plugs. Also, install all dust caps on all of the connectors on the fuel injection pump. This helps prevent fluid loss, and this helps to keep contaminants from entering the system.

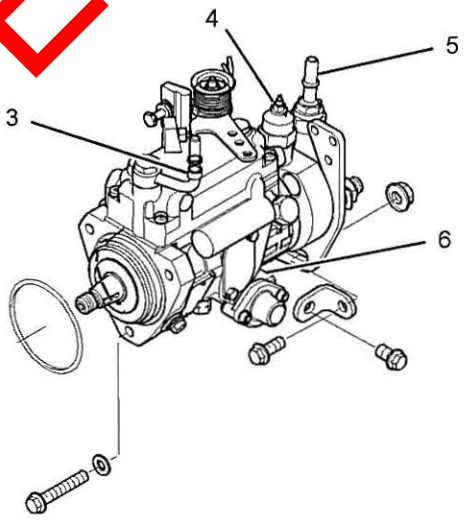

Illustration 20 g01062395

3. Disconnect the fuel return line (3).

4. Disconnect the fuel line (5).

5. Disconnect the harness assembly (4) from the timing advance solenoid (6).

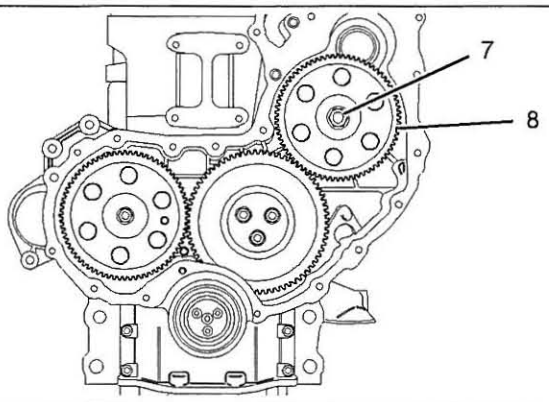

Illustration 21 g01062397
Typical example

6. Remove the nut (7) and the washer from the shaft of the fuel injection pump.

7. Use a suitable puller in order to remove the fuel injection pump gear (8).

Note: Do not pry the fuel injection pump gear (9) from the shaft of the fuel injection pump.

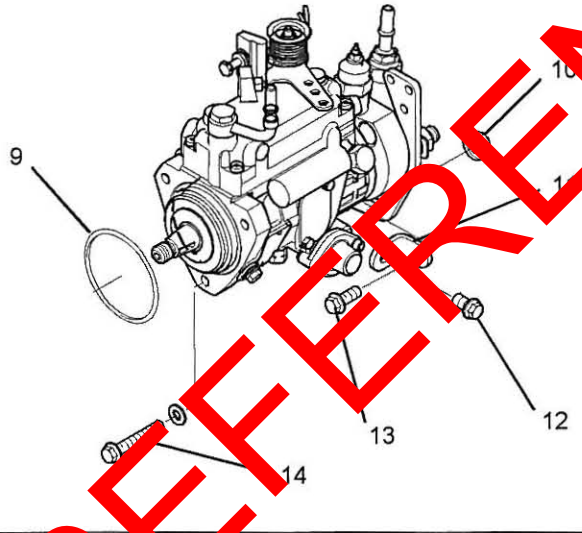

Illustration 22 g01062396

8. Remove the nut (10). Remove the bolt (13).

9. If necessary, remove the setscrew (14) and the bracket (11) from the cylinder block.

10. Remove the setscrews (14) in order to remove the fuel injection pump.

11. Remove the fuel injection pump from the front housing. Remove the O-ring (9) and discard the O-ring from the fuel injection pump.

i02224700

Fuel Injection Pump - Remove (Delphi DPG)

Removal Procedure

Start By:

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

b. Remove the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston".

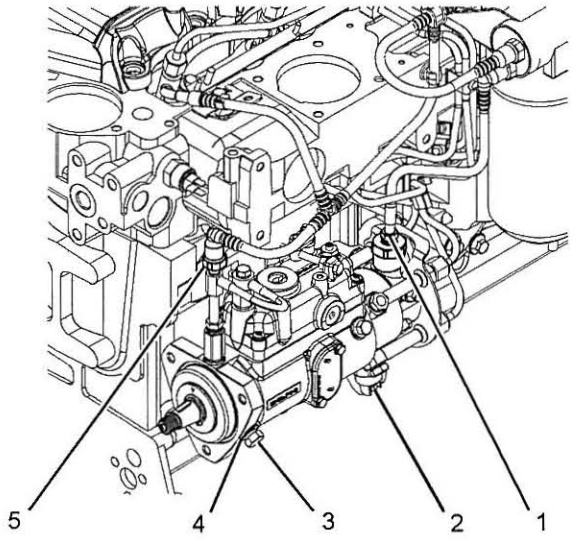

Illustration 23 g01122132

2. Loosen the locking screw (3). Rotate the spacer (4) in order to allow the locking screw (3) 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 the locking screw (3) to a torque of 13 N·m (9.6 lb ft).

Note: The locking screw (3) 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.

Note: Put identification marks on all fuel hose assemblies and on all tube assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies and plug all tube assemblies with suitable plastic plugs. Also install dust caps on all of the connectors on the fuel injection pump. This helps prevent fluid loss, and this helps to keep contaminants from entering the system.

3. Disconnect the fuel return line (5).

4. Disconnect the fuel line (1).

5. Disconnect the harness assembly from the fuel shutoff solenoid (2).

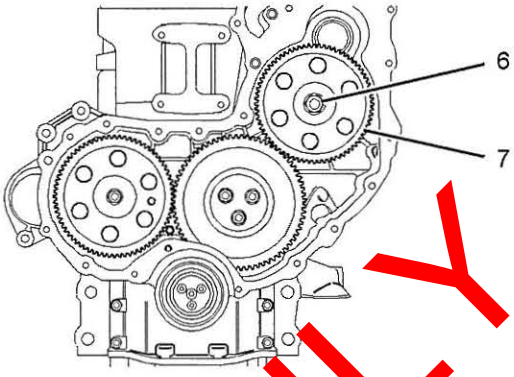

Illustration 24 g01122133

6. Remove the nut (6) and the washer from the shaft of the fuel injection pump.

7. Use a suitable puller in order to remove the fuel injection pump gear (7).

Note: Do not pry the fuel injection pump gear (7) from the shaft of the fuel injection pump.

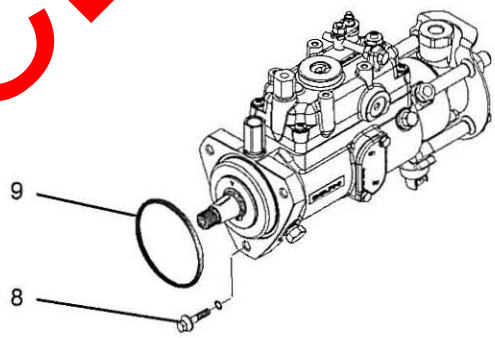

Illustration 25 g01122134

8. Remove the setscrews (8) in order to remove the fuel injection pump.

9. Remove the fuel injection pump from the front housing. Remove the O-ring (9) and discard the O-ring from the fuel injection pump.

i01941022

Fuel Injection Pump - Remove (Bosch EPVE for the 1104 engines only)

Removal Procedure

Start By:

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

b. Remove the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston".

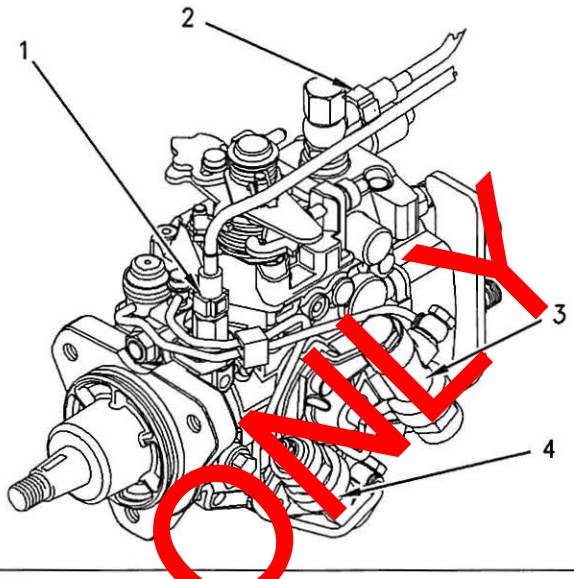

Illustration 26 g00996409

Note: Put identification marks on all fuel hose assemblies and on all tube assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies and plug all tube assemblies with suitable plastic plugs. Also install dust caps on all of the connectors on the fuel injection pump. This helps prevent fluid loss, and this helps to keep contaminants from entering the system.

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

3. Disconnect the wiring harness assembly from the cold start advance unit (3). Disconnect the wiring harness assembly from the engine shutoff solenoid (4).

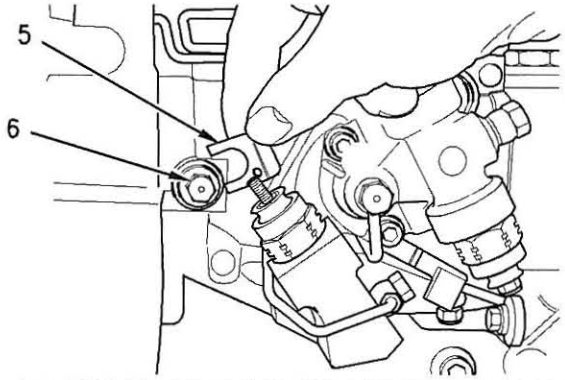

Illustration 27 g00996410

4. Loosen the locking screw (6). Move the spacer (5) in order to allow the locking screw (6) 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 the locking screw (6) to a torque of 31 N·m (23 lb ft).

Note: The locking screw (6) 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.

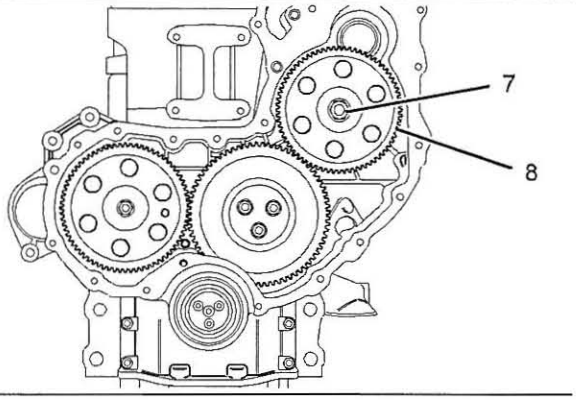

Illustration 28 g01011474

5. Remove the nut (7) and the washer from the shaft of the fuel injection pump.

6. Use a suitable puller in order to remove the fuel injection pump gear (8).

Note: Do not pry the fuel injection pump gear from the shaft of the fuel injection pump.

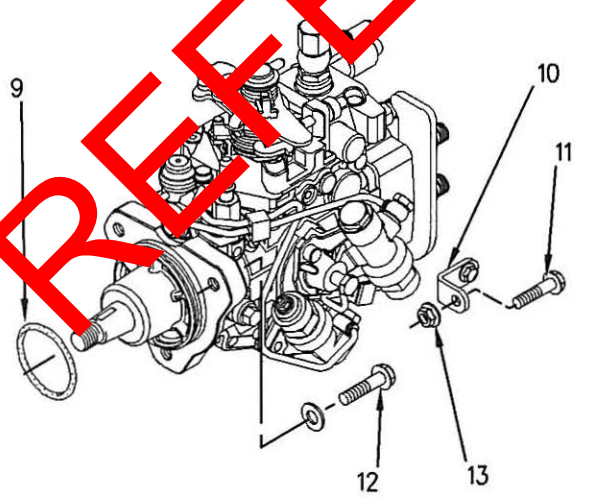

Illustration 29 g00996474

7. Remove the nut (13). Remove the bolt (11).

8. If necessary, remove the setscrew and the bracket (10) from the cylinder block.

9. Remove the setscrews (12) in order to remove the fuel injection pump.

10. Remove the fuel injection pump from the front housing. Remove the O-ring (9) from the fuel injection pump and discard the O-ring.

i220108

Fuel Injection Pump - Remove (Delphi DPA)

Removal Procedure

Start By:

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

b. Remove the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston".

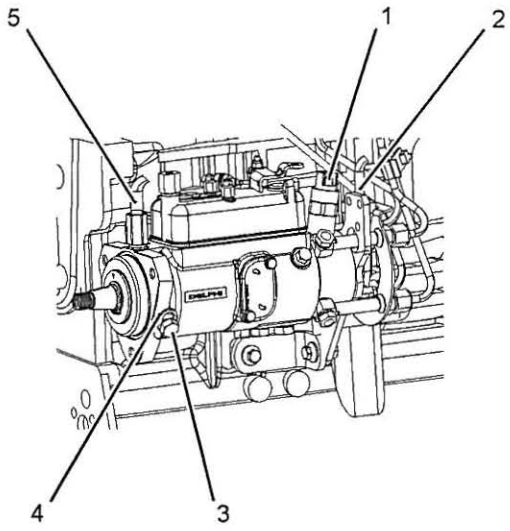

Illustration 30 g01120559
Typical example

2. Loosen the locking screw (3). Rotate the spacer (4) in order to allow the locking screw (3) 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 the locking screw (3) to a torque of 13 N·m (9.6 lb ft).

Note: The locking screw (3) 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.

Note: Put identification marks on all fuel hose assemblies and on all tube assemblies for installation purposes. After being disconnected, plug all fuel hose assemblies and plug all tube assemblies with suitable plastic plugs. Also install dust caps on all of the connectors on the fuel injection pump. This helps prevent fluid loss and this helps to keep contaminants from entering the system.

3. Disconnect the fuel return line (5).

4. Disconnect the fuel line (2).

5. Disconnect the harness assembly from the fuel shutoff solenoid (1).

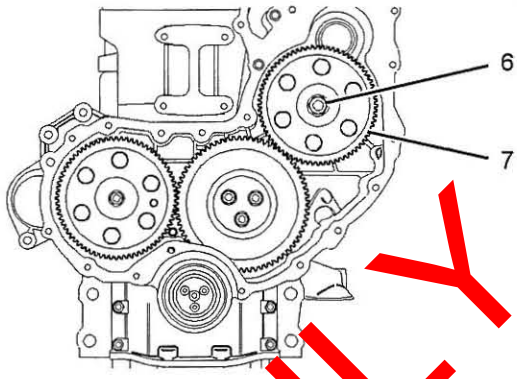

Illustration 31 g01120567
Typical example

6. Remove the nut (6) and the washer from the shaft of the fuel injection pump.

7. Use a suitable puller in order to remove the fuel injection pump gear (7).

Note: Do not pry the fuel injection pump gear (7) from the shaft of the fuel injection pump.

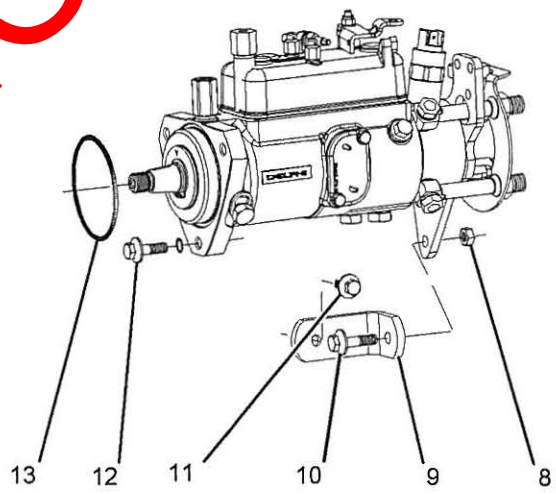

Illustration 32 g01120575
Typical example

8. Remove the nut (8). Remove the bolt (10).

9. If necessary, remove the setscrew (11) and the bracket (9) from the cylinder block.

10. Remove the setscrews (12) in order to remove the fuel injection pump.

11. Remove the fuel injection pump from the front housing. Remove the O-ring (13) and discard the O-ring from the fuel injection pump.

i02216957

Fuel Injection Pump - Install (Delphi DP210)

Installation Procedure

Note: The installation procedure is identical for the four cylinder and the three cylinder engines. The illustrations show the four cylinder engine.

Note: The shaft of the fuel injection pump must remain locked until the timing gear (9) has been installed and tightened onto the shaft of the fuel injection pump. The locking screw (5) must remain locked until you are instructed to loosen the locking screw. The fuel injection pump must be returned to your Perkins Dealer if the shaft of the fuel injection pump was rotated accidentally.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Fuel Injection Timing - Check".

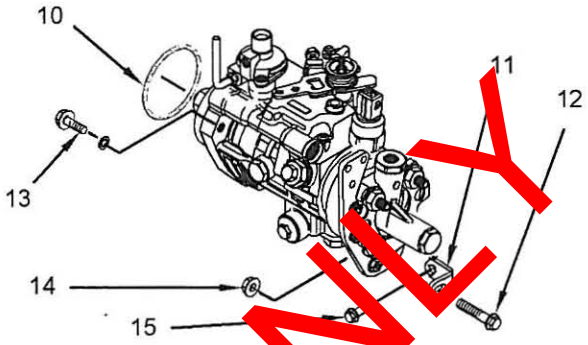

Illustration 33 g01062058
Typical example

Note: Do not lubricate the new O-ring (10). The O-ring should be installed dry.

2. Install the new O-ring (10) onto the fuel injection pump. Position the fuel injection pump onto the front housing. Install the setscrews (13). Tighten the setscrews (13) to a torque of 25 N·m (18 lb ft).

Note: The two steps that follow are only required if the bracket (11) is installed on the fuel injection pump.

3. Install the setscrew (15) and the bracket (11) onto the cylinder block if the bracket was previously removed. Ensure that the bracket (11) supports the fuel injection pump without applying any other external force on the fuel injection pump. Tighten the setscrew (15) to a torque of 44 N·m (32 lb ft).

4. Install the bolt (12) and the nut (14).

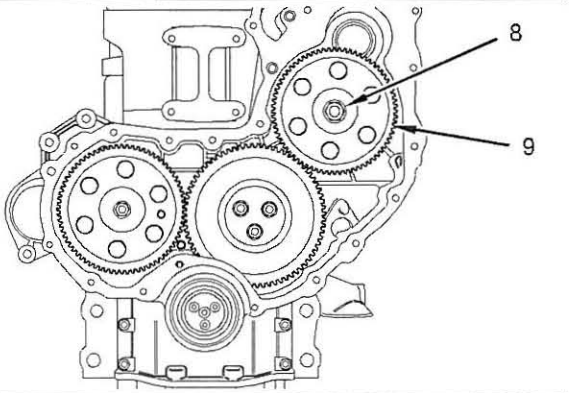

Illustration 34 g01011369
Typical example

Note: Ensure that the mating surfaces of the fuel injection pump gear and the shaft of the fuel injection pump are clean. Lubricate the threads of the shaft for the fuel injection pump. The nut (8) must turn freely until contact is made with the fuel injection pump gear.

5. Position the fuel injection pump gear (9) onto the shaft of the fuel injection pump. Install the washer and the nut (8). Rotate the fuel injection pump gear (9) in a counterclockwise direction in order to remove the backlash. Tighten the nut (8) to a torque of 24 N·m (17 lb ft).

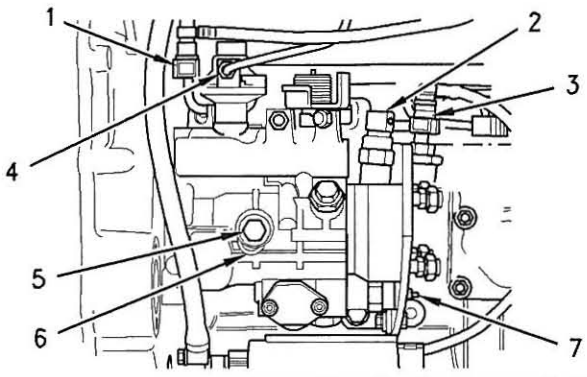

Illustration 35 g00956204
Typical example

6. Connect the harness assembly to the timing advance solenoid (7).

7. Connect the harness assembly (2).

8. Remove all of the dust caps from the connectors on the fuel injection pump. Remove all of the plugs from the fuel hose assemblies and from the tube assemblies.

9. Connect the fuel line (3), the fuel return line (1), and the tube assembly (4) to the fuel injection pump.

10. Loosen the locking screw (5). Move the spacer (6) in order to prevent the locking screw (5) from tightening against the shaft of the fuel injection pump. Tighten the locking screw (5) to a torque of 12 N·m (106 lb in).

Note: The spacer (6) must be correctly positioned and locking screw (5) must be tightened in order to prevent the locking screw from contacting the shaft of the fuel injection pump.

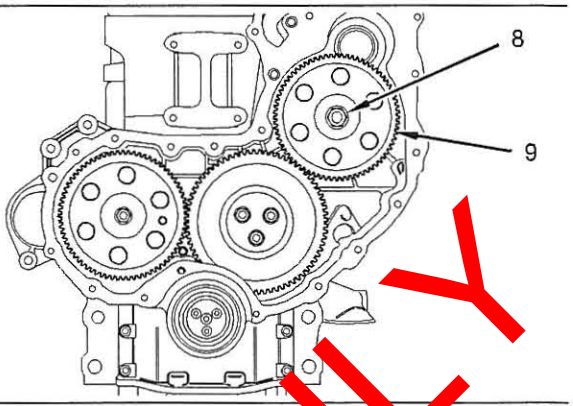

Illustration 36 g01011369
Typical example

11. Tighten the nut (8) to a torque of 88 N·m (65 lb ft).

End By:

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

b. Install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

c. Install the fuel injection lines. Refer to this Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

i02075327

Fuel Injection Pump - Install (Delphi STP)

Installation Procedure

Note: The shaft of the fuel injection pump must remain locked until the timing gear (8) has been installed and tightened onto the shaft of the fuel injection pump. The locking screw (1) must remain locked until you are instructed to loosen the locking screw. The fuel injection pump must be returned to your Perkins Dealer if the shaft of the fuel injection pump was rotated accidentally.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Fuel Injection Timing - Check".

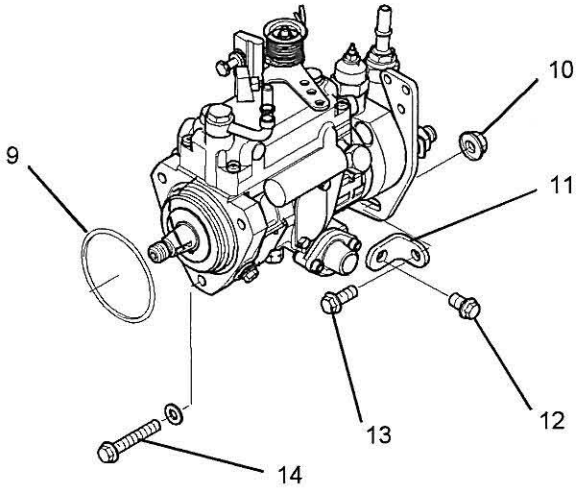

Illustration 37 g01062396

Note: Do not lubricate the new O-ring (9). The O-ring should be installed dry.

2. Install the new O-ring (9) onto the fuel injection pump. Position the fuel injection pump onto the front housing. Install the setscrews (14). Tighten the setscrews (14) to a torque of 25 N·m (18 lb ft).

3. Install the setscrew (12) and the bracket (11) onto the cylinder block if the bracket was previously removed. Ensure that the bracket (11) supports the fuel injection pump without applying any other external force on the fuel injection pump. Tighten the setscrew (12) to a torque of 44 N·m (32 lb ft).

4. Install the bolt (13) and the nut (10).

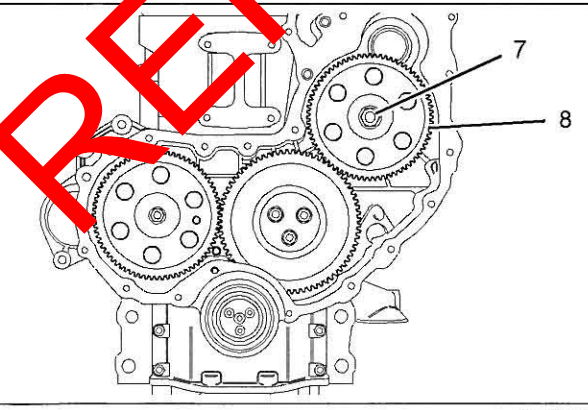

Illustration 38 g01062397

Typical example

Note: Ensure that the mating surfaces of the fuel injection pump gear and the shaft of the fuel injection pump are clean. Lubricate the threads of the shaft for the fuel injection pump. The nut (7) must turn freely until contact is made with the fuel injection pump gear.

5. Position the fuel injection pump gear (8) onto the shaft of the fuel injection pump. Install the washer and the nut (7). Rotate the fuel injection pump gear (8) in a counterclockwise direction in order to remove the backlash. Tighten the nut (7) to a torque of 24 N·m (17 lb ft).

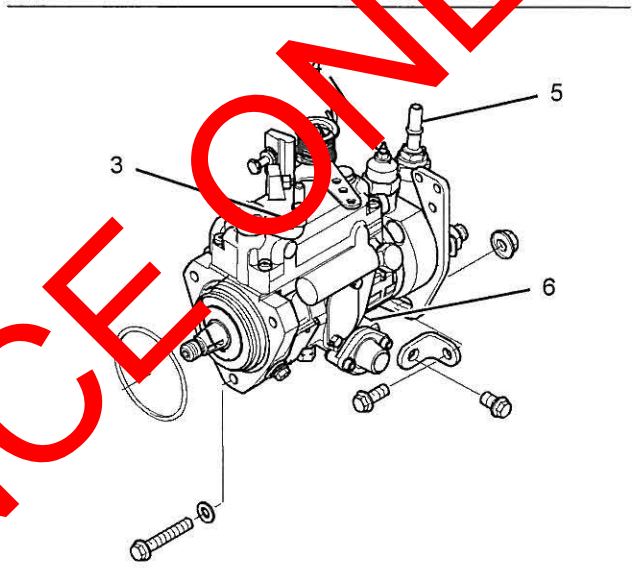

Illustration 39 g01062395

6. Connect the harness assembly to the timing advance solenoid (6).

7. Connect the harness assembly (4).

8. Remove all of the dust caps from the connectors on the fuel injection pump. Remove all of the plugs from the fuel hose assemblies and from the tube assemblies.

9. Connect the fuel line (5) to the fuel injection pump. Connect the fuel return line (3) to the fuel injection pump.

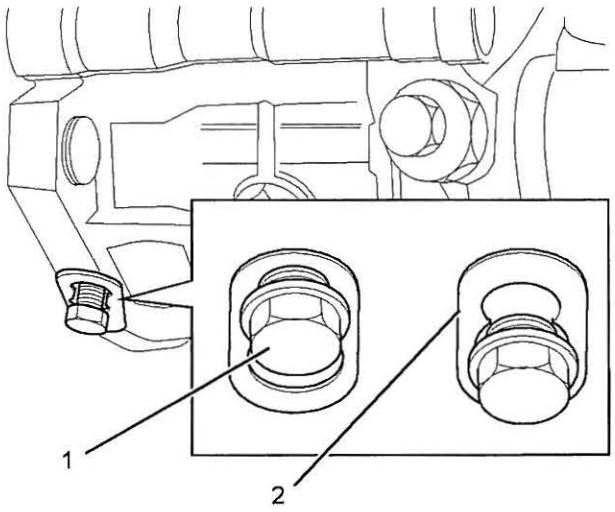

Illustration 40 g01061708

10. Loosen the locking screw (1). Move the spacer (2) in order to prevent the locking screw (1) from tightening against the shaft of the fuel injection pump. Tighten the locking screw (1) to a torque of 12 N·m (8.8 lb ft).

Note: The spacer (2) must be correctly positioned and locking screw (1) must be tightened in order to prevent the locking screw from contacting the shaft of the fuel injection pump.

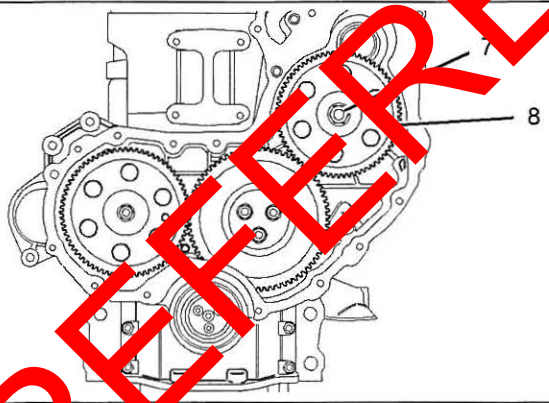

Illustration 41 g01062397
Typical example

11. Tighten the nut (7) to a torque of 88 N·m (65 lb ft).

End By:

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

b. Install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

c. Install the fuel injection lines. Refer to this Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

i02224733

Fuel Injection Pump - Install (Delphi DPG)

Installation Procedure

Note: The installation procedure is identical for the four cylinder and the three cylinder engines. The illustrations show the four cylinder engine.

Note: The shaft of the fuel injection pump must remain locked until the timing gear (7) has been installed and tightened onto the shaft of the fuel injection pump. The locking screw (3) must remain locked until you are instructed to loosen the locking screw. The fuel injection pump must be returned to your Perkins Dealer if the shaft of the fuel injection pump was rotated accidentally.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Fuel Injection Timing - Check".

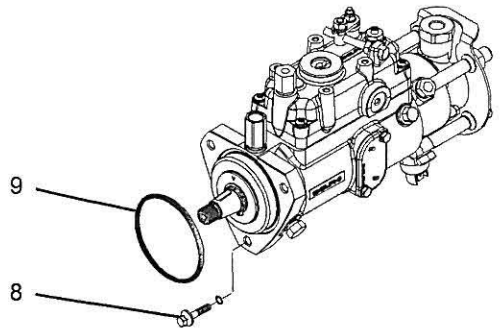

Illustration 42 g01122134

Typical example

Note: Do not lubricate the new O-ring (9). The O-ring should be installed dry.

2. Install the new O-ring (9) onto the fuel injection pump. Position the fuel injection pump onto the front housing. Install the setscrews (8). Tighten the setscrews (8) to a torque of 25 N·m (18 lb ft).

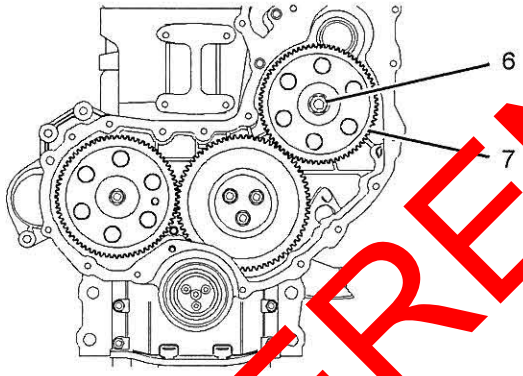

Illustration 43 g01122133

Note: Ensure that the mating surfaces of the fuel injection pump gear and the shaft of the fuel injection pump are clean. Lubricate the threads of the shaft for the fuel injection pump. The nut (6) must turn freely until contact is made with the fuel injection pump gear.

3. Position the fuel injection pump gear (7) onto the shaft of the fuel injection pump. Install the washer and the nut (6). Rotate the fuel injection pump gear (7) in a counterclockwise direction in order to remove the backlash. Tighten the nut (6) to a torque of 24 N·m (17 lb ft).

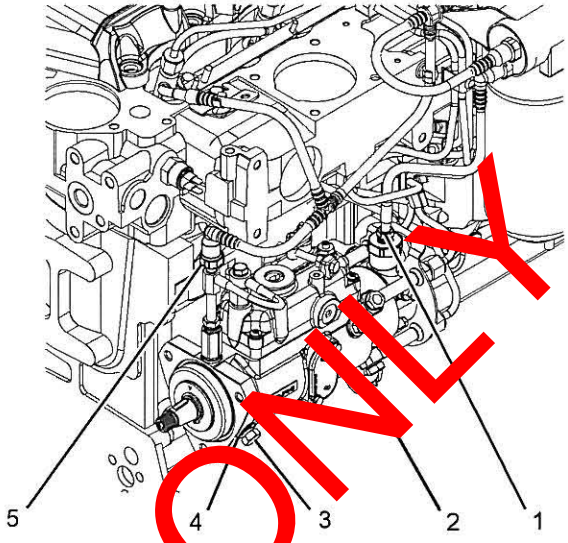

Illustration 44 g01122132

4. Connect the harness assembly to the fuel shutoff solenoid (2).

5. Remove all of the dust caps from the connectors on the fuel injection pump. Remove all of the plugs from the fuel hose assemblies and from the tube assemblies.

6. Connect the fuel line (1) and the fuel return line (5) to the fuel injection pump.

7. Loosen the locking screw (3). Move the spacer (4) in order to prevent the locking screw (3) from tightening against the shaft of the fuel injection pump. Tighten the locking screw (3) to a torque of 12 N·m (106 lb in).

Note: The spacer (4) must be correctly positioned and locking screw (3) must be tightened in order to prevent the locking screw from contacting the shaft of the fuel injection pump.

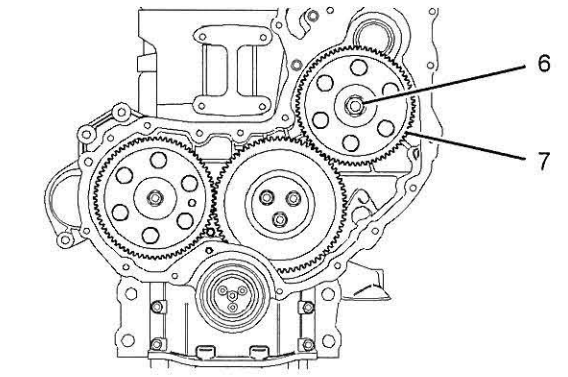

Illustration 45 g01122133

8. Tighten the nut (6) to a torque of 88 N·m (65 lb ft).

End By:

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

b. Install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

c. Install the fuel injection lines. Refer to this Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

i01943877

Fuel Injection Pump - Install (Bosch EPVE for the 1104 engines only)

Installation Procedure

Note: The shaft of the fuel injection pump must remain locked until the timing gear (8) has been installed and tightened onto the shaft of the fuel injection pump. The locking screw (6) must remain locked until you are instructed to loosen the locking screw. The Bosch EPVE fuel injection pump can be timed to the engine by a technician. Refer to the Testing and Adjusting Manual, "Fuel Injection Pump Timing - Check and Fuel Injection Pump Timing - Adjust" if the shaft of the fuel injection pump was rotated accidentally.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Fuel Injection Timing - Check".

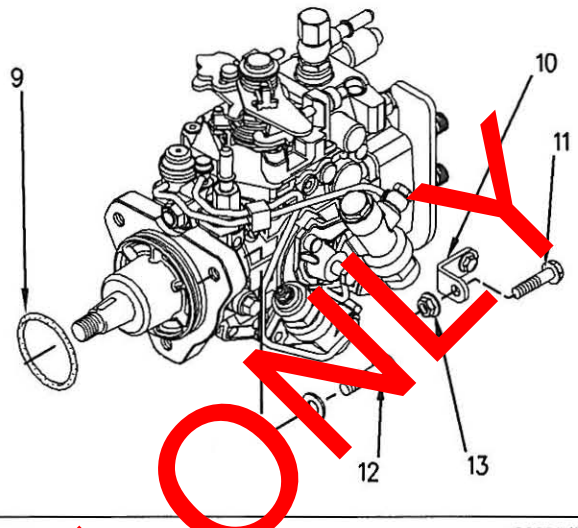

Illustration 46 g00996474

2. Lightly lubricate a new O-ring (9) with Perkins 17[illegible]-501 Silicone Fluid MS200/1000. Install the new O-ring (9) onto the fuel injection pump. Position the fuel injection pump on the front housing. Install the setscrews (12). Tighten the setscrews to a torque of 25 N·m (18 lb ft).

3. Install the setscrew and the bracket (10) onto the cylinder block if the bracket was previously removed. Ensure that the bracket (10) supports the fuel injection pump without applying any other external force on the fuel injection pump. Tighten the setscrew to a torque of 44 N·m (32 lb ft).

4. Install the bolt (11) and the nut (13).

Note: Ensure that the mating surfaces of the fuel injection pump gear (8) and the shaft of the fuel injection pump are clean. Lubricate the threads of the shaft for the fuel injection pump. The nut (7) must turn freely until contact is made with the fuel injection pump gear (8).

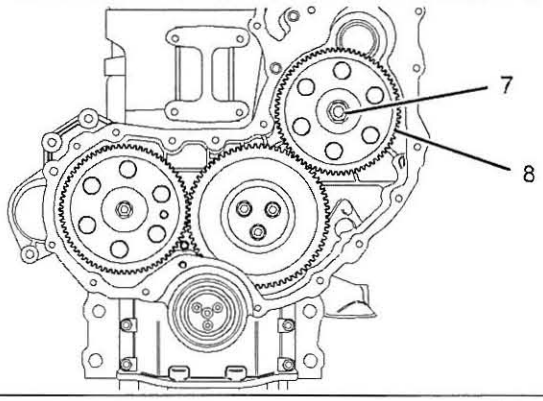

Illustration 47 g01011474

5. Position the fuel injection pump gear (8) onto the shaft of the fuel injection pump. Install the washer and the nut (7). Rotate the fuel injection pump gear (8) in a counterclockwise direction in order to remove the backlash. Tighten the nut (7) to a torque of 24 N·m (17 lb ft).

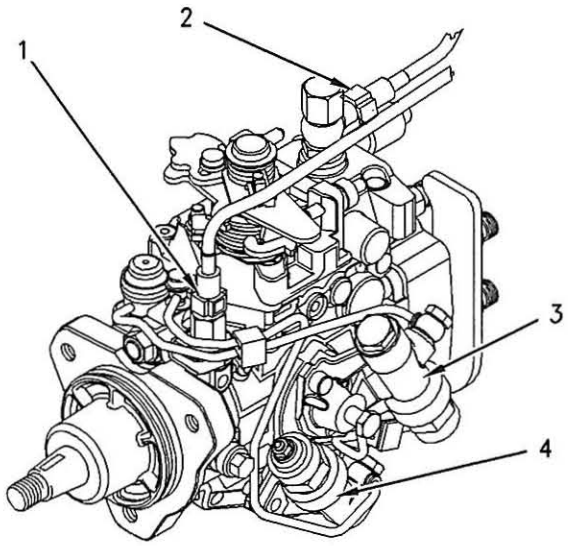

Illustration 48 g00996409

6. Connect the wiring harness assembly to the engine shutoff solenoid (4).

7. Connect the wiring harness assembly to the cold start advance unit (3).

8. Remove all of the dust caps from the connectors on the fuel injection pump. Remove all of the plugs from the fuel hose assemblies and from the tube assemblies.

9. Connect the tube assembly (2) to the fuel injection pump. Connect the tube assembly (1) to the fuel injection pump.

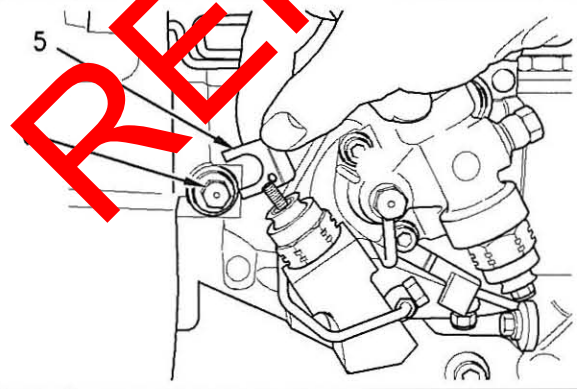

Illustration 49 g00996410

10. Loosen the locking screw (6). Move spacer (5) in order to prevent the locking screw (6) from tightening against the shaft of the fuel injection pump. Tighten the locking screw (6) to a torque of 12 N·m (106 lb in).

Note: The spacer (5) must be installed and the locking screw (6) must be tightened in order to prevent the locking screw from contacting the shaft of the fuel injection pump.

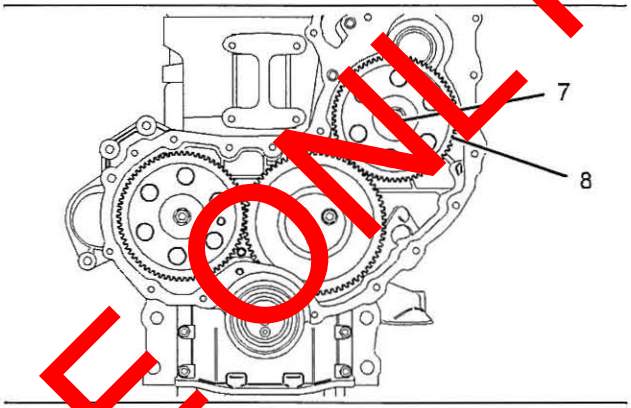

Illustration 50 g01011474

11. Tighten the nut (7) to a torque of 88 N·m (65 lb ft).

End By:

a. Install the front cover. Refer to this Disassembly and Assembly Manual, “Front Cover - Remove and Install”.

b. Install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, “Crankshaft Pulley - Remove and Install”.

c. Install the fuel injection lines. Refer to this Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

i02224693

Fuel Injection Pump - Install (Delphi DPA)

Installation Procedure

Note: The shaft of the fuel injection pump must remain locked until the timing gear (7) has been installed and tightened onto the shaft of the fuel injection pump. The locking screw (3) must remain locked until you are instructed to loosen the locking screw. The fuel injection pump must be returned to your Perkins Dealer if the shaft of the fuel injection pump was rotated accidentally.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Fuel Injection Timing - Check".

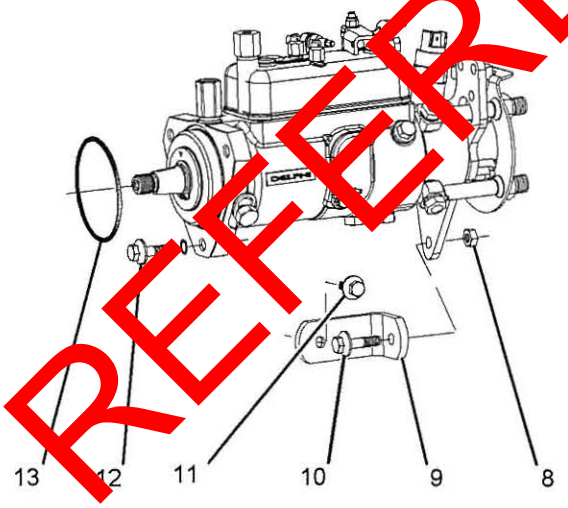

Illustration 51 g01120575

Note: Do not lubricate the new O-ring (13). The O-ring should be installed dry.

2. Install the new O-ring (13) onto the fuel injection pump. Position the fuel injection pump onto the front housing. Install the setscrews (12). Tighten the setscrews (12) to a torque of 25 N·m (18 lb ft).

3. Loosely install the setscrew (11) and the bracket (9) onto the cylinder block if the bracket was previously removed. Loosely install the bolt (10) and the nut (8). Ensure that the bracket (9) supports the fuel injection pump without applying any other external force on the fuel injection pump. Tighten the setscrew (11), the bolt (10) and the nut (8) to a torque of 44 N·m (32 lb ft).

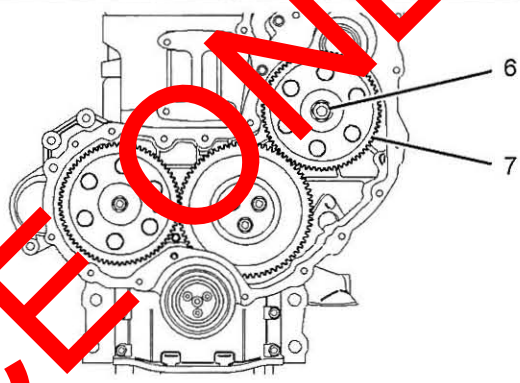

Illustration 52 g01120567

Note: Ensure that the mating surfaces of the fuel injection pump gear and the shaft of the fuel injection pump are clean. Lubricate the threads of the shaft for the fuel injection pump. The nut (6) must turn freely until contact is made with the fuel injection pump gear.

4. Position the fuel injection pump gear (7) onto the shaft of the fuel injection pump. Install the washer and the nut (6). Rotate the fuel injection pump gear (7) in a counterclockwise direction in order to remove the backlash. Tighten the nut (6) to a torque of 24 N·m (17 lb ft).

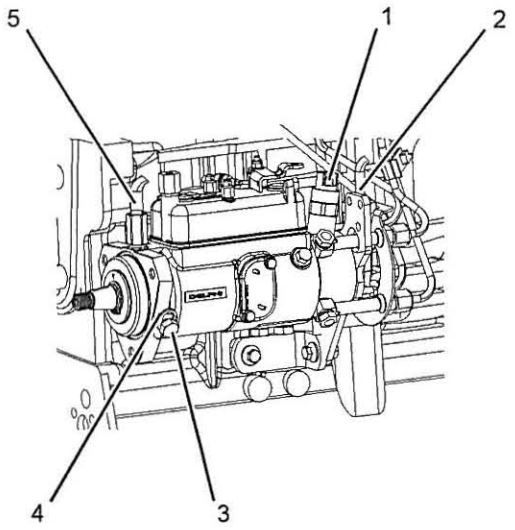

Illustration 53 g01120559

5. Connect the harness assembly to the fuel shutoff solenoid (1).

6. Remove all of the dust caps from the connectors on the fuel injection pump. Remove all of the plugs from the fuel hose assemblies and from the tube assemblies.

7. Connect the fuel line (2) and the fuel return line (3) to the fuel injection pump.

8. Loosen the locking screw (3). Move the spacer (4) in order to prevent the locking screw (3) from tightening against the shaft of the fuel injection pump. Tighten the locking screw (3) to a torque of 12 N·m (106 lb in).

Note: The spacer (4) must be correctly positioned and locking screw (3) must be tightened in order to prevent the locking screw from contacting the shaft of the fuel injection pump.

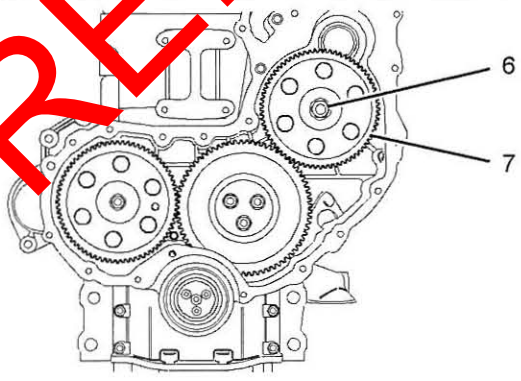

Illustration 54 g01120567

9. Tighten the nut (6) to a torque of 88 N·m (65 lb ft).

End By:

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

b. Install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

c. Install the fuel injection lines. Refer to this Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

i01938589

Fuel Injector - Remove

Removal Procedure

Start By:

a. Remove the cover for the fuel injectors. Refer to this Disassembly and Assembly Manual, "Fuel Injector Cover - Remove and Install".

b. Remove the fuel injection lines. Refer to this 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.

1. Disconnect the tube assemblies from the fuel filter base for the fuel inlet and the fuel outlet.

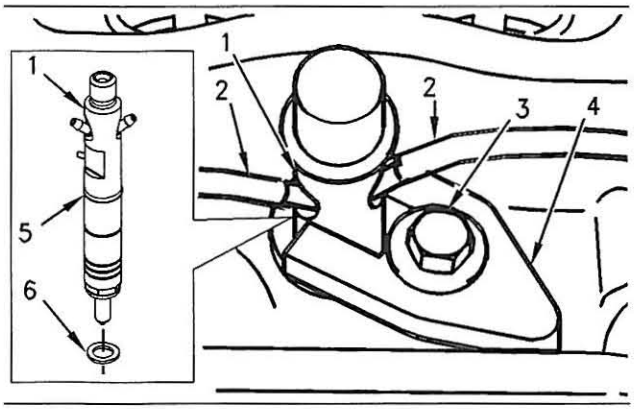

Illustration 55 g00975056

2. Remove the fuel hose (2) from the fuel injector (1).

3. Remove the setscrew (3). Remove the clamp (4) from the fuel injector (1).

4. Remove the fuel injector (1) from the cylinder head. Remove the O-ring seal (5) from the fuel injector (1) and discard the O-ring.

5. Remove the seat washer (6) from the cylinder head and discard the seat washer.

Note: If the original seat washer is not removed, the projection of the fuel injector will be incorrect when a new seat washer is installed.

2241916

Fuel Injector - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

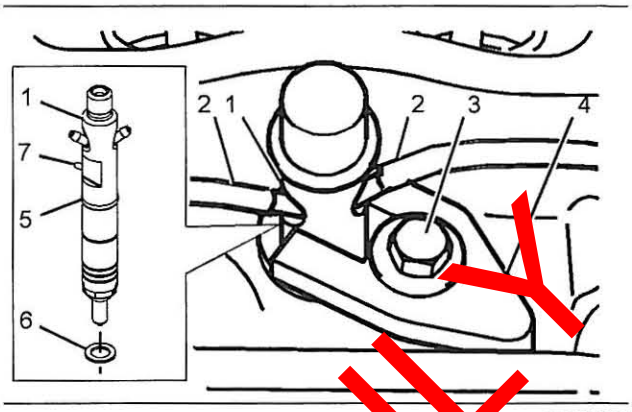

Illustration 56 g01129982

1. Lubricate the seat washer (6) with clean engine oil. Install a new seat washer (6) in the cylinder head.

Note: If the original seat washer (6) is reused, the projection of the fuel injector (1) will be incorrect.

2. Install a new O-ring seal (5) on fuel injector (1). Install the fuel injector (1) in the cylinder head.

Note: Alignment Pin (7) must be located opposite clamp (4).

3. Position clamp (4) on the fuel injector (1). Install setscrew (3). Tighten the setscrew to a torque of 27 N·m (20 lb ft).

4. Install hose (2) to the fuel injector (1).

End By:

a. Install the fuel injection lines. Refer to this Disassembly and Assembly, “Fuel Injection Lines - Install”.

b. Install the cover for the fuel injectors. Refer to this Disassembly and Assembly Manual, “Fuel Injector Cover - Remove and Install”.

i01944022

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: The removal procedure is identical for the three cylinder and the four cylinder engines.

1. Thoroughly clean the outer surface of the turbocharger (1).

2. Loosen the hose clamps and remove the air inlet hose at the turbocharger compressor housing.

Note: Exhaust elbows are only an option for the four cylinder engines.

3. Remove the exhaust pipe from the turbocharger outlet or remove the exhaust pipe from the exhaust elbow. Refer to the OEM provided information for the correct procedure in order to remove the exhaust pipe.

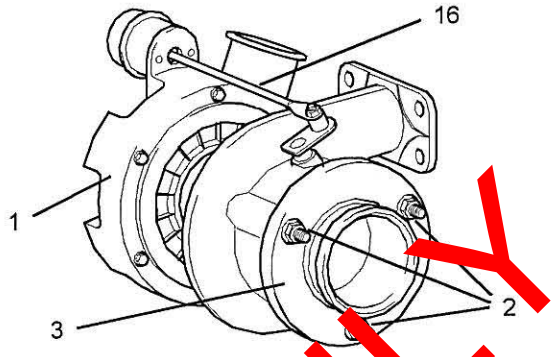

Illustration 57 g01038600
Typical example

4. If an exhaust elbow is installed, remove the exhaust elbow. Refer to this Disassembly and Assembly Manual, "Exhaust Elbow - Remove and Install".

5. Remove the nuts (2) and remove the exhaust adapter (3) from the turbocharger (1).

6. Place a suitable container below the turbocharger (1) in order to collect any spillage of oil.

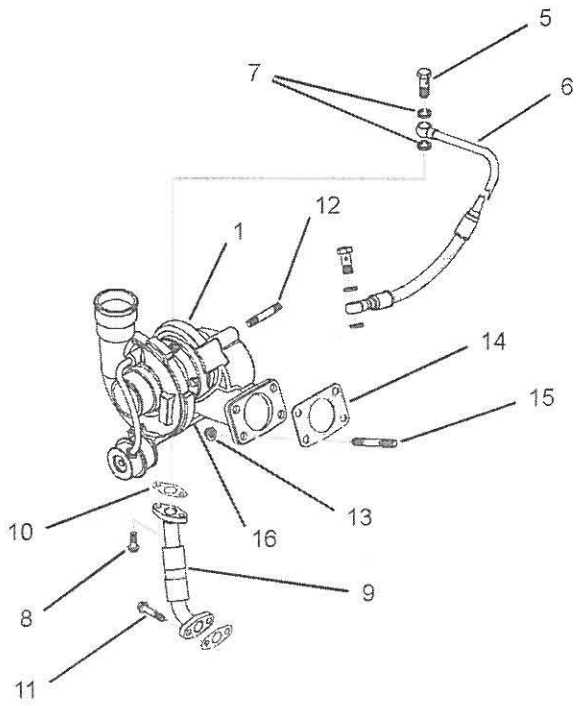

Illustration 58 g01038396
Typical example

7. Remove the banjo bolts (5). Remove the oil supply tube assembly (6) and the washers (7) from the turbocharger (1). Discard the washers (7). If necessary, remove the oil supply tube assembly (6) from the cylinder block and discard the washers.

8. Remove the setscrews (8). Remove the oil drain tube assembly (9) from the turbocharger (1). Remove the joint (10) and discard the joint. If necessary, remove the setscrews (11) and remove the oil drain tube assembly (9) from the cylinder block. Discard the joint.

9. If necessary, remove the studs (12) from the turbocharger housing.

Note: Do not use the actuator rod of the wastegate (16) to lift the turbocharger (1).

10. Remove the nuts (13). Remove the turbocharger (1). Remove the gasket (14). Discard the gasket (14). If necessary, remove the studs (15) from the exhaust manifold.

11. Install suitable plastic plugs into the oil supply and into the oil drain ports of the turbocharger (1). Install suitable plastic covers to the inlet and to the outlet of the turbocharger (1). Install suitable plastic plugs to the oil supply tube assembly (6) and to the oil drain tube assembly (9). Install suitable plastic covers to the manifold ports.

0194402

Turbocharger - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The installation procedure is identical for the three cylinder and the four cylinder engines.

1. Remove all of the plastic plugs from all of the ports of the turbocharger (1). Clean the mating surfaces of the exhaust manifold and the turbocharger. Clean the mating surfaces of the turbocharger to the oil supply tube assembly (6) and the turbocharger to the oil drain tube assembly (9).

2. Ensure that all of the turbocharger inlet and outlet ports are clean and free from restrictions. The turbocharger shaft must rotate freely.

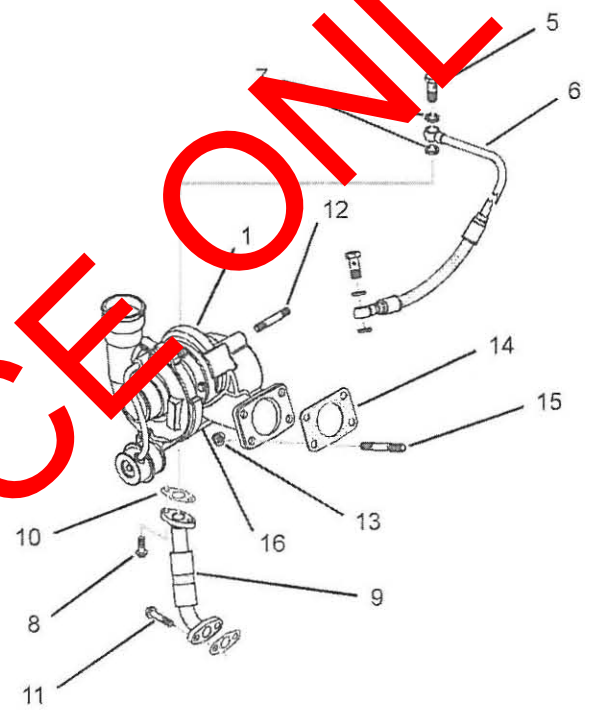

Illustration 59 g01038396
Typical example

3. If the studs (15) were previously removed, install the studs into the exhaust manifold. Install a new gasket (14) over the studs (15).

Note: Do not use any sealant on the gasket (14).

Note: Do not use the actuator rod of the wastegate (16) to lift the turbocharger (1).

4. Position the turbocharger (1) onto the exhaust manifold.

5. Install the nuts (13). Tighten the nuts (13) to a torque of 47 N·m (35 lb ft).

6. Lubricate the bearing housing of the turbocharger (1) with clean engine oil.

7. Inspect all of the oil hose assemblies (6 and 9). If necessary, replace the hose assemblies (6 and 9).

Note: The top flange of the oil drain tube assembly (9) is secured to the turbocharger (1) with 6 mm setscrews (8). The bottom flange of the oil drain tube assembly (9) is secured to the cylinder block with 8 mm setscrews (11).

8. Position a new joint (10) and the oil drain tube assembly (9) onto the bottom of the turbocharger (1). Install the 6 mm setscrews (8). Tighten the 6 mm setscrews (8) to a torque of 9 N·m (80 lb in).

9. Position a new joint and the oil drain tube assembly (9) onto the cylinder block. Tighten the 8 mm setscrews (11) to a torque of 22 N·m (16 lb ft).

10. Position the new washers (7) and the oil supply tube assembly (6) onto the turbocharger (1). Install the banjo bolt (5). Tighten the banjo bolt (5) to a torque of 22 N·m (16 lb ft).

Note: Ensure that the oil supply tube assembly (6) does not come into contact with any other component when the assembly is installed onto the engine.

11. Install the new washers and the oil supply tube assembly (6) to the cylinder block. Tighten the banjo bolt to a torque of 22 N·m (16 lb ft).

12. If the studs (12) were previously removed, install the studs into the turbocharger housing.

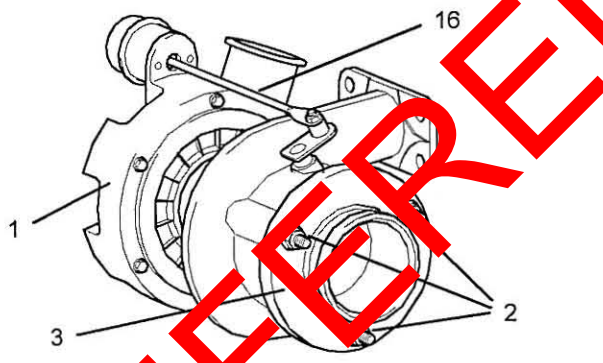

Illustration 60 g01038406
Typical exam

13. Positi n the haust adapter (3) onto the studs (12) t the nuts (2). Do not tighten the nuts (at this time.

Note: Exhaust elbows are only an option for the four cylinder engines.

14. If equipped, install the exhaust elbow onto the exhaust adapter (3). Refer to this Disassembly and Assembly Manual, “Exhaust Elbow - Remove and Install”.

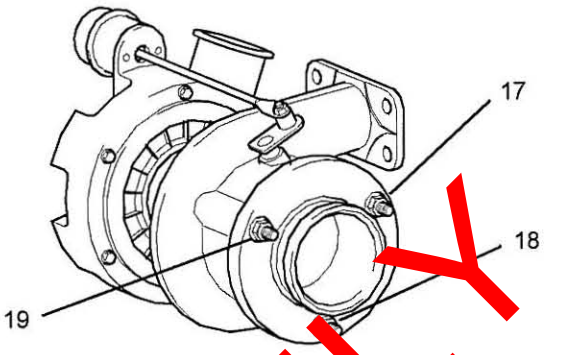

Illustration 61 g01038456

15. Tighten the three nuts ger tight in the sequence (17), (18), and (19). ighten the nuts (17), (18), and (19) in the same sequence to a torque of 25 N·m (18 l ft).

16. Ens e that there is no restriction in the inlet hose. Po ition the air inlet hose on the turbocharger c mpr ssor housing. Install the hose clamps. Tig en the ose clamps to a torque of 5 N·m (44 lb)

Note: he air inlet hose has a reflective heat shield hat artially covers the hose. The reflective heat shield must be installed toward the engine. The eflective heat shield must be kept clean and free from dust, oil or paint.

Note: Apply a solution of water and 5% soap to the inlet of the turbocharger in order to install a new air inlet hose. Do not use oil or grease in order to install the air inlet hose.

17. Position the exhaust pipe onto the exhaust elbow or onto the turbocharger outlet (3). Refer to the OEM information for the correct procedure in order to install the exhaust pipe.

i01946913

Exhaust Manifold - Remove and Install

Removal Procedure for the Three Cylinder Engine

Start By:

a. Remove the turbocharger, if equipped. Refer to this Disassembly and Assembly Manual, “Turbocharger - Remove”.

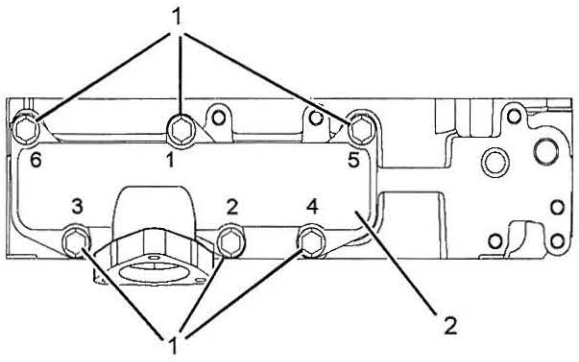

Illustration 62 g01038601

1. Remove the setscrews (1) in the reverse numerical order to the Illustration 62. This will help to prevent any distortion of the exhaust manifold (2).

2. Remove the exhaust manifold gasket from the cylinder head and remove the exhaust manifold (2). Discard the exhaust manifold gasket.

Installation Procedure for the Three Cylinder Engine

Note: The improper installation of the exhaust manifold (2) can result in a cracked exhaust manifold. The setscrews (1) for the exhaust manifold must be tightened in the correct sequence and tightened to the correct torque.

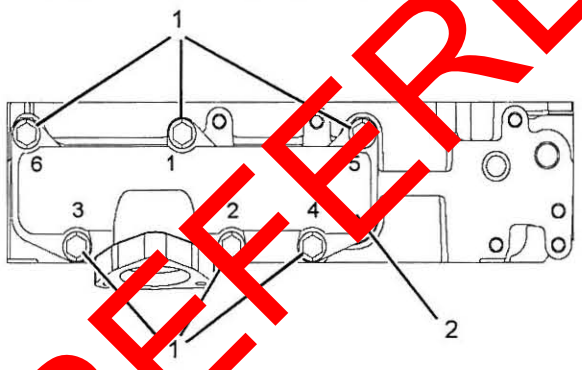

Illustration 63 g01038601

1. Loosely install two suitable studs into the holes (5 and 6) as guides.

Note: Do not use any sealant on the exhaust manifold gasket.

2. Position the new exhaust manifold gasket onto the studs in the cylinder head. Position the exhaust manifold (2) onto the studs. Install the setscrews (1) finger tight in order to secure the exhaust manifold to the cylinder head.

3. Remove the two studs and install the remaining setscrews (1). Ensure that the setscrews (1) are tightened in the sequence that is shown in Illustration 63. Tighten the setscrews evenly to a torque of 33 N·m (24 lb ft).

End By:

a. Install the turbocharger, if equipped. Refer to this Disassembly and Assembly Manual, "Turbocharger - Install".

Removal Procedure for the Four Cylinder Engine

Start By:

a. Remove the turbocharger, if equipped. Refer to this Disassembly and Assembly Manual, "Turbocharger - Remove".

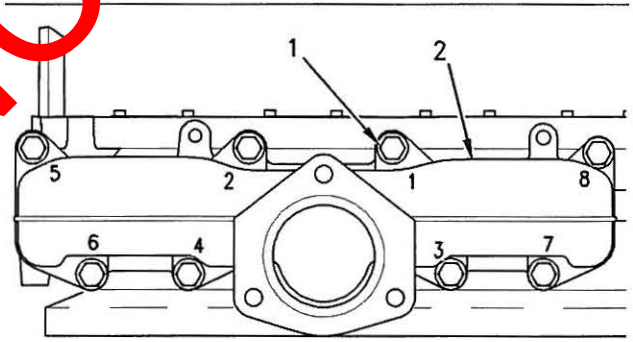

Illustration 64 g00951398

1. Remove the setscrews (1) in the reverse numerical order to the Illustration 64. This will help to prevent any distortion of the exhaust manifold (2).

2. Remove the exhaust manifold gasket from the cylinder head and remove the exhaust manifold (2). Discard the exhaust manifold gasket.

Installation Procedure for the Four Cylinder Engine

Note: The improper installation of the exhaust manifold (2) can result in a cracked exhaust manifold. The setscrews (1) for the exhaust manifold must be tightened in the correct sequence and tightened to the correct torque.

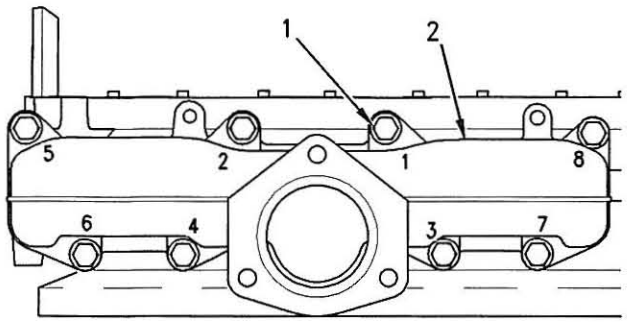

Illustration 65 g00951398

1. Loosely install two suitable studs into the holes (5 and 8) as guides.

Note: Do not use any sealant on the exhaust manifold gasket.

2. Position the new exhaust manifold gasket onto the studs in the cylinder head. Position the exhaust manifold (2) onto the studs. Install the setscrews (1) finger tight in order to secure the exhaust manifold to the cylinder head.

3. Remove the two studs and install the remaining setscrews (1). Ensure that the setscrews (1) are tightened in the sequence that is shown in Illustration 65. Tighten the setscrews evenly to a torque of 33 N·m (24 lb ft).

End By:

a. Install the turbocharger, if equipped. Refer to this Disassembly and Assembly Manual, "Turbocharger - Install".

i02216959

Exhaust Elbow - Remove and Install (If Equipped)

Removal Procedure

Start By:

a. Remove the exhaust pipe. Refer to the OEM information for the correct procedure in order to remove the exhaust pipe.

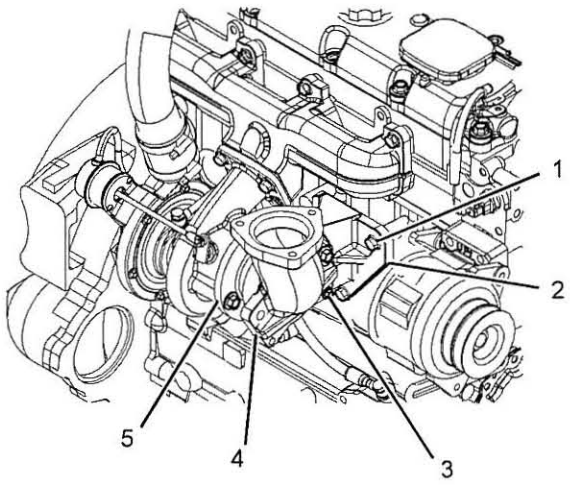

Illustration 66 g01135897
Typical example

1. Remove the setscrews (3) from the exhaust elbow (4). Remove the setscrews (1) and remove the bracket (2) from the cylinder block. Remove the exhaust elbow (4) from the exhaust adapter (5).

Installation Procedure

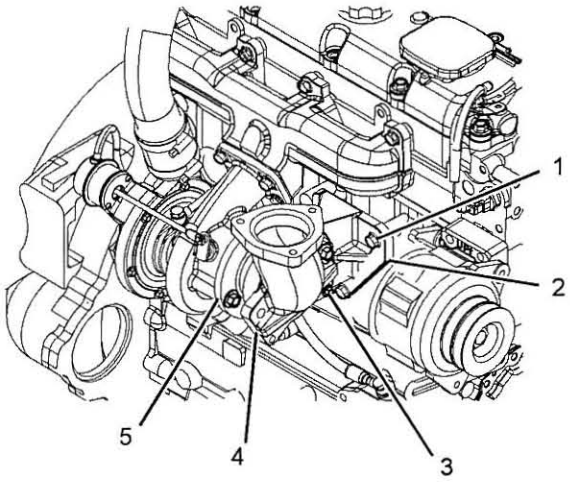

Illustration 67 g01135897

Typical example

1. Thoroughly clean the exhaust elbow (4) and the exhaust adapter (5).

2. Install the exhaust elbow (4) onto the exhaust adapter (5). Position the bracket (2) onto the cylinder block and install the setscrews (1). Tighten the setscrews (1) finger tight. Align the exhaust elbow with the bracket (2). Install the setscrews (3) in order to secure the exhaust elbow (4) to the bracket (2). Tighten the setscrews (1) and tighten the setscrews (3) to a torque of 44 N·m (33 lb ft).

.

End By:

a. Install the exhaust pipe. Refer to the OEM information for the correct procedure in order to install the exhaust pipe.

i01947651

Inlet and Exhaust Valve Springs - Remove and Install

Removal Procedure

Table 1

Required Tools		
Part Number	Part Description	Qty
21825666	Valve Spring Compressor	1
27610235	Setscrew Adapter	1

Start By:

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

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 still installed onto the cylinder block. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valves - Remove and Install" for the correct procedure that should be used to remove the valve springs from a cylinder head that has been removed from the cylinder block.

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

1. Use the following procedure in order to find the top dead center position for the appropriate piston.

⚠ 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.

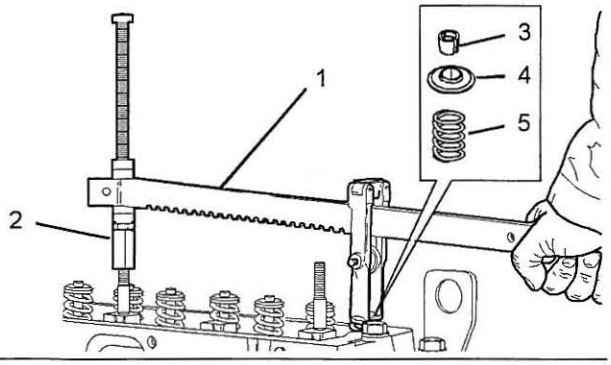

Illustration 68 g01015085

a. Install 21825666 Valve Spring Compressor (1) and the appropriate 27610235 Setscrew Adapter (2) in position on the cylinder head in order to compress the appropriate valve spring (5).

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

b. Compress the valve spring (5) sufficiently in order to open the valve only. Do not compress the valve spring sufficiently so that the valve keepers (3) could be removed from the recess in the valve stem.

c. Turn the crankshaft until the piston touches the valve.

d. Continue to turn the crankshaft until the valve stem is at the highest point. The piston is now at top dead center. Release the applied pressure of the valve spring compressor (1) at the top center position.

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

2. Use the valve spring compressor (1) in order to compress the valve spring (5). Remove the valve keepers (3).

3. Carefully release the pressure on the valve spring compressor (1). Remove the valve spring retainer (4) and the valve spring (5).

Note: If you are replacing all of the valve springs, the procedure can be done on two cylinders at the same time. The procedure can be done on cylinder 1 and cylinder 4, and on cylinder 2 and cylinder 3. Remember that the crankshaft must not be turned while the valve springs are removed. Ensure that all of the valve springs are installed before changing from one pair of cylinders to the other pair of cylinders.

Installation Procedure

Table 2

Required Tool		
Part Number	**Part Description**	**Qty**
21825666	Valve Spring Compressor	1
27610235	Setscrew Adapter	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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.

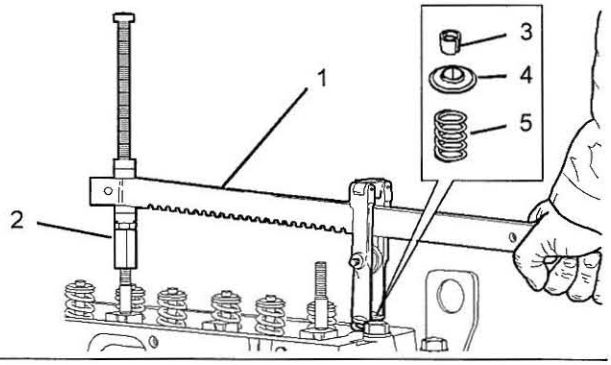

Illustration 69 g01015085

1. Place the new valve spring (5) into position.

2. Install the valve spring retainer (4).

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

3. Install the valve spring compressor (1) in position on the cylinder head in order to compress the appropriate valve spring (5). Compress the valve spring (5).

4. Install the valve keepers (3).

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

5. Carefully release the pressure on the valve spring compressor (1). Remove the valve spring compressor (1). Ensure that all of the valves are secured in place by a valve spring and valve keepers. Rotate the crankshaft through about 45 degrees in order to clear the piston from the valve. Lightly strike the top of the valve with a soft hammer in order to ensure that the valve keepers (3) are properly installed.

Note: If you are replacing all of the valve springs the procedure can be done on two cylinders at the same time. The procedure can be done on cylinder 1 and cylinder 4, and on cylinder 2 and cylinder 3.

End By:

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

i07947652

Inlet and Exhaust Va...s - Remove and Instal...

Removal Proced...

Table 3

Required Tools		
Part Numb...r	Part Description	Qty
2...825...96	Valve Depth Gauge	1
...182...	Valve Spring Compressor	1
27...0235	Setscrew Adapter	1

Start By:

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

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

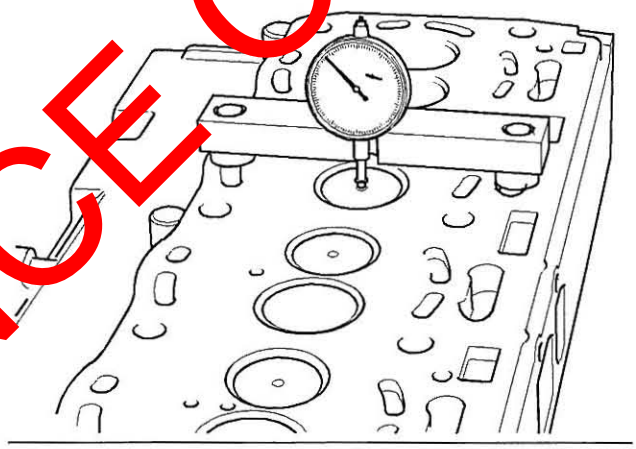

Illustration 70 g01015306
Typical example

1. Use a dial indicator to check the depth of the valves below the face of the cylinder head before the valve springs are removed. Refer to the illustration 70 and refer to Specifications, "Cylinder Head Valves" for the correct dimensions.

Note: The head of the inlet valve has a larger diameter than the head of the exhaust valve.

2. Place a numerical index mark on the heads of the inlet valves and on the exhaust valves so that each valve can be installed in the correct sequence during installation.

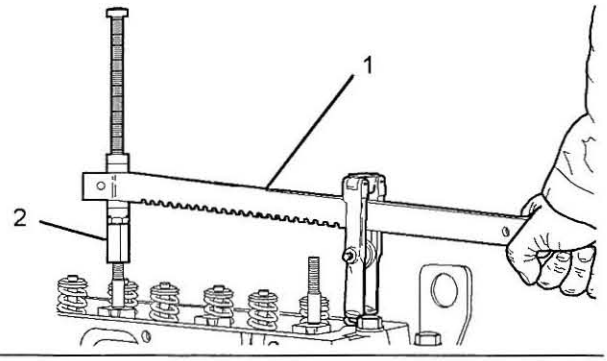

Illustration 71 g01015303
Typical example

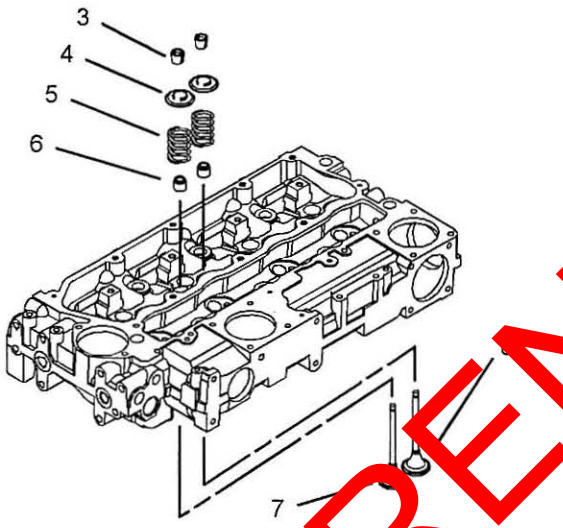

Illustration 72 g01015305
Typical example

3. Install 2182566[illegible] Valve S[illegible]ing Compressor (1) and the appro[illegible]iate [illegible]7610[illegible]5 Setscrew Adapter (2) in positi[illegible]n on [illegible]e cylinder head in order to compres[illegible] the appr[illegible]riate valve spring (5).

WARNING

P[illegible]son[illegible]l [illegible]ury can result from being struck by part[illegible] 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.

4. Compress the valve spring (5).
5. Remove the valve keepers (3).
6. Carefully release the pressure on the valve spring compressor (1). Remove the valve spring compressor (1) and the setscrew adapter (2) from the cylinder head.
7. Remove the valve spring retainer (4).
8. Remove the valve spring (5).
9. Remove the valve stem seal (6). Discard the valve stem seal (6).
10. Remove the appropri[illegible]te va[illegible]or 8).
11. Repeat Step[illegible] to Ste[illegible]10 [illegible]r each inlet valve (7) and for each [illegible]xhaust v[illegible]lve (8).

Installation Procedure

Tabl[illegible]4

Required Tools		
Part Num[illegible]er	Part Description	Qty
218[illegible]5666	Valve Spring Compressor	1
[illegible]7610235	Setscrew Adapter	1
21825496	Valve Depth Gauge	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

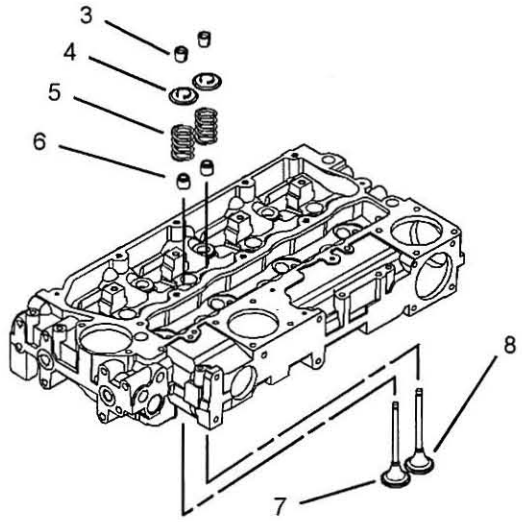

Illustration 73 g01015305
Typical example

1. Carefully clean the bottom face of the cylinder head. Ensure that there is no debris in the inlet and exhaust ports. Also ensure that there is no debris in the coolant passages and in lubrication passages. Inspect the cylinder head. Refer to the Testing and Adjusting Manual, "Cylinder Head Inspect" for further information.

2. Inspect all of the valve seats for wear and for damage. Refer to the Specifications Manual, "Cylinder Head Valves" for further information. Also refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valve Seat Inserts - Remove and Install" and refer to Testing and Adjusting Manual, "Valve Depth - Inspect " for further information. Replace any worn parts.

3. Inspect all of the valve guides for wear and for damage. Refer to the Specifications Manual, "Cylinder Head Valves" for further information. Also refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valve Guides - Remove and Install" and refer to Testing and Adjusting Manual, "Valve Guide - Inspect" for further information. Replace any worn parts.

4. Inspect the valves if the valves are not replacement parts. Refer to the Specifications Manual, "Cylinder Head Valves" for further information.

5. Lubricate the stems of all of the inlet valves (7) and lubricate the stems of all of the exhaust valves (8) with clean engine oil. Install the inlet valves (7) and the exhaust valves (8) in the appropriate positions.

6. Carefully turn over the cylinder head and ensure that all of the valves remain in place. Place the machined surface of the cylinder head onto a clean, soft surface.

Note: The valve guides must be clean and dry before installing the valve stem seals (6).

7. Install a new valve stem seal (6) onto each of the valve guides.

8. Inspect the valve springs (5) for wear and for the correct installed length. Refer to the Specifications Manual, "Cylinder Head Valves" for further information on the correct installed length of the valve springs (5). Replace any worn parts.

9. Install the valve springs (5) onto the cylinder head.

10. Install the valve spring retainers (4).

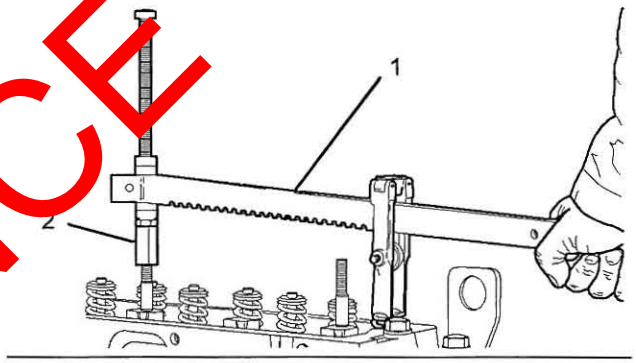

Illustration 74 g01015303
Typical example

WARNING

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

Make sure to wear all necessary protective equipment.

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

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

11. Install 21825666 Valve Spring Compressor (1) and the appropriate 27610235 Setscrew Adapter (2) in position on the cylinder head in order to compress the appropriate valve spring (5).

12. Install the valve keepers (3).

13. Carefully release the pressure on the valve spring compressor (1). Remove the valve spring compressor (1) and the setscrew adapter (2) from the cylinder head. Gently strike the top of the appropriate valves with a soft hammer in order to ensure that the valve keepers (3) are properly installed.

14. Repeat Step 11 to Step 13 for all of the valves (7 and 8).

15. Turn over the cylinder head. Use a dial indicator to check the depth of the new valves below the face of the cylinder head. Refer to Illustration 70 and refer to the Specifications Manual, "Cylinder Head Valves" for more information on the inlet valves and the exhaust valves. If the depth of the new valves is below the correct depth, the valve seat inserts must be replaced. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valve Seat Inserts - Remove and Install".

End By:

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

i01947653

Inlet and Exhaust Valve Guides - Remove and Install

Removal Procedure

Table 5

Required Tools		
Part Number	**Part Description**	**Qty**
21825478	Valve Guide Remover/Replacer	1
21825479	Valve Guide Adapter	1

Start By:

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

b. Remove the inlet valves and the exhaust valves. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valves - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

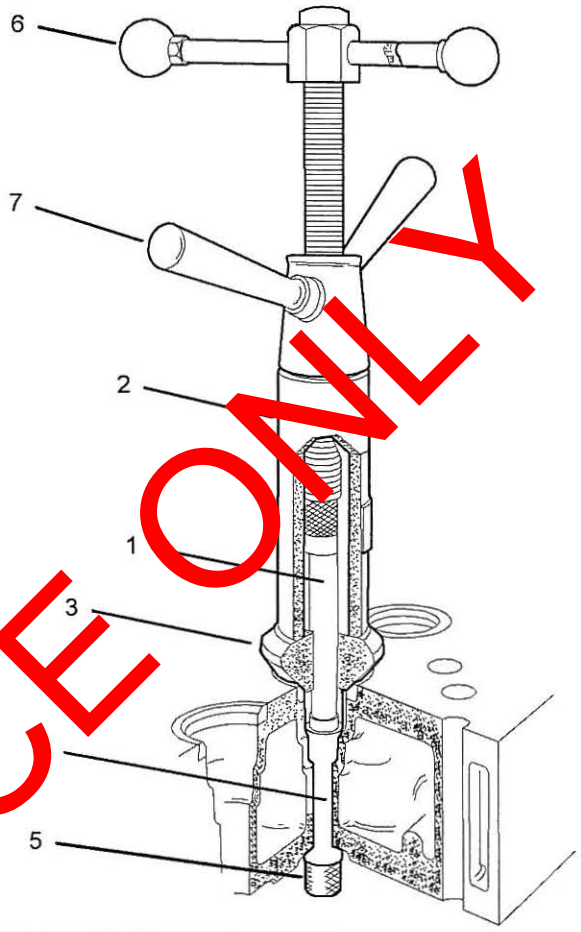

Illustration 75 g01016267

1. Install the 21825479 Valve Guide Adapter (1) into the 21825478 Valve Guide Remover/Replacer (2).

2. Place the spacer (3) into the appropriate valve seat.

3. Pass the adapter (1) through the valve guide (4) and install the valve guide remover/replacer (2) onto the spacer (3).

4. Install the attachment (5) in order to secure the adapter (1) to the valve guide (4).

5. Hold the top handle (6) and turn the bottom handle (7) counterclockwise in order to push the valve guide (4) from the cylinder head.

6. Repeat Step 2 to Step 5 in order to extract each appropriate valve guide (4).

7. Discard all of the valve guides (4) that were removed from the cylinder head.

Note: When new valve guides are installed, new valves and new valve seat inserts must be installed.

8. Remove the valve seat inserts. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valve Seat Inserts - Remove and Install".

Installation Procedure

Table 6

Required Tools		
Part Number	**Part Description**	**Qty**
21825478	Valve Guide Remover/Replacer	1
27610234	Valve Guide Adapter	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

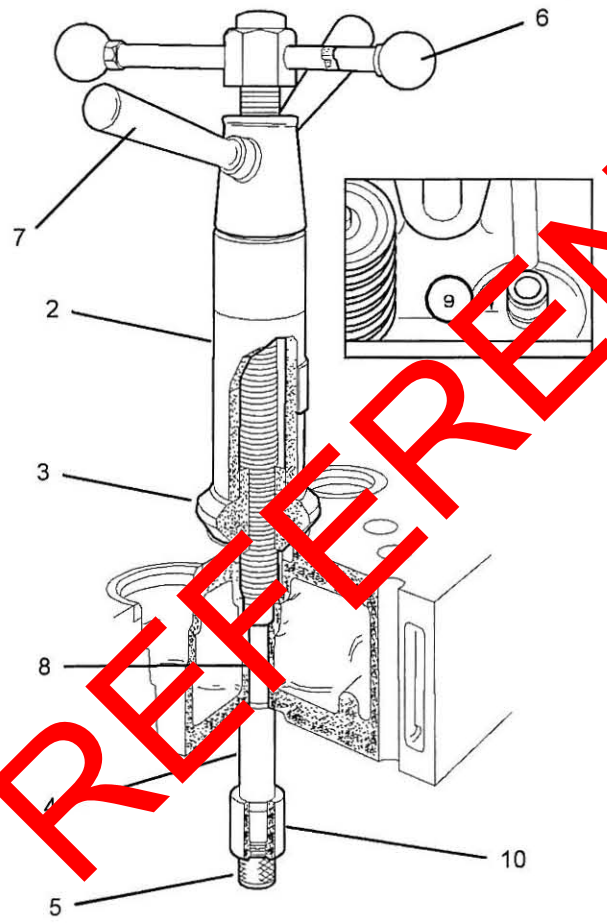

Illustration 76 g01016462

1. Clean the parent bores in the cylinder head for all of the appropriate valve guides (4).

2. Install the 27610234 Valve Guide Adaptor (8) into the 21825478 Valve Guide Remover/Replacer (2).

3. Install the spacer (3) into the appropriate valve seat.

4. Lubricate the outer surface of a new valve guide (4) with clean engine lubricating oil. Pass the adapter (8) through the parent bore for the valve guide (4) and position the valve guide remover/replacer (2) onto the spacer (3).

5. Install the adapter (10) beneath the valve guide (4). Install the attachment (5) in order to secure the adapter (10) to the valve guide (4).

Note: The valve guide (4) should protrude above the cylinder head. Ensure that the protrusion (9) is within limits.

6. Hold the top handle (6) and turn the bottom handle (7) clockwise in order to pull the valve guide (4) into the cylinder head. Continue to pull the valve guide (4) into the cylinder head until the correct amount of protrusion (9) is reached. The valve guides should protrude 12.35 to 12.65 mm (0.4862 to 0.4980 inch) above the valve spring recess.

7. Repeat the Step 3 to Step 6 in order to install each appropriate valve guide.

Note: The parent bores of the valve guides must be reamed to the correct size after the valve guides have been installed into the cylinder head. Also, the valve inserts must be inserted and the seat faces must be cut to the correct angle. The same tool is used to finish both components.

8. Install the valve seat inserts and finish both components. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valve Seat Inserts - Remove and Install".

End By:

a. Install the inlet valves and the exhaust valves. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valves - Remove and Install".

i01947654

Inlet and Exhaust Valve Seat Inserts - Remove and Install

Removal Procedure

Start By:

a. Remove the inlet valves and the exhaust valves. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valves - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: When new valve seat inserts are installed, new valves and new valve guides must be installed.

1. Remove the appropriate valve guides. Install partially finished valve guides. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valve Guides - Remove and Install".

Note: The inserts for the inlet valves are a larger diameter than the exhaust valve inserts.

2. Use the partially finished bore of the valve guide as a pilot bore in order to remove the valve insert by machining. Also use the partially finished bore of the valve guide as a pilot bore in order to machine a recess for a new valve seat. Refer to the Specifications Manual, "Cylinder Head Valves" for the required dimensions of the recess for the valve seat. Remove all debris from the cylinder head ports and passages.

3. Repeat the Step 2 for all of the appropriate valve seats.

Installation Procedure

Table 7

Required Tools		
Part Number	**Part Description**	**Qty**
27610030	Valve Guide/Valve Seat Reamer/Cutter	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: If the cylinder head has been previously ground then the bottom face of valve seat must be ground in order to ensure that the valve seat will be installed correctly into the cylinder head. A 30 degree chamfer must be machined to the outer edge of the valve seat after the back face of the valve insert has been ground to the correct dimensions. The 30 degree chamfer must be within the tolerance of 0.91 mm (0.036 inch) to 1.3 mm (0.051 inch). Also, the chamfer must be inclined to the vertical face of the valve insert.

Note: Do not use a hammer in order to install the valve insert into the machined recess in the cylinder head.

Note: Do not apply any lubricant before the new valve seat insert is installed into the cylinder head.

1. Use a suitable tool to install the valve seat insert into the machined recess in the cylinder head.

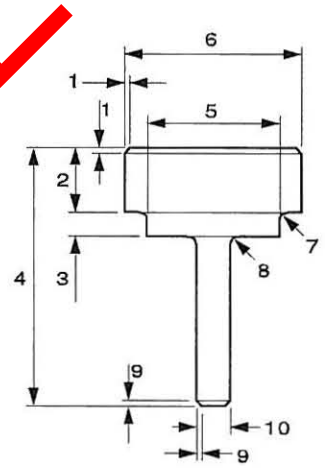

Illustration 77 g01016768

2. If necessary, a suitable tool can be manufactured. Refer to the illustration 77. Also refer to the table 8 and refer to the table 9 for suitable dimensions.

Table 8

Tool for the Inlet Valve Seat Inserts	
Callout	**Dimension**
1	1.5 mm (0.06 inch)
2	20 mm (0.80 inch)
3	6.8 mm (0.268 inch) to 7.1 mm (0.279 inch)
4	100 mm (3.94 inch)
5	38.1 mm (1.500 inch) to 38.3 mm (1.508 inch)
6	46.25 mm (1.82 inch) to 46.5 mm (1.83 inch)
7	Maximum radius 1.4 mm (0.055 inch)
8	Maximum radius 1.5 mm (0.06 inch)
9	1.5 mm (0.06 inch)
10	8.77 mm (0.345 inch) to 8.80 mm (0.346 inch)

Table 9

Tool for the Exhaust Valve Seat Inserts	
Callout	**Dimension**
1	1.5 mm (0.06 inch)
2	20 mm (0.80 inch)
3	7.2 mm (0.283 inch) to 7.5 mm (0.295 inch)
4	100 mm (3.94 inch)
5	34.38 mm (1.353 inch) to 34.58 mm (1.361 inch)
6	41.75 mm (1.643 inch) to 42.00 mm (1.653 inch)
7	Maximum radius 1.4 mm (0.055 inch)
8	Maximum radius 1.5 mm (0.06 inch)
9	1.5 mm (0.06 inch)
10	8.77 mm (0.345 inch) to 8.80 mm (0.346 inch)

3. Put the appropriate valve seat insert in position. Install the special tool that was manufactured previously, through the valve seat insert and use the pilot bore of the valve guide in order to center the tool and the insert into the recess. Lightly tap the valve seat insert in order to start the installation. Press the valve seat insert into the recess with a suitable press. Ensure that the bottom of the valve seat insert is against the bottom of the recess.

4. Repeat Step 3 for the remaining valve seat inserts.

5. After installing the valve guides and valve seat inserts, the valve guides must be reamed and the valve seat inserts must be cut to the finished diameter. The valve guides and valve seat inserts are cut and reamed in one operation. This procedure ensures the concentricity of the valve seat to the valve guide in order to create a good seal. Refer to the Specifications Manual, "Cylinder Head Valves" for the finished diameter of the valve guides and valve seat inserts.

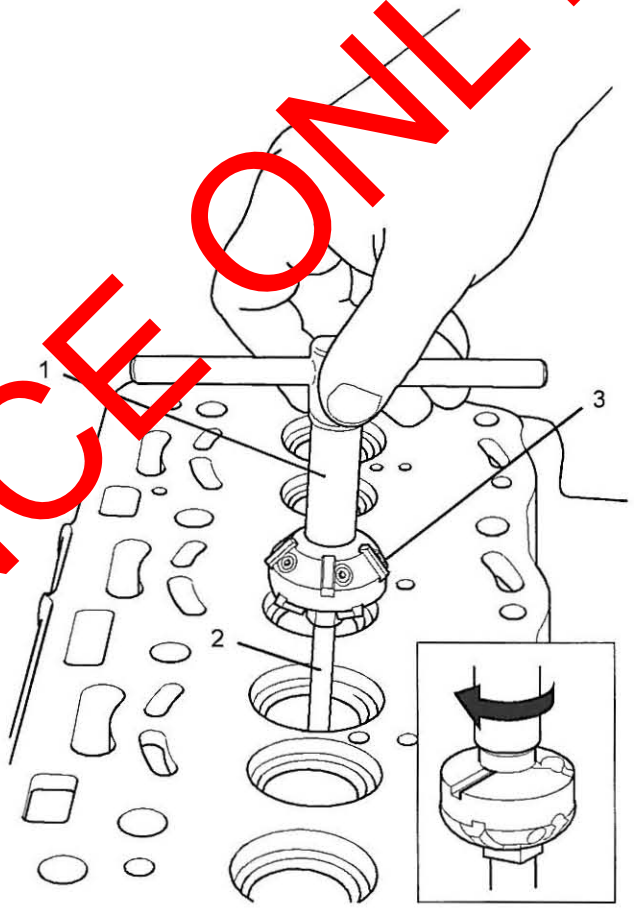

Illustration 78 g01017975

Note: Ensure that the 27610030 Valve Guide/Valve Seat Reamer/Cutter is assembled correctly with the correct angle of cutter (3) for the valve seat toward the cylinder head.

Note: Ensure that the cutter (3) for the valve seat is not allowed to contact the valve seat insert until the valve guide has been reamed to the correct size.

6. Set the diameter of the cutter (3) to the correct size for the valve seat to be cut. Refer to the Specifications Manual, "Cylinder Head Valves" for the correct diameter. Position the reamer (2) of the tool (1) into the appropriate valve guide. Carefully turn the handle in a clockwise direction and gradually move the reamer (2) into the valve guide until the valve guide is reamed to the finished size.

7. Continue to turn the handle in a clockwise direction in order to cut the valve seat insert. Remove the minimum amount of material in order to ensure a good valve seat. Keep the valve seat as narrow as possible.

8. Remove the tool (1). Clean the debris from the valve guide and the valve seat.

9. Repeat Step 6 to Step 8 in order to cut all of the appropriate valve seats.

End By:

a. Install the inlet valves and the exhaust valves. Refer to this Disassembly and Assembly Manual, "Inlet and Exhaust Valves - Remove and Install".

i02262593

Engine Oil Filter Base - Remove and Install

Removal Procedure for an Oil Filter with a Separate Filter Element

Note: This procedure is for the removal of an oil filter with an oil filter housing and a separate oil filter element.

Note: The oil filter can be installed vertically or the oil filter can 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.

1. Remove all dirt, oil, and grease from the engine oil filter assembly and from the drain plug of the engine oil pan. Place a suitable container beneath the drain plug of the engine oil pan.

2. Operate the engine until the engine is warm. Stop the engine.

3. Remove the oil drain plug and the O-ring from the engine oil pan. Drain the engine oil into the container for storage or disposal.

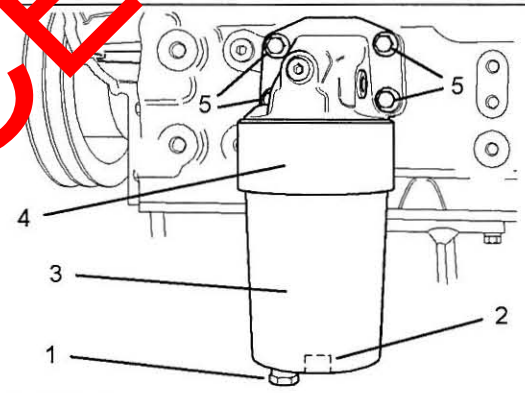

Illustration 79 g01018261
Typical example

Note: The drain plug (1) in the horizontal type of oil filter is installed in the filter head (4) instead of the oil filter housing (3). Do not remove the drain plug (1) from this type of oil filter.

4. Place a suitable container beneath the drain plug (1) in the oil filter housing (3). Remove the drain plug (1) from the oil filter housing (3) and remove the O-ring from the drain plug (1). Discard the O-ring. Collect any engine oil that drains from the oil filter housing (3).

5. Install a ratchet with a 1/2 inch square drive into the recess (2) in the base of the oil filter housing (3) in order to remove the oil filter housing.

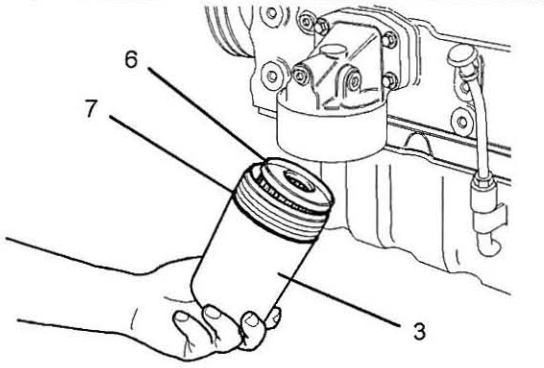

Illustration 80 g01018307
Typical example

6. Remove the oil filter element (6) from the oil filter housing (3). Remove the O-ring (7) from the oil filter housing (3). Discard the O-ring (7).

Note: Step 1 to Step 6 is the procedure for removing the oil filter element. Step 6 to Step 9 is the additional procedure for removing the oil filter base (4).

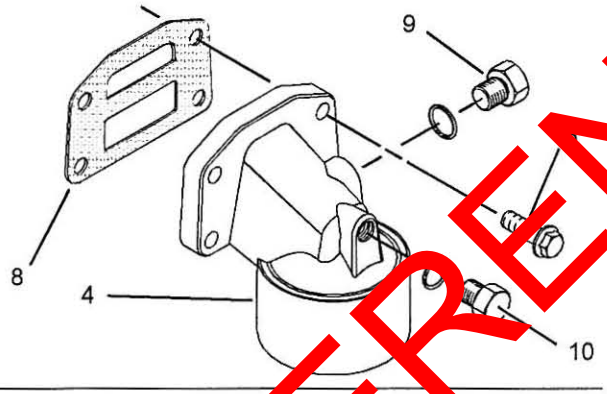

Illustration 81 g01018337
Typical example

7. Remove the setscrews (5).

8. Remove the engine oil filter base (4) from the cylinder block. Remove the joint (8) and discard the joint.

9. If necessary, remove the plug (9) and the O-ring.

10. If necessary, remove the plug (10) and the O-ring.

Installation Procedure for an Oil Filter with a Separate Filter Element

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Step 1 to Step 5 is the procedure for installing the oil filter base if the oil filter base was previously removed. Step 6 to Step 11 is the procedure for installing the oil filter element.

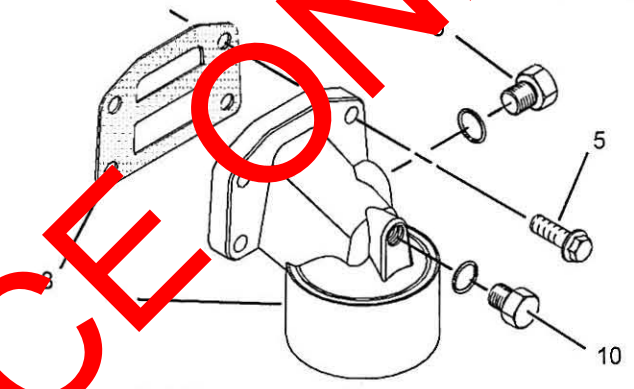

Illustration 82 g01018337
Typical example

1. Clean the oil passages within the oil filter base (4). Clean the mating surfaces of the cylinder block and the engine oil filter base (4).

2. Inspect the O-ring for the plug (10) if the plug was removed from the oil filter base (4). If necessary, replace the O-ring. Install the O-ring and the plug (10) into the oil filter base (4). Tighten the plug (10) to a torque of 12 N·m (9 lb ft).

3. Inspect the O-ring for the plug (9) if the plug was removed from the oil filter base (4). If necessary, replace the O-ring. Install the O-ring and the plug (9) into the oil filter base (4). Tighten the plug (9) to a torque of 12 N·m (9 lb ft).

Note: New setscrews (5) have sealant on the first 13 mm (0.5 inch) of the threads. In order to reuse the old setscrews (5), clean the old sealant from the setscrews and apply 21820117 POWERPART Threadlock and Nutlock to the setscrews.

Note: Do not lubricate the new joint (8).

4. Install the setscrews (5) into the oil filter base (4). Install a new joint (8) onto the setscrews (5). Install the setscrews (5) into the cylinder block.

5. Evenly tighten the setscrews (5) to a torque of 22 ± 5 N·m (16 ± 4 lb ft).

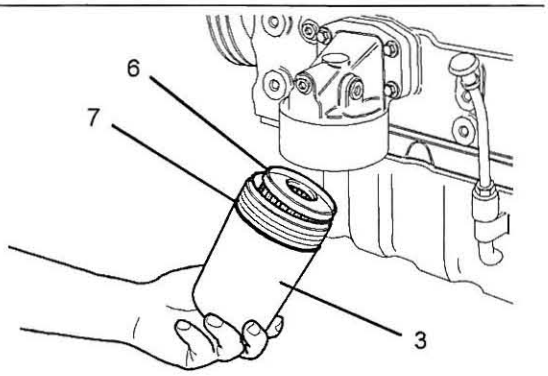

Illustration 83 g01018307
Typical example

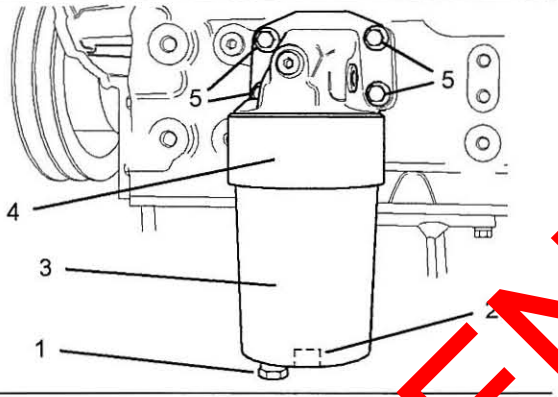

Illustration 84
Typical example

6. Clean the inner surface of the oil filter housing (3). Clean the mating surfaces of the oil filter base (4) and the oil filter housing (3). Install a new O-ring onto the drain plug (1) if the drain plug was removed previously. Install the drain plug (1) into the oil filter housing (3). Tighten the drain plug (1) finger tight.

7. Lubricate a new O-ring (7) with clean engine lubricating oil. Install the new O-ring (7) onto the oil filter housing (3). Install a new oil filter element (6) into the oil filter housing (3). Rotate the oil filter element (6) in order to lock the element in the oil filter housing (3).

Note: Add clean engine lubricating oil into the oil filter housing (3) if the oil filter is installed vertically on the engine. Allow sufficient time for the added oil to flow through the oil filter element (6).

8. Screw the oil filter housing (3) into the oil filter base (4) by hand. Install a 1/2 inch square drive into the recess (2) in order to tighten the oil filter housing (3) to a torque of 25 N·m (18 lb ft).

9. Tighten the drain plug (1) to a torque of 12 N·m (9 lb ft).

10. Inspect the O-ring for the drain plug for the engine oil pan. If necessary, replace the O-ring. Install the O-ring onto the drain plug for the engine oil pan and install the drain plug into the engine oil pan. Tighten the drain plug to the correct torque. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install" for the correct torque. Remove the suitable containers beneath the engine oil pan and beneath the oil filter housing.

11. Fill the engine oil to the correct level that is indicated on the engine oil level gauge. Refer to the Operation and Maintenance Manual, "Refill Capacities" for the lubrication system capacity of the engine.

Removal Procedure for a Spin-On Oil Filter

Note: This procedure is for the removal of an oil filter with an oil filter element that has an integral housing.

Note: The oil filter can be installed vertically or the oil filter can 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.

1. Remove all dirt, oil, and grease from the engine oil filter assembly and from the drain plug of the engine oil pan. Place a suitable container beneath the drain plug of the engine oil pan.

2. Operate the engine until the engine is warm. Stop the engine.

3. Remove the oil drain plug and the O-ring from the engine oil pan. Drain the engine oil into the container for storage or disposal.

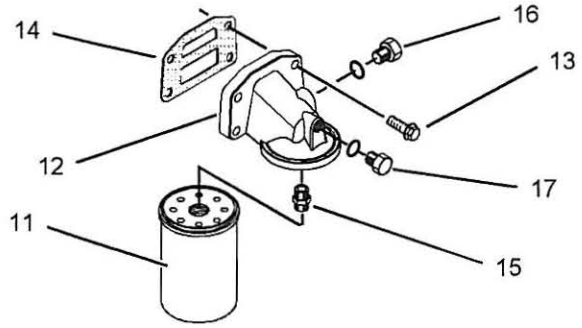

Illustration 85 g01018706
Typical example

4. Place a suitable container beneath the oil filter element (11).

5. Use a suitable strap wrench in order to remove the oil filter element (11). Discard the oil filter element (11) in a suitable manner.

Note: Step 1 to Step 5 is the procedure for removing the oil filter element (11). Step 6 to Step 9 is the additional procedure for removing the oil filter base (12).

6. Remove the setscrews (13).

7. Remove the engine oil filter base (12) from the cylinder block. Remove the joint (14) and discard the joint.

8. If necessary, remove the adapter (15) from the oil filter base (12).

9. If necessary, remove the plug (16) and the O-ring.

10. If necessary, remove the plug (17) and the O-ring.

Installation Procedure for a Spin-On Oil Filter

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Step 1 to Step 6 is the procedure for installing the oil filter base if the oil filter base was previously removed. Step 7 to Step 10 is the procedure for installing the oil filter element.

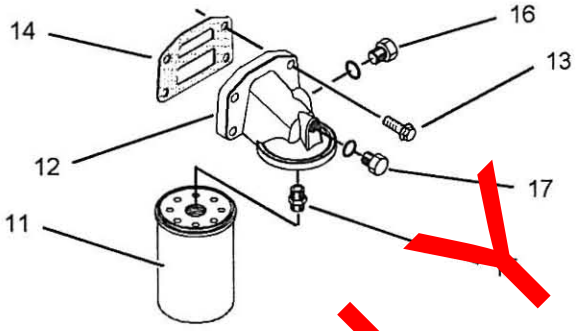

Illustration 86 g01018706
Typical example

1. Clean the oil passages within the oil filter base (12). Clean the mating surfaces of the cylinder block and the engine oil filter base (12).

2. Inspect the adapter (15) if the adapter was removed from the oil filter base (12). Apply 21820117 Powerpart to the last 10 mm (0.3 inch) of the thread on the adapter. Install the adapter (15) into the oil filter base (12). Tighten the adapter (15) to a torque of 28 ± 4 N·m (20 ± 3 lb ft).

3. Inspect the O-ring for the plug (17) if the plug was removed from the oil filter base (12). If necessary, replace the O-ring. Install the O-ring and the plug (17) into the oil filter base (12). Tighten the plug (17) to a torque of 12 N·m (9 lb ft).

4. Inspect the O-ring for the plug (16) if the plug was removed from the oil filter base (12). If necessary, replace the O-ring. Install the O-ring and the plug (16) into the oil filter base (12). Tighten the plug (16) to a torque of 12 N·m (9 lb ft).

Note: New setscrews (13) have sealant on the first 13 mm (0.5 inch) of the threads. In order to reuse the old setscrews (13), clean the old sealant from the setscrews and apply 21820117 POWERPART Threadlock and Nutlock to the setscrews.

Note: Do not lubricate the new joint (14).

5. Install the setscrews (13) into the oil filter base (12). Install a new joint (14) onto the setscrews (13). Install the setscrews (13) into the cylinder block.

6. Evenly tighten the setscrews (13) to a torque of 22 ± 5 N·m (16 ± 4 lb ft).

7. Clean the mating surface of the oil filter base (12) to the oil filter element (11).

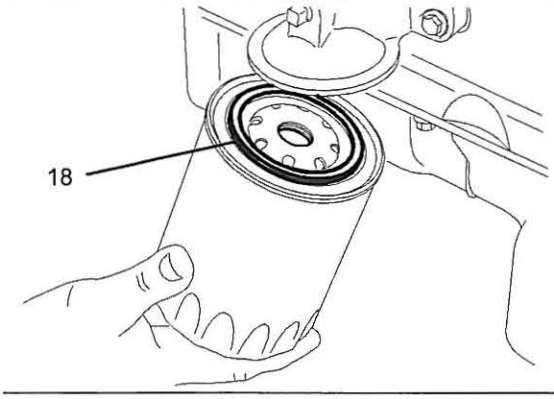

Illustration 87 g01018743

8. Lubricate the top of the O-ring (18) with clean engine lubricating oil. Spin the new oil filter element (11) onto the adapter (15). Tighten the oil filter element (11) by hand. Do not use a strap wrench to tighten the oil filter element (11).

9. Inspect the O-ring for the drain plug for the engine oil pan. If necessary, replace the O-ring. Install the O-ring onto the drain plug for the engine oil pan and install the drain plug into the engine oil pan. Tighten the drain plug to the correct torque. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install" for the correct torque. Remove the suitable container beneath the engine oil pan and beneath the oil filter housing.

10. Fill the engine oil to the correct level that is indicated on the engine oil level gauge. Refer to the Operation and Maintenance Manual, "Refill Capacities" for the lubrication system capacity of the engine.

i02259834

Engine Oil Cooler - Remove

Removal Procedure for Three Cylinder Engine

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.

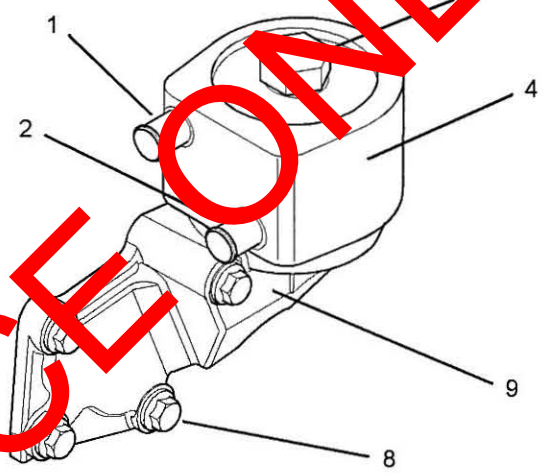

Illustration 88 g01041195

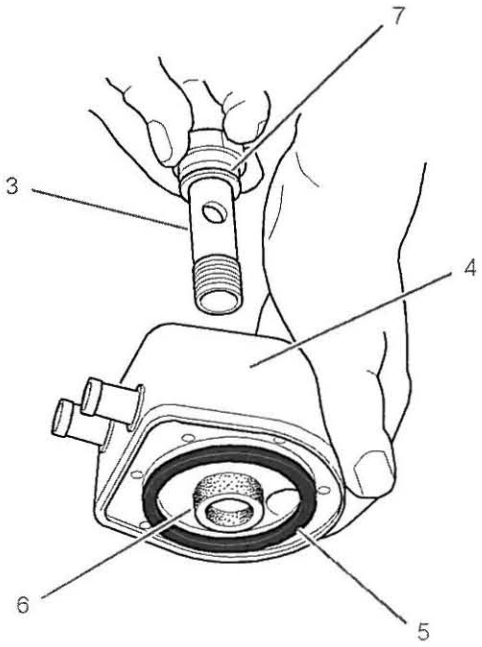

Illustration 89 g01041194

1. Drain the coolant from the engine into a suitable container. Drain the engine oil from the engine into a suitable container. Refer to the Operation and Maintenance Manual for the procedure on draining the engine coolant and the engine oil.

2. Remove the hose clamp and the hose from the coolant inlet (1). Remove the hose clamp and the hose from the coolant outlet (2).

3. Remove the adapter (3) from the oil cooler body (4).

4. Remove the O-rings (5) and (6). Discard the O-rings (5) and (6).

5. Remove the sealing ring (7). Discard the sealing ring (7).

6. If necessary, remove the setscrews (8) in order to remove the oil cooler base (9) from the cylinder block. Remove the joint from the cylinder block. Discard the joint.

Removal Procedure for Four Cylinder Engine

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 engine into a suitable container. Drain the engine oil from the engine into a suitable container. Refer to the Operation and Maintenance Manual for the procedure on draining the engine coolant and the engine oil.

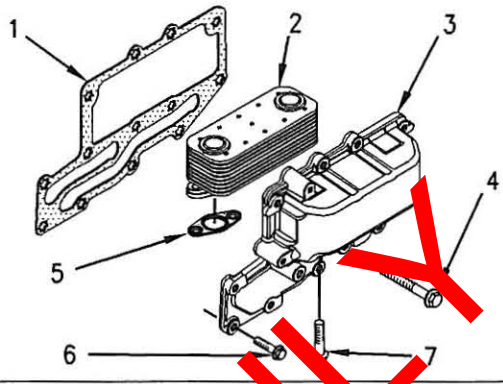

Illustration 90 g00952614

Note: Do not remove the setscrews (7) at this time.

2. Remove the setscrews (6). Remove the setscrews (4).

3. Remove the housing (3) from the cylinder block.

4. Remove the setscrews (7). Remove the engine oil cooler (2) and the seals (5) from the housing (3). Discard the seals (5).

5. Remove the joint (1) from the cylinder block. Discard the joint (1).

i02641598

Engine Oil Cooler - Install

Installation Procedure for the Three Cylinder Engine

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

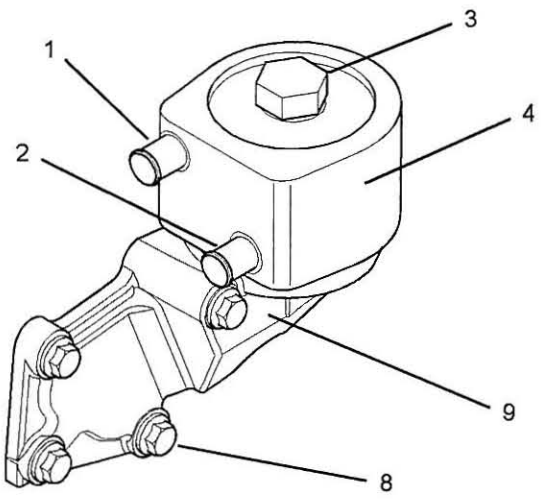

Illustration 91 g01041195

1. Clean the mating surfaces of the oil cooler base (9) and the oil cooler body (4). If the oil cooler base (9) was removed, clean the mating surfaces of the oil cooler base and the cylinder block.

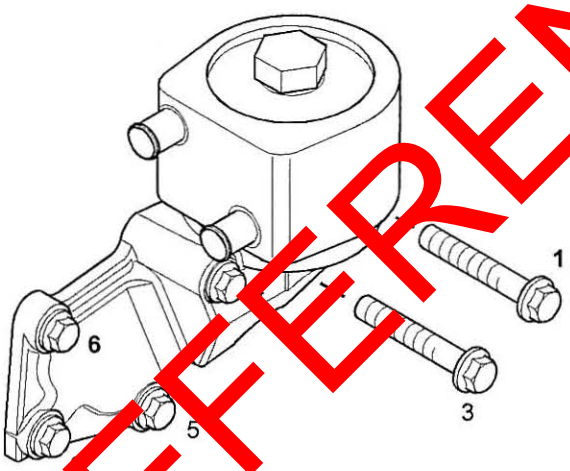

Illustration 92 g01041030
Tightening sequence

Note: Do not use sealant on the new joint between the cylinder block and the oil cooler base (9).

2. If the oil cooler base (9) was removed from the cylinder block, install setscrews into setscrew holes (1) and (6) in the oil cooler base. Install a new joint onto the two setscrews and secure the oil cooler base (9) to the cylinder block. Install the remainder of the setscrews (8). Tighten the setscrews (8) in the sequence 1, 2, 3, 4, 5, and 6 to a torque of 22 N·m (16 lb ft). Refer to the illustration 92.

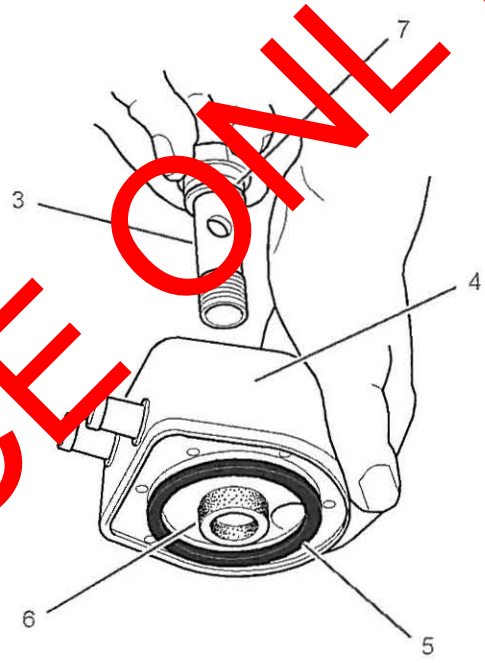

Illustration 93 g01041194

3. Install new O-rings (5) and (6) onto the oil cooler body (4). Position the oil cooler body (4) onto the oil cooler base (9).

4. Install a new sealing ring (7) onto the adapter (3). Install the adapter (3) through the oil cooler body (4) and into the oil cooler base (9). Tighten the adapter (3) to a torque of 57 N·m (42 lb ft).

5. Install the appropriate hose to the coolant outlet (2). Tighten the hose clamp to a torque of 3.5 N·m (31 lb in).

6. Install the appropriate hose to the coolant inlet (1). Tighten the hose clamp to a torque of 3.5 N·m (31 lb in).

7. Fill the cooling system with coolant. Fill the lubrication system with engine oil. Refer to the Operation and Maintenance Manual, “Refill Capacities” for the cooling system capacity and for the lubrication system capacity of the engine.

Installation Procedure for the Four Cylinder Engine

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

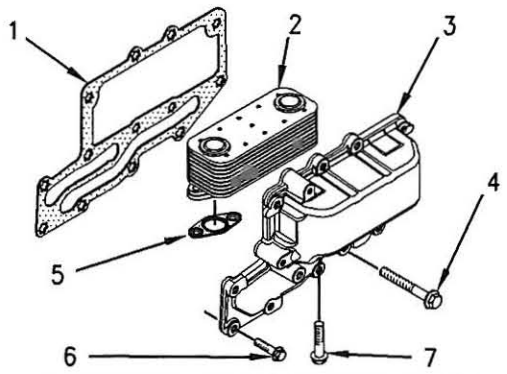

Illustration 94 g00952614

1. Clean the mating surfaces of the housing (3) and the cylinder block.

2. Position the engine oil cooler (2) and the new seals (5) in the housing (3). Install the setscrews (7) in order to secure the engine oil cooler (2) to the housing (3).

Note: Do not use sealant on the joint (1).

3. Position the housing (3) and the new joint (1) onto the cylinder block. Install the setscrews (4) and the setscrews (6) in order to secure the housing (3) to the cylinder block.

4. Tighten all of the setscrews (4, 6 and 7) to the correct torque. Tighten the setscrews to a torque of 22 N·m (16 lb ft).

Note: Refer to the Operation and Maintenance Manual, "Refill Capacities" for the cooling system capacity and for the lubrication system capacity of the engine.

5. Fill the cooling system with coolant. Fill the lubrication system with engine oil.

i01958106

Engine Oil Relief Valve - Remove and Install (Engine Oil Pump)

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to the Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

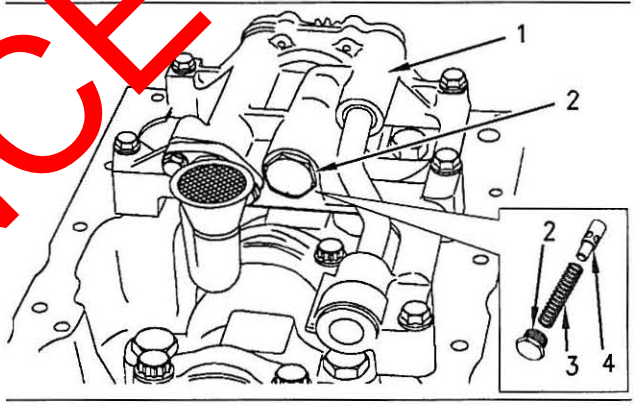

Illustration 95 g00959674

⚠ WARNING

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

Make sure to wear all necessary protective equipment.

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

1. Remove the plug (2). Remove the spring (3) and the plunger (4) from the engine oil pump (1).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the spring (3) and the plunger (4) of the engine oil relief valve. Check the spring (3) and the plunger (4) for wear or for other damage. The plunger (4) must slide easily within the bore of the oil relief valve within the engine oil pump (1). Lubricate the spring (3) and the plunger (4) with clean engine oil.

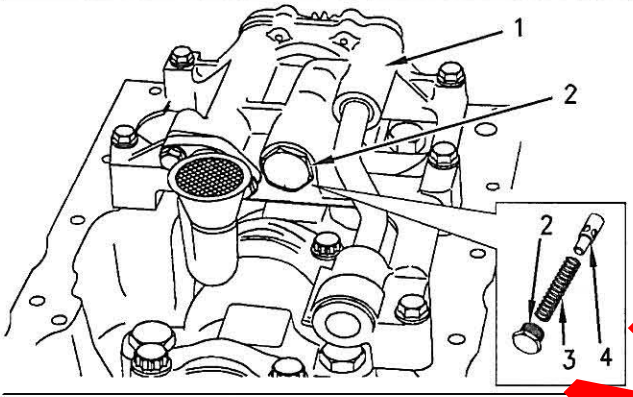

Illustration 96 g0095[illegible]74

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. Install the plunger (4) and the spring (3) in the engine oil pump (1).

3. Install the plug (2). Tighten the plug (2) to a torque of [illegible] N·m [illegible] lb ft).

End By:

a. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i01958108

Engine Oil Relief Valve - Remove and Install (Balancer Unit for the 1104 engines only)

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

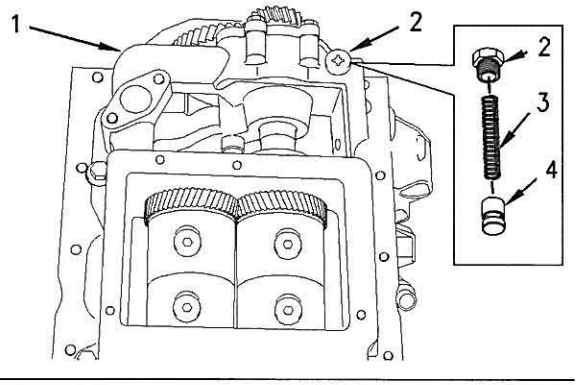

Illustration 97 g00979780

WARNING

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

Make sure to wear all necessary protective equipment.

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

1. Remove the plug (2). Remove the spring (3) and the plunger (4) from the balancer unit (1).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the spring (3) and the plunger (4) of the engine oil relief valve. Check the spring (3) and the plunger (4) for wear or for other damage. The plunger (4) must slide easily within the bore of the oil relief valve within the balancer unit (1). Lubricate the spring (3) and the plunger (4) with clean engine oil.

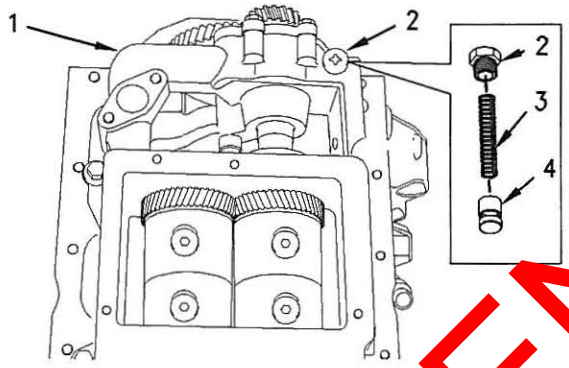

Illustration 98 g0097978

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. Install the plunger (4) and the spring (3) into the balancer unit (1).

3. Install the plug (2). Tighten the plug (2) to a torque of 22 N·m (16 lb ft).

End By:

a. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i01958101

Engine Oil Pump - Remove (Engines Without a Balancer)

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "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 this Disassembly and Assembly Manual, "Balancer Group - Remove" for information on the removal of the engine oil pump on 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.

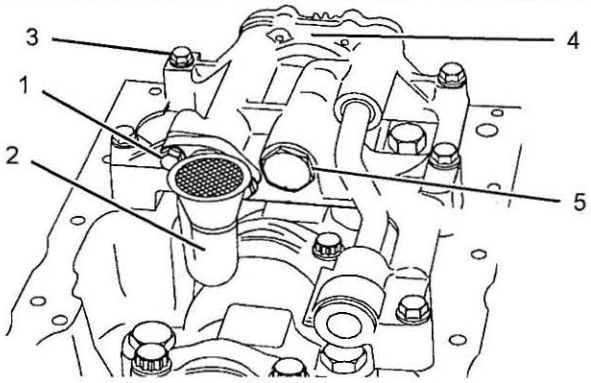

Illustration 99 g01019045

1. Remove the setscrews (1) and the suction pipe (2).

2. Remove the setscrews (3). Remove the assembly of the engine oil pump (4) from the cylinder block.

3. If necessary, remove the pressure relief valve (5) from the assembly of the engine oil pump (4). Refer to this Disassembly and Assembly Manual, “Engine Oil Relief Vave - Remove and Install”.

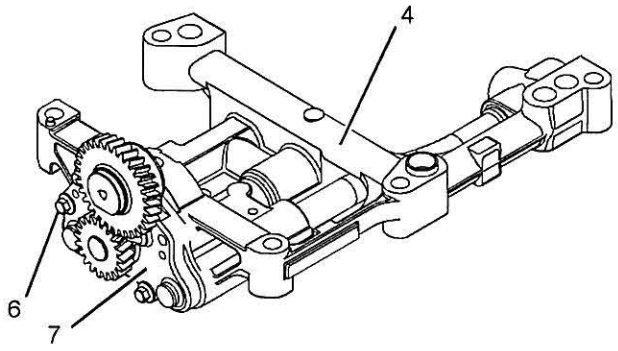

Illustration 100 g01019047

4. Remove the setscrews (6). Remove the engine oil pump (7) from the assembly of the engine oil pump (4).

5. If necessary, remove the setscrews and remove the front cover assembly from the engine oil pump (7) in order to inspect the components within the engine oil pump.

Engine Oil Pump - Install (Engines Without a Balancer)

Installation Procedure

Note: This procedure is for the installation of the engine oil pump on engines that are not equipped with a balancer. Refer to this Disassembly and Assembly Manual, “Balancer Group - Install” for information on the installation of the engine oil pump on 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. Clean all of the internal components of the oil pump if the front cover of the oil pump was previously removed in order to inspect the internal components. Check the internal components for wear and for other 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 movement of the rotor. Refer to the Systems Operation/Testing and Adjusting Manual, “Engine Oil Pump - Inspect”. Replace the engine oil pump if any of the components are worn or damaged.

2. Lubricate the inner rotor and the outer rotor of the engine oil pump with clean engine lubricating oil. Install the front cover of the engine oil pump onto the body of the oil pump. Install the setscrews and tighten the setscrews in order to secure the front cover to the body.

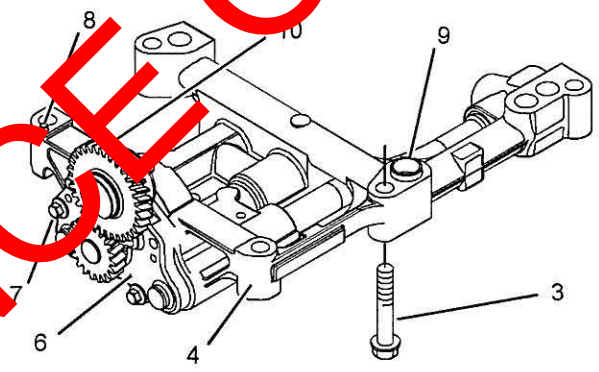

Illustration 101 g01019312

3. Fill engine oil pump (6) with clean engine oil.

4. Install the engine oil pump (6) into the assembly of the engine oil pump (4). Install the setscrews (7). Tighten the setscrews to a torque of 9 N·m (80 lb in).

5. Ensure that the dowel pin (8) and the hollow dowel (9) are correctly located in the cylinder block. Install the assembly of the engine oil pump (4) onto the dowels (8 and 9).

6. Install the setscrews (3). Tighten the setscrews to a torque of 44 N·m (32 lb ft).

7. Check the backlash between the idler gear (10) of the oil pump and the crankshaft gear. Refer to the Specifications Manual, “Gear Group - Front” for further information.

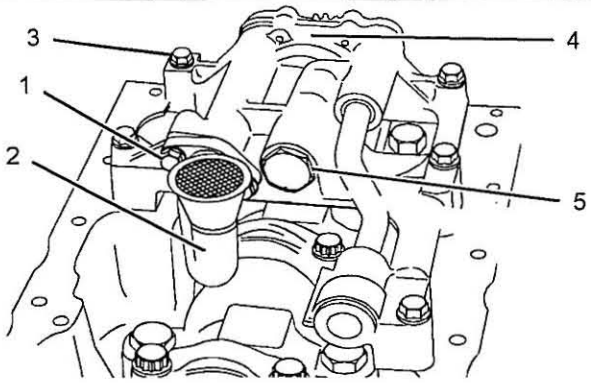

Illustration 102 g01019045

8. If the pressure relief valve (5) was removed, install the pressure relief valve. Refer to this Disassembly and Assembly Manual, "Engine Oil Relief Valve - Remove and Install" for further information.

9. Position the suction pipe (2) and install the setscrews (1).

End By:

a. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i0199165

Water Pump - Remove

Removal Procedure

Start By:

a. Remove the fan. Refer to this Disassembly and Assembly Manual, "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.

2. Loosen the clamps and remove the hose from the water pump inlet.

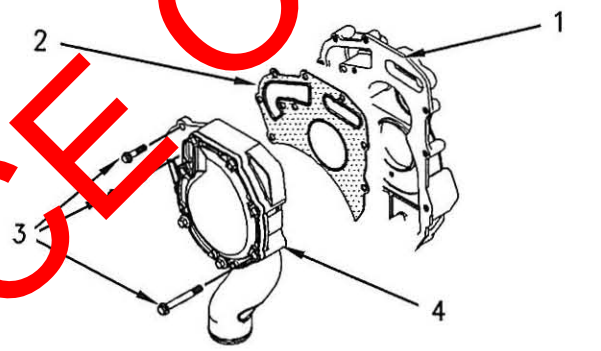

Illustration 103 g00952695

3. Remove the setscrews (3) that fasten the water pump (4) to the front housing (1).

4. If necessary, gently tap the water pump (4) with a soft hammer in order to loosen the water pump.

5. Remove the water pump (4). Remove the joint (2) from the front housing (1) and the water pump (4). Discard the joint (1).

i01962207

Water Pump - Disassemble

Disassembly Procedure

Start By:

a. Remove the water pump. Refer to this Disassembly and Assembly Manual, "Water Pump - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

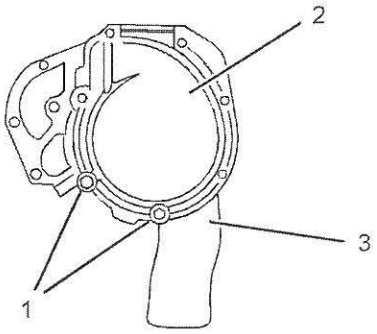

Illustration 104 g01019550

1. Remove the setscrews (1) from the cover (2) of the water pump (3). Remove the joint between the cover (2) and the water pump (3). Discard the joint.

Note: All of the other setscrews are removed during the removal of the water pump.

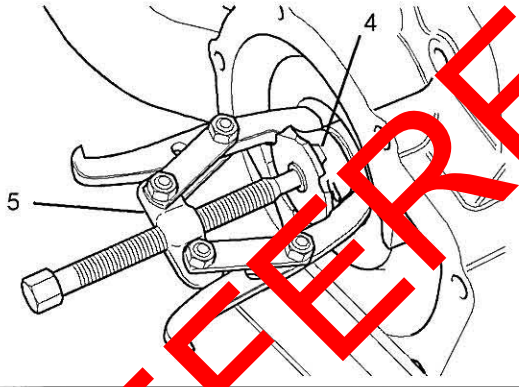

Illustration 105 g01019566

2. Drill twelve 6.35 mm (0.25 inch) holes between the existing holes in the impeller (4). Break pieces from the impeller (4) in order to install a suitable puller (5) with two legs onto the impeller. Remove the impeller (4) with the suitable puller (5).

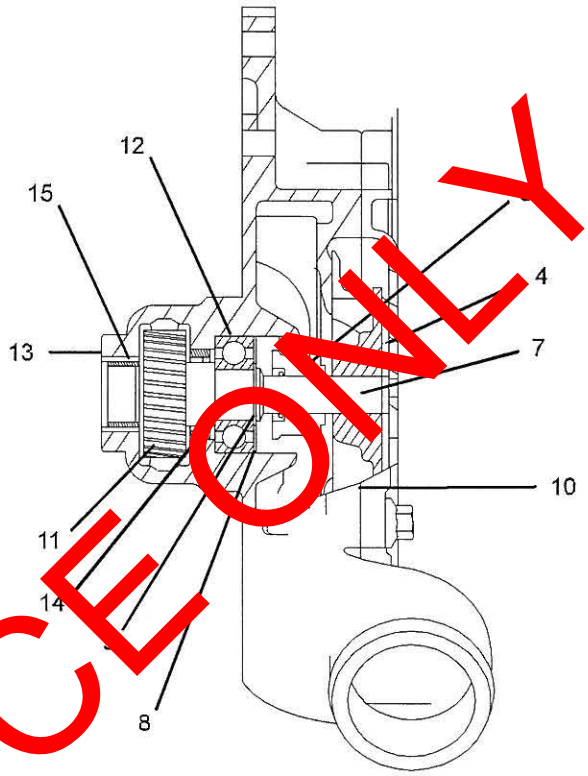

Illustration 106 g01020061

Note: It will be necessary to break the coolant seal (6) in order to remove the coolant seal from the water pump (3).

3. Drill three 3.175 mm (0.125 inch) holes that are equally spaced into the coolant seal (6). The holes should be drilled into the face of the coolant seal (6) that would have faced the impeller (4). Insert three 25.4 mm (1.00 inch) long self-tapping screws into the drilled holes. Insert a suitable lever into the coolant inlet of the water pump (3). Use the suitable lever under the self-tapping screws in order to evenly pull the coolant seal (6) off the shaft (7). If necessary, remove the center sleeve of the coolant seal from the shaft with a suitable extractor.

4. Remove the outer circlip (8) and discard the outer circlip. Remove the inner circlip (9) and discard the inner circlip.

5. Support the machined face (10) of the housing of the water pump (3) on a suitable support. Press on the shaft (7) until the gear (11) and the bearing (12) are free from the shaft. Discard the shaft (7) and the bearing (12). Remove the gear (11) through the side of the housing of the water pump (3).

6. Support the machined face (13) of the housing of the water pump (3) on a suitable support. Insert a suitable mandrel on the oil seal (14) and press the oil seal out of the housing of the water pump (3). The oil seal (14) can be removed through the side of the housing of the water pump (3) after the seal has been released from the housing. Discard the oil seal (14).

7. Use a suitable mandrel to press the needle bearing (15) out of the housing of the water pump (3). Discard the needle bearing (15).

i01962206

Water Pump - Assemble

Assembly Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

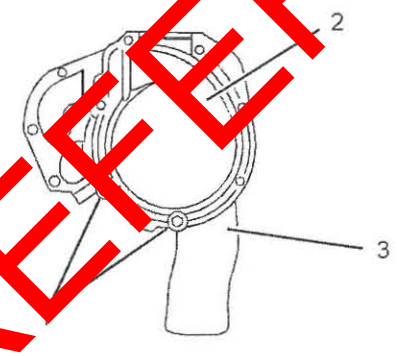

Illustration 107 g01019550

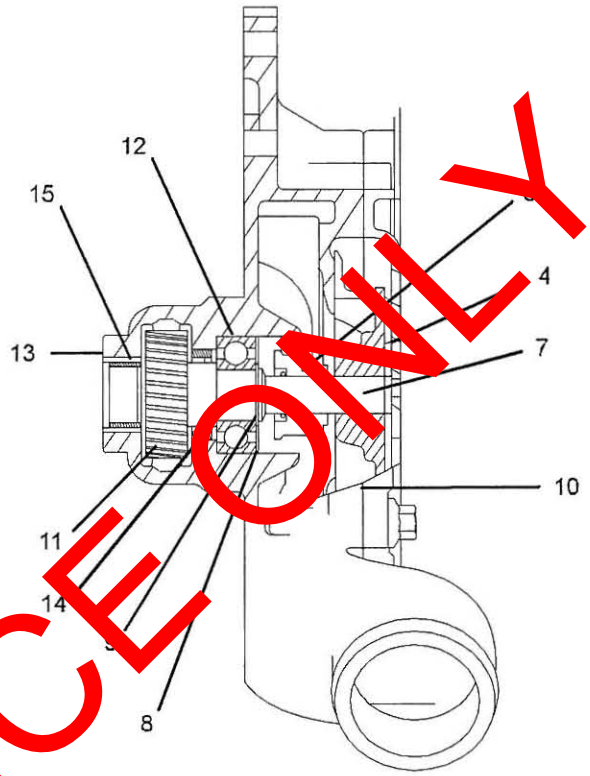

Illustration 108 g01020061

1. Thoroughly clean the inside of the housing of the water pump (3). Ensure that the bores for the bearings (12 and 15) and the coolant seal (6) are clean and free from corrosion.

2. Inspect the gear (11) for wear and/or damage. If necessary, replace the gear (11).

3. Support the machined face (13) of the housing of the water pump (3). Use a suitable mandrel and a suitable press to press a new oil seal (14) into the housing of the water pump (3). Stop pressing the oil seal (14) into the housing when the lower face of the oil seal is level with the lower face of the recess for the oil seal.

4. Install the gear (11) through the side of the housing for the water pump (3). Use a suitable adapter to press the shaft (7) through the oil seal (14) and into the gear (11). Continue to press the shaft (7) into the gear (11) until there is a gap of 1.5 mm (0.060 inch) between the gear and the top of the housing for the gear within the housing of the water pump (3).

5. Use a suitable adapter in order to press the bearing (12) against the shoulder of the recess for the bearing.

6. Install a new circlip (8) into the recess with the housing for the water pump (3). Install a new circlip (9) into the recess in the shaft (7). Ensure that both circlips (8 and 9) are installed correctly.

7. Support the machined face (10) of the housing of the water pump (3) on a suitable support. Press the needle bearing (15) into the housing for the bearing. Continue to press the needle bearing (15) into the housing until the needle bearing is either level with the top face of the housing or the needle bearing is no more than a maximum of 0.5 mm (0.020 inch) below the top face of the housing.

8. Support the machined face (13) of the housing of the water pump (3) on a suitable support.

Note: Avoid hand contact with the coolant seal (6). The coolant seal (6) must not be contaminated by oil or grease. The coolant seal (6) must only be touched and/or held at the edge of the outer flange.

Note: Do not lubricate the coolant seal (6).

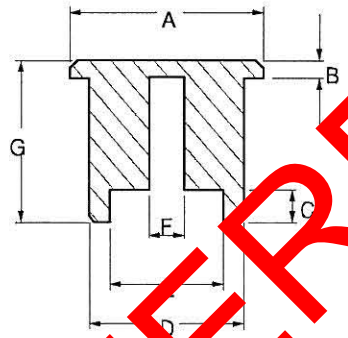

Illustration 109 g01019850

9. Manufacture a suitable tool in order to press the new coolant seal (6) into position. The tool should be made to the dimensions shown in the illustration 109 and the table 10.

Table 10

Dimensions			
A	54.0 mm (2.126 inch)	**E**	44.0 mm (1.732 inch)
B	6.0 mm (0.236 inch)	**F**	18.0 mm (0.709 inch)
C	10.0 mm (0.394 inch)	**G**	54.0 mm (2.126 inch)
D	48.0 mm (1.890 inch)		

10. Install the new coolant seal (6) onto the shaft (7) with the largest diameter of the coolant seal toward the bearing (12). Push the coolant seal (6) onto the shaft (7) until the coolant seal is in contact with the counterbore for the coolant seal. Ensure that the coolant seal (6) is square with the counterbore. Use a suitable adapter in order to press the coolant seal (6) into the counterbore until the outer flange of the coolant seal is in contact with the body of the water pump (3). Maintain the pressure on the coolant seal (10) for about 10 seconds in order to ensure that the coolant seal remains in position.

11. Press the impeller (4) onto the shaft (7) until the top of the impeller is level with the top of the shaft.

12. Install a new joint to the cover (2) to the body of the water pump (3). Install the cover (2) to the water pump (3).

13. Install the setscrews (1). Torque the setscrews (1) to a torque of 22 N·m (16 lb ft).

End By:

a. Install the water pump. Refer to this Disassembly and Assembly Manual, "Water Pump - Remove and Install".

i01991661

Water Pump - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Inspect the drive gear for the water pump (4) for wear or other damage. If necessary, replace the drive gear.

2. Clean the joint faces of the water pump (4) and the front housing (1).

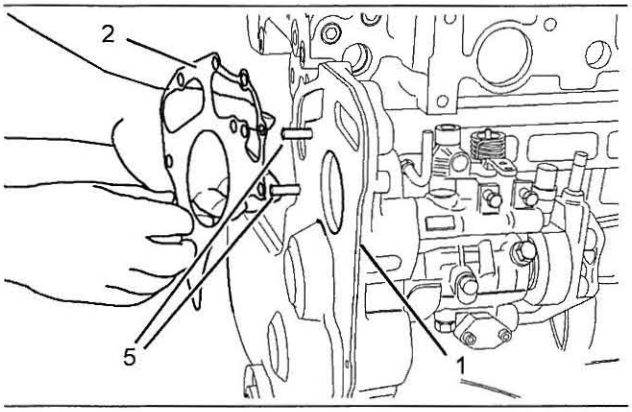

Illustration 110 g01019549

3. Install two guide studs (5) into the front housing (1).

Note: Do not use sealant on the new joint (2) for the water pump (4).

4. Install the new joint (2) onto the front housing (1).

5. Install the water pump (4) onto the front housing (1).

Note: New setscrews have sealant to the first 13 mm (0.5 inch) of the threads. In order to reuse the old setscrews, clean the old sealant from the setscrews and apply 21820117 POWERPART Threadlock and Nutlock to the setscrews (3).

6. Install the setscrews (3) that fasten the water pump (4) to the front housing (1). Do not tighten the setscrews (3) at this time.

7. Remove the guide studs (5) and install the remaining setscrews (3).

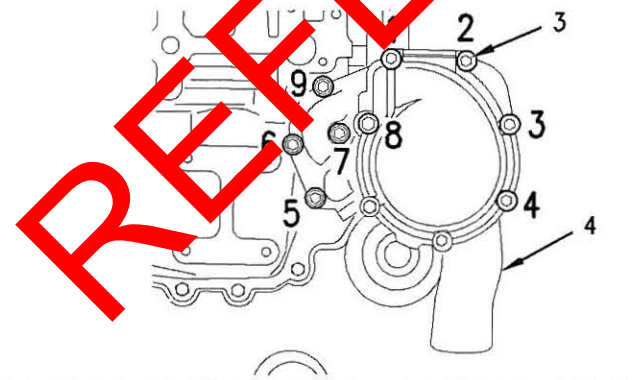

Illustration 111 g00952731

Note: Tighten the setscrews (3) evenly in order to pull the water pump (4) into the front housing (1).

8. Tighten the setscrews (3) in the sequence that is shown in the illustration 111 to a torque of 22 N·m (16 lb ft).

9. Install the hose to the water pump inlet. Tighten the hose clamps.

10. Fill the cooling system with coolant. Refer to the Operation and Maintenance Manual, "Refill Capacities" for the cooling system capacity.

End By:

a. Install the fan. Refer to the Disassembly and Assembly Manual, "Fan - Remove and Install".

i02641605

Water Temperature Regulator - Remove and Install

Removal Procedure

Table 1

Required Tools		
Part Number	**Part Description**	**Qty**
27610226	Thermostat Tool	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. Drain the coolant from the cooling system to a level below the water temperature regulator into a suitable container for storage or disposal.

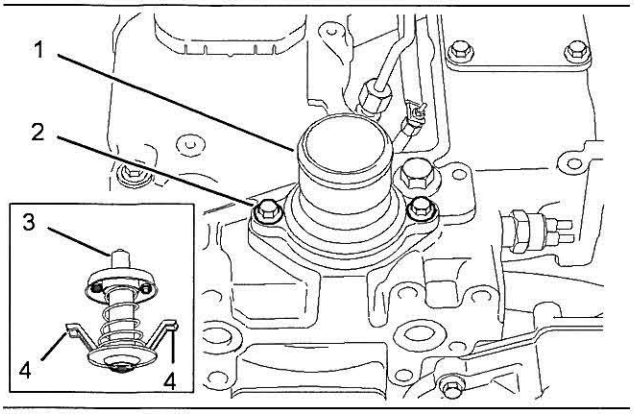

Illustration 112 g01019333

2. Loosen the hose clamps from the upper radiator hose and remove the upper radiator hose from the water temperature regulator housing (1).

3. Remove the setscrews (2) that hold water temperature regulator housing (1) in position on the cylinder head. Remove the water temperature regulator housing (1). Remove the O-ring from the water temperature regulator housing (1). Discard the O-ring.

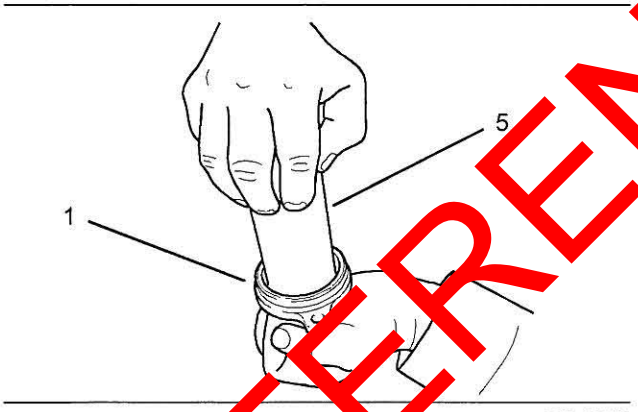

Illustration 113 g01019344

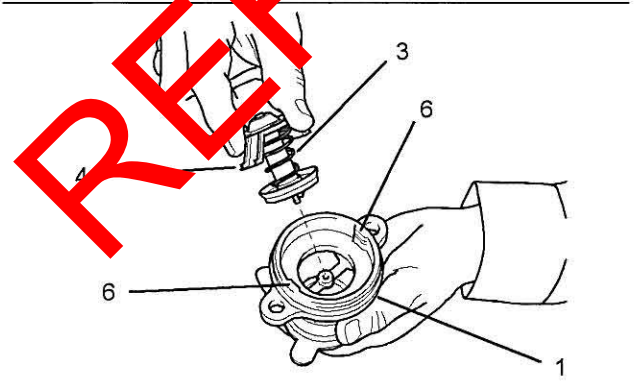

Illustration 114 g01019356

4. Install the 27610226 Thermostat Tool (5) into the water temperature regulator housing (1). Press on the tool (5) in order to squeeze the retainers (4). Rotate the tool (5) in order to release the water temperature regulator (3) from the tabs (6) of the water temperature regulator housing (1). Remove the tool (5) from the water temperature regulator housing (1). Remove the water temperature regulator (3) from the water temperature regulator housing (1).

5. Refer to the Systems Operation/Testing and Adjusting Manual, "Water Temperature Regulator - Test" for the correct procedure on testing the water temperature regulator. If necessary, replace the water temperature regulator (3).

Installation Procedure

Table 12

Required Tools		
Part Number	Part Description	Qty
27610226	Thermostat Tool	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

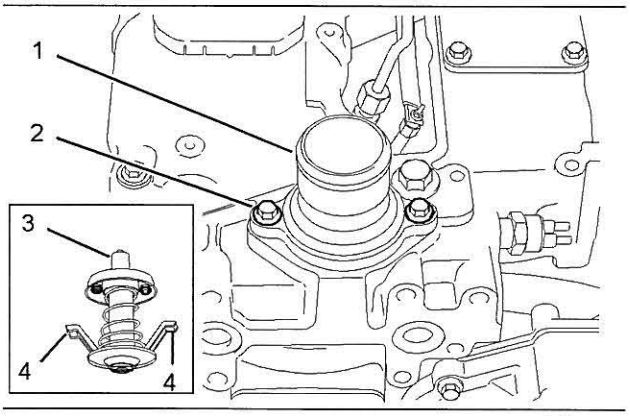

Illustration 115 g01019333

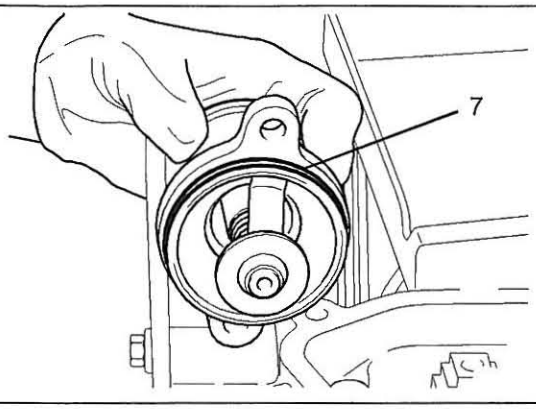

Illustration 116 g01019377

1. Clean the water temperature regulator housing (1). Ensure that the tabs (6) for the retainers (4) are clean. Ensure that the seat for the O-ring (7) is clean.

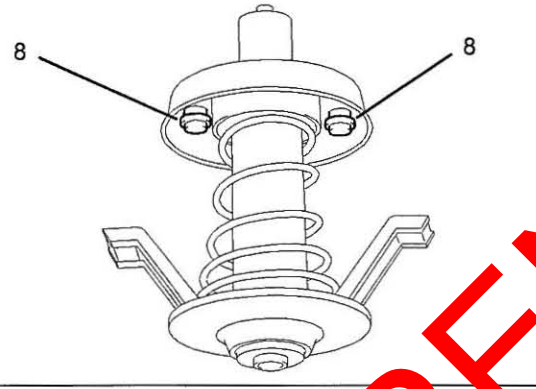

Illustration 117 g01019381

2. The water temperature regulator (3) has two vents (8) that are opened and closed by the valve pin. These two vents (8) bleed hot water and/or air through the water temperature regulator (3) when the water temperature regulator is in the closed position. Ensure that the valve pins (8) can move freely in the vents.

3. Lubricate the new O-ring (7) with 21820221 POWERPART Red Rubber Grease. Install the O-ring (7) into the appropriate groove in the water temperature regulator housing (1).

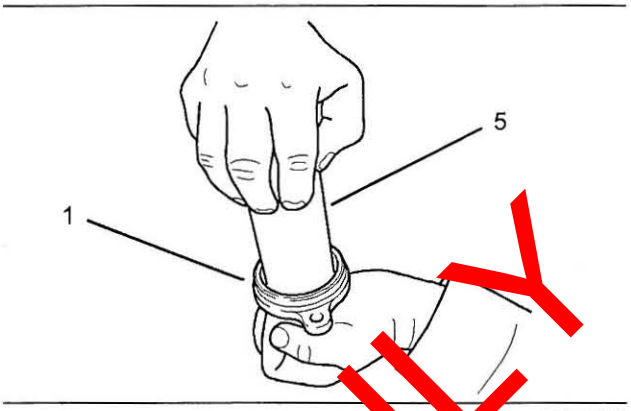

Illustration 118 g01019344

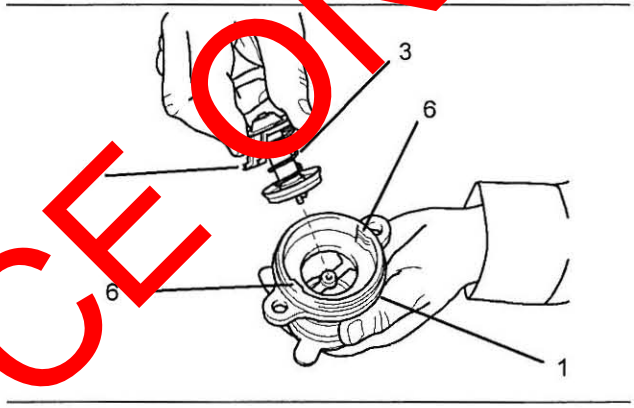

Illustration 119 g01019356

4. Position the water temperature regulator (3) in the water temperature regulator housing (1). Install the 27610226 Thermostat Tool (5) in order to squeeze the retainers (4). Rotate the tool (5) in order to secure the water temperature regulator (3) into the water temperature regulator housing (1).

Note: The retainers (4) must be inserted behind the tabs of the water temperature regulator housing (1) in order to secure the water temperature regulator (3) during engine operation.

5. Ensure that the retainers (4) are correctly installed within the tabs (6). Position the water temperature regulator housing (1) onto the cylinder head.

6. Install the setscrews (2) that fasten the water temperature regulator housing (1) to the cylinder head. Tighten the setscrews (2) to a torque of 44 N·m (32 lb ft).

7. Install the upper radiator hose and tighten the hose clamps securely.

8. Fill the cooling system to the proper level. Refer to the Operation and Maintenance Manual, “Refill Capacities” for further information.

i02259836

Flywheel - Remove

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

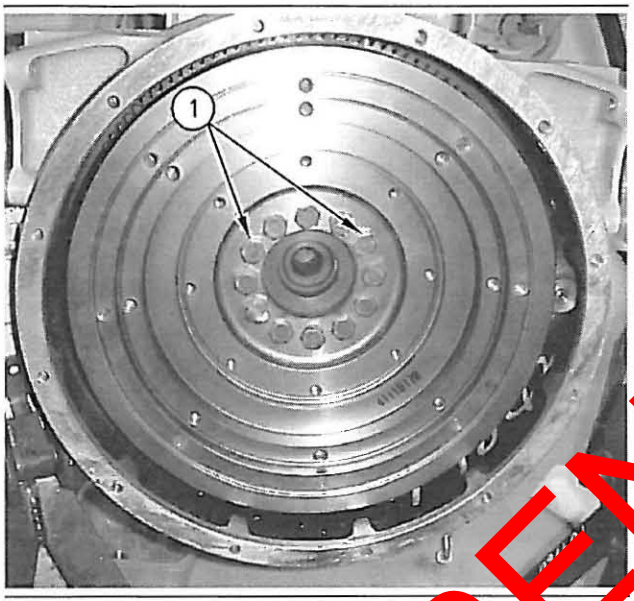

Illustration 120

1. Remove the two setscrews (1).

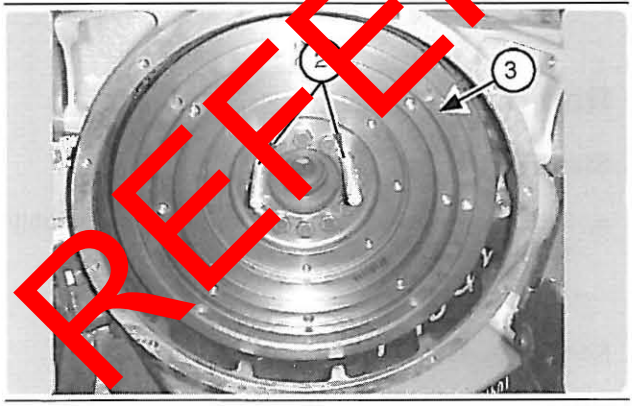

Illustration 121 g01020091
Typical example

2. Install two suitable studs (2) as guides.

Note: The flywheel (3) is heavy. Use suitable lifting equipment to support the flywheel (3) before the remainder of the setscrews (1) are removed.

3. Remove the remaining setscrews (1) that secure flywheel (3) to the crankshaft and then remove the flywheel.

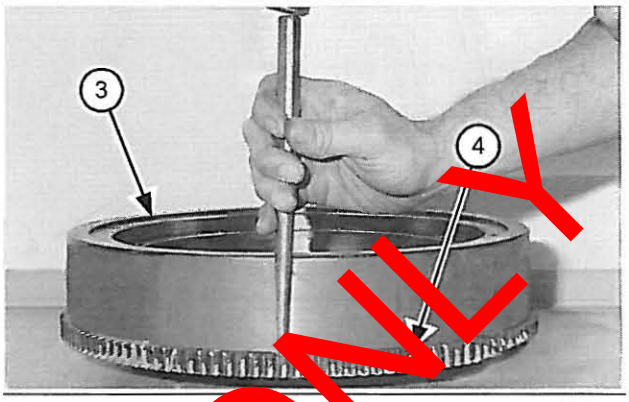

Illustration 122 g01020099

4. Check the condition of the ring gear (4). Remove the ring gear (4) if the ring gear is worn or damaged.

Note: Identify the orientation of the ring gear on the flywheel and the position of the chamfer on the teeth for the correct positioning when the new ring gear is installed.

5. Place the flywheel (3) and the ring gear (4) on a suitable support. Use a hammer and a chisel in order to remove the ring gear (4) from the flywheel (3).

i02231069

Flywheel - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

⚠ WARNING

Always wear protective gloves when handling parts that have been heated.

1. Thoroughly clean the flywheel housing. Inspect the crankshaft rear seal for leaks. If there are any oil leaks refer to this Disassembly and Assembly Manual, “Crankshaft Rear Seal - Remove”.

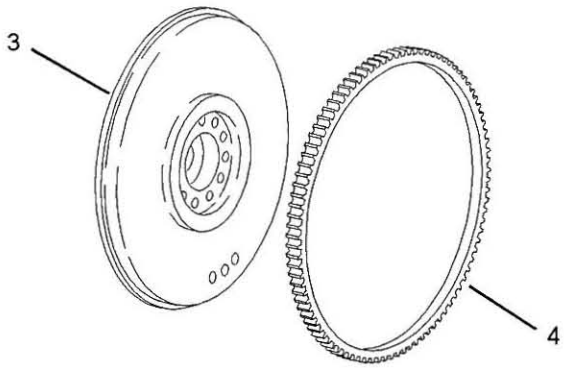

Illustration 123 g01020131

Note: If the ring gear (4) has been removed from the flywheel (3), identify the orientation of the new ring gear in order to install the ring gear correctly onto the flywheel.

Note: Do not use a torch to heat the ring gear (4).

2. Heat the ring gear (4) to 250 °C (480 °F) in an oven in order to install the ring gear onto the flywheel (3). Ensure that the orientation of the ring gear (4) is correct and quickly install the ring gear onto the flywheel (3).

3. Clean the flywheel (3) and the ring gear (4) when the ring gear has cooled.

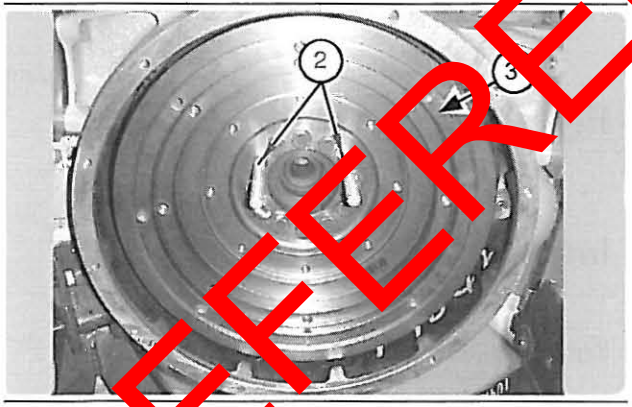

Illustration 124 g01020091

4. Ensure that the guide studs (2) are still installed in the crankshaft.

5. If an alignment pin is installed, ensure that the alignment hole in the mounting face of the flywheel is aligned with the alignment pin on the mounting face on the crankshaft.

Note: The flywheel (3) is heavy. Use suitable lifting equipment to support the flywheel until the setscrews (1) have been installed.

6. Install the flywheel (3) onto the two guide studs (2).

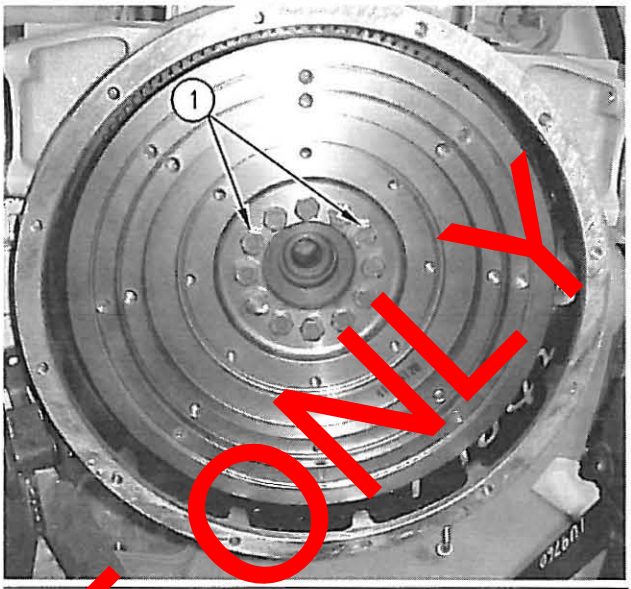

Illustration 125 g00905926

7. Install most of the setscrews (1) finger tight. Remove the guide studs (2). Install the remainder of the setscrews (1).

8. Tighten the setscrews (1) to a torque of 105 N·m (77 lb ft).

9. Check the alignment of the flywheel (3) with the crankshaft. Refer to the Testing and Adjusting Manual, "Flywheel - Inspect".

i01963624

Crankshaft Rear Seal - Remove

Removal Procedure

Start By:

a. Remove the flywheel. Refer to this Disassembly and Assembly Manual, "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.

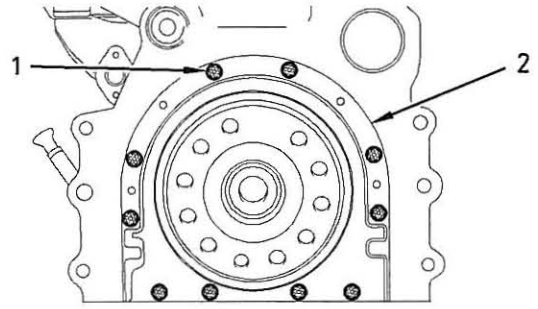

Illustration 126 g00991388

Note: The assembly of the crankshaft rear seal (2) is nonserviceable. If the assembly of the crankshaft rear seal (2) is removed, the assembly must be replaced.

1. Remove the setscrews (1) from the assembly of the crankshaft rear seal (2).

2. Remove the assembly of the crankshaft rear seal (2) from the cylinder block. Discard the assembly of the crankshaft rear seal (2).

i01963627

Crankshaft Rear Seal - Install

Installation Procedure

Note: The crankshaft rear seal and the housing for the crankshaft rear seal are manufactured as a one-piece assembly. The assembly of the crankshaft rear seal uses ten setscrews in order to fasten the assembly to the cylinder block.

Note: The assembly of the crankshaft rear seal is lubricated during manufacture. Do not lubricate the seal or the crankshaft flange before installation.

Note: Inspect the crankshaft rear seal and replace the assembly if there is the slightest sign of damage to the seal.

Note: The following procedure assumes that the crankshaft rear seal is a replacement assembly.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

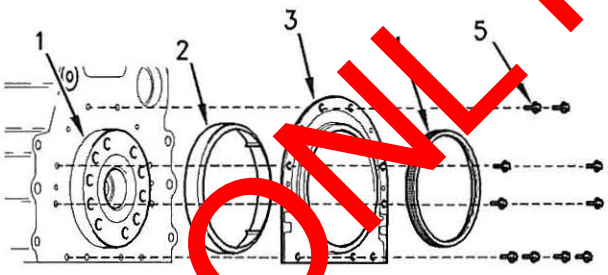

Illustration 127 g01004915

1. Ensure that the crankshaft flange (1) is clean, dry and free from rough metal edges. Ensure that the face of the cylinder block and the bridge in the crankcase are clean and dry.

2. Remove the packaging from the new assembly of the crankshaft rear seal (3). Ensure that the plastic sleeve (2) is squarely installed within the seal of the assembly of the crankshaft rear seal (3). The plastic sleeve (2) is included in order to protect the lip of the seal as the lip is pushed over the crankshaft flange (1).

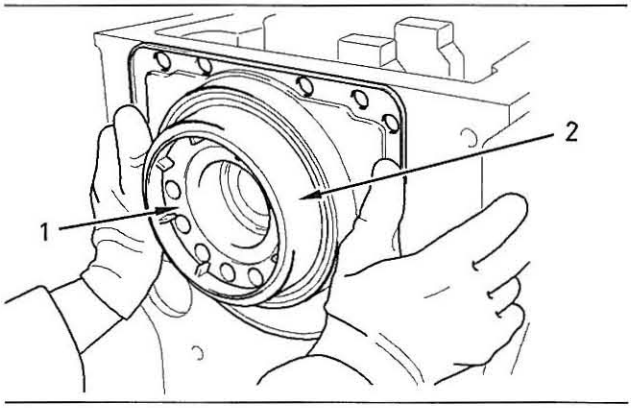

Illustration 128 g01004958
Typical example

3. Place the assembly of the crankshaft rear seal (3) over the crankshaft flange (1) and engage the plastic sleeve (2) onto the crankshaft flange.

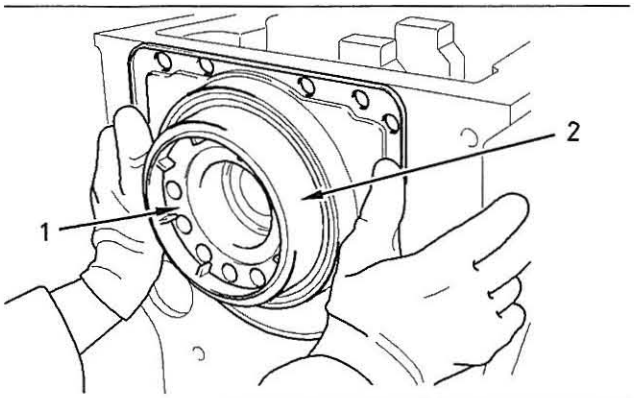

Illustration 129 g01004958

Typical example

4. Ensure that the plastic sleeve (2) is engaged onto the crankshaft flange (1). Push the assembly of the crankshaft rear seal (3) evenly and push the assembly smoothly onto the crankshaft flange (1) until the assembly is against the cylinder block. During this process, the plastic sleeve (2) will be forced out of the assembly of the crankshaft rear seal (3). Discard the plastic sleeve (2).

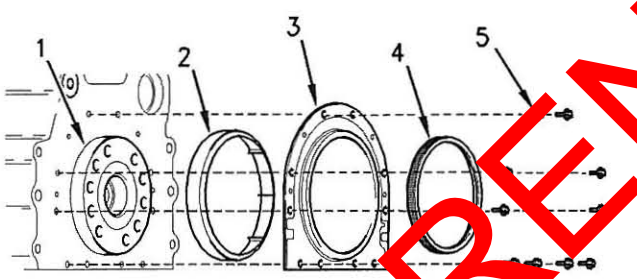

Illustration 130 g01004915

5. Rotate the assembly of the crankshaft rear seal (3) in order to align the setscrew holes in the assembly with the setscrew holes in the rear face of the cylinder block.

6. By using the new setscrews (5), loosely secure the assembly of the crankshaft rear seal (3) to the cylinder block.

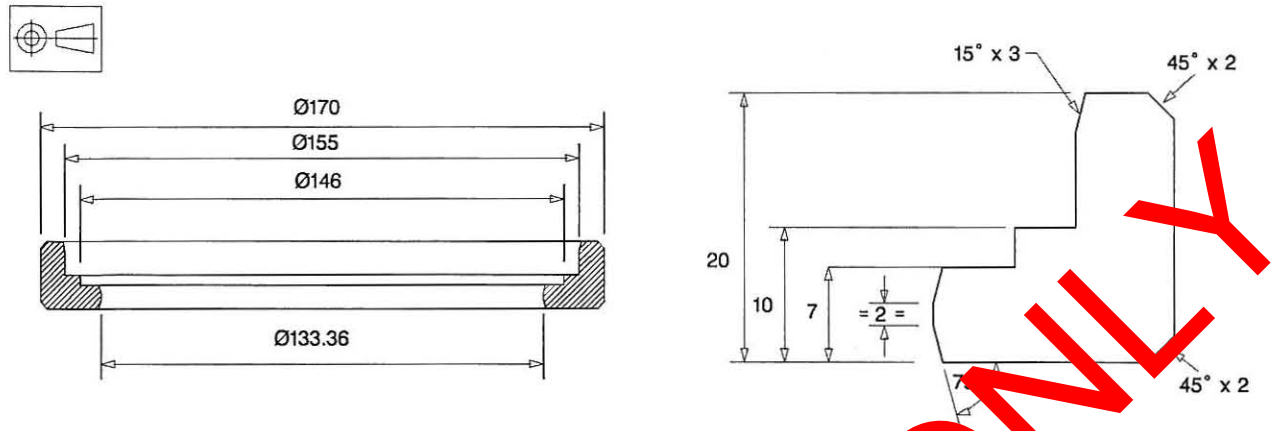

Illustration 131 g00975010

Note: The alignment tool (4) is not currently available from Perkins. Refer to the illustration 131 for the required dimensions in order to manufacture an alignment tool (4) locally.

7. Install the alignment tool (4) onto the crankshaft flange (1) and over the assembly of the crankshaft rear seal (3) in order to align the assembly with the crankshaft flange.

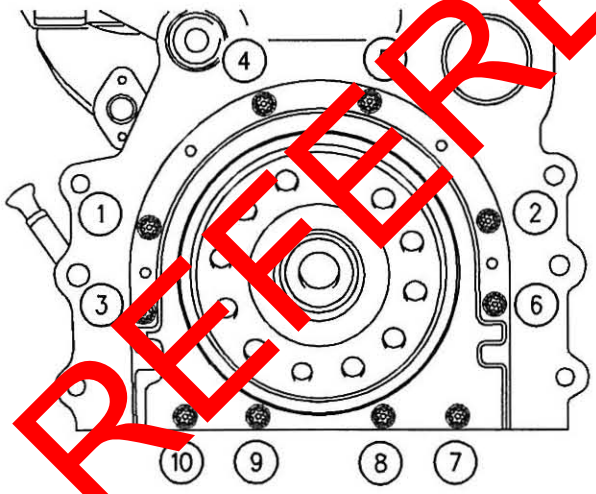

Illustration 132 g00915076

8. Tighten the setscrews (5) in the sequence 1, 2, 3, 4, 5, 6, 7, and 10 to a torque of 22 N·m (16 lb ft). Refer to the illustration 132.

9. Remove the alignment tool (4). Tighten the setscrews 8 and 9 to a torque of 22 N·m (16 lb ft). Refer to the illustration 132.

End By:

a. Install the flywheel housing. Refer to this Disassembly and Assembly Manual, "Flywheel Housing - Remove and Install".

b. Install the flywheel. Refer to this Disassembly and Assembly Manual, "Flywheel - Install".

i01964071

Crankshaft Wear Sleeve (Rear) - Remove

Removal Procedure

Start By:

a. Remove the crankshaft rear seal. Refer to this Disassembly and Assembly Manual, "Crankshaft Rear Seal - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Install a deep score mark along the length of the wear sleeve.

2. Insert a suitable tool between the crankshaft flange and the wear sleeve next to the score mark. The wear sleeve should break along the score mark. Remove the wear sleeve. Discard the wear sleeve.

3. Use a suitable solvent in order to remove any old sealant from the crankshaft.

i01964075

Crankshaft Wear Sleeve (Rear) - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

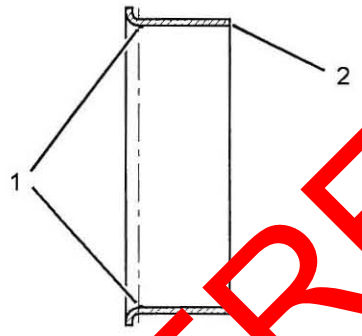

Illustration 133 g01020643

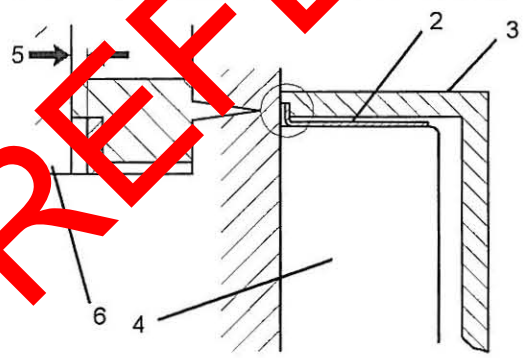

Illustration 134 g01020497

1. Ensure that the crankshaft flange (4) is thoroughly clean, dry, and free from old sealant prior to the installation of a new crankshaft wear sleeve (2). Remove any rough edges from the crankshaft flange (4).

2. Use a prybar to move the crankshaft toward the front of the engine.

3. Apply a small continuous bead (1) of 21820518 POWERPART Liquid Gasket to the inner surface 5.00 mm (0.197 inch) from the flange end of crankshaft wear sleeve (2).

4. Position crankshaft wear sleeve (2) on the crankshaft flange (4). Position the installation tool (3) that is provided with the new crankshaft wear sleeve (2) over the crankshaft wear sleeve. Use a hammer to drive the crankshaft wear sleeve (2) onto the crankshaft flange (4). The flange of the crankshaft wear sleeve (2) must be within (5) 0.40 to 0.60 mm (0.017 to 0.024 inch) of the cylinder block (6).

5. Remove the installation tool (3). Measure the distance between the flange of the crankshaft wear sleeve (2) and the cylinder block (6) in two places that are 180 degrees from each other. The correct distance (5) is 0.40 to 0.60 mm (0.017 to 0.024 inch).

6. After the crankshaft wear sleeve (2) has been installed, remove any rough edges from the crankshaft flange (4) and the crankshaft wear sleeve (2).

End By:

a. Install the crankshaft rear seal. Refer to this Disassembly and Assembly Manual, “Crankshaft Rear Seal - Install”.

i01963628

Flywheel Housing - Remove and Install

Removal Procedure

Start By:

a. Remove the electric starting motor. Refer to this Disassembly and Assembly Manual, “Electric Starting Motor - Remove and Install”.

b. Remove the flywheel. Refer to this Disassembly and Assembly Manual, “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.

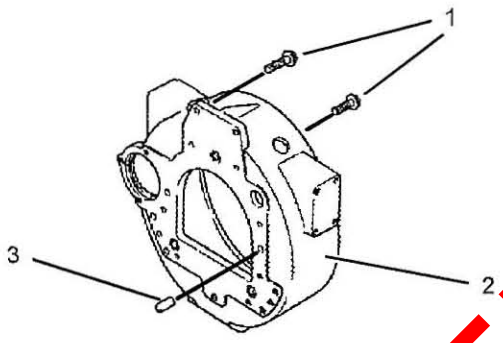

Illustration 135 g01020398

Note: The flywheel housing (2) is heavy. Use suitable lifting equipment to support the flywheel housing (2) while the setscrews (1) are being removed and while the flywheel housing is being removed.

1. Remove all of the setscrews (1) from the flywheel housing (2).
2. Remove the flywheel housing (2). If necessary, hit the flywheel housing with a soft faced hammer in order to separate the flywheel housing (2) from the dowels (3) in the cylinder block.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

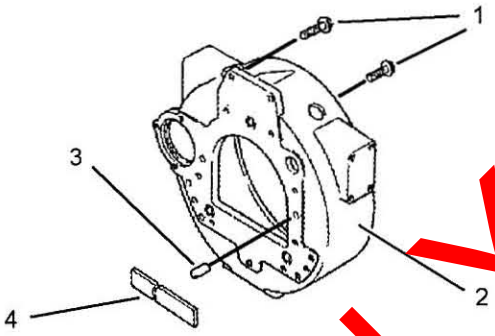

Illustration 136 g01020405

1. Clean the rear face of the cylinder block and the mating surface of the flywheel housing (2).
2. If a felt seal (4) is installed, replace the felt seal. Inspect the dowels (3) in the cylinder block that align the flywheel housing (2). Replace the dowels (3), if necessary.

Note: The flywheel housing (2) is heavy. Use suitable lifting equipment to support the flywheel housing (2) while the flywheel housing is being lifted and while the setscrews (1) are being installed.

3. Install the flywheel housing (2) onto the dowels (3) that are in the cylinder block.
4. Install all of the setscrews (1) that attach the flywheel housing (2) to the cylinder block.

   Tighten the setscrews (1) to the following torque:

M10 “8.8”	44 N·m (33 lb ft)
M10 “10.9”	63 N·m (46 lb ft)
M12 “8.8”	75 N·m (55 lb ft)
M12 “10.9”	115 N·m (85 lb ft)

5. Check the alignment of the flywheel housing (2) with the cylinder block. Refer to the Testing and Adjusting Manual, “Flywheel Housing - Inspect”.

End By:

a. Install the flywheel. Refer to this Disassembly and Assembly Manual, “Flywheel - Install”.

b. Install the electric starting motor. Refer to this Disassembly and Assembly Manual, “Electric Starting Motor - Remove and Install”.

i02217476

Crankshaft Pulley - Remove and Install

Standard and Non-standard Pulleys

Start By:

a. Remove the V-Belts. Refer to this Disassembly and Assembly Manual, "V-Belts - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Identify the type of pulley that is installed on the engine. The standard pulley has four apertures. Refer to illustration 137. The non-standard pulley has three apertures and a weight in place of the fourth aperture. Refer to illustration 138. Refer to the applicable procedure that follows.

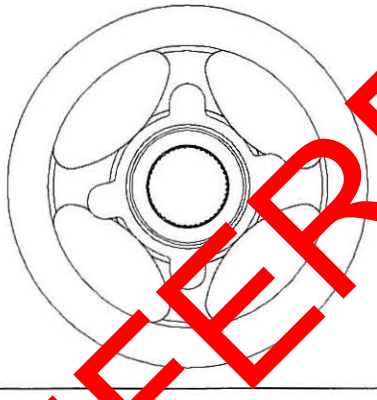

Illustration 137 g01126952
Standard Pulley

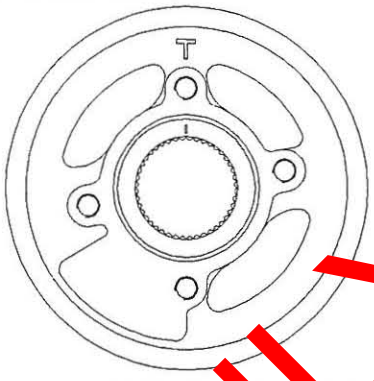

Illustration 138 g01126955
Non-standard Pulley

Removal and Installation of the Standard Pulley (If equipped)

Remove the Standard Pulley

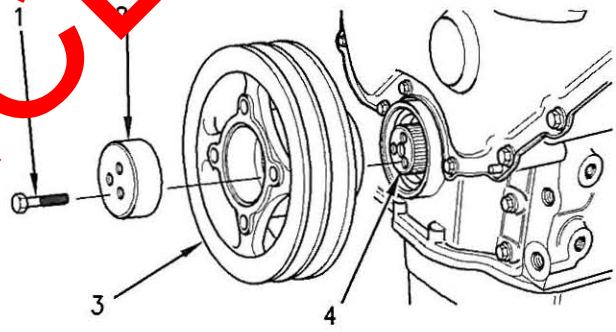

Illustration 139 g00952102

1. Remove the setscrews (1) and then remove the thrust block (2).
2. Remove the pulley (3) from the crankshaft (4).

Install the Standard Pulley

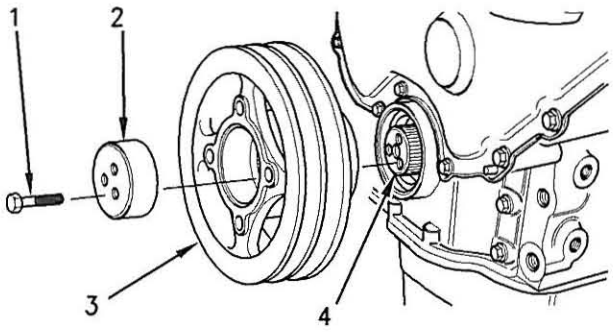

Illustration 140 g00952102

1. Clean the pulley (3) and clean the thrust block (2). Inspect the pulley (3) and the thrust block (2) for wear and for damage. If necessary, replace any damaged component. Inspect the area on the pulley that is normally in contact with the crankshaft front seal. If there is excessive wear then a wear sleeve can be installed. Refer to the Disassembly and Assembly Manual, "Crankshaft Wear Sleeve (Front) - Remove and Crankshaft Wear Sleeve (Rear) - Install" for further details.
2. Position the pulley (3) onto the crankshaft (4).
3. Lubricate the threads and the shoulder of the setscrews (1) with clean engine oil. Position the thrust block (2) and install the setscrews (1). Tighten the setscrews evenly to a final torque of 115 N·m (85 lb ft).
4. Tighten each of the setscrews (1) again to the same torque in order to ensure that the setscrews are still at the required torque.

Removal and Installation of the Non-standard Pulley (if equipped)

There are two procedures for removal and installation of the non-standard pulley. One procedure is used when the crankshaft is not replaced. The second procedure is used when the non-standard pulley is removed prior to replacement of the crankshaft.

Remove the Non-standard Pulley when the Crankshaft is Not Replaced

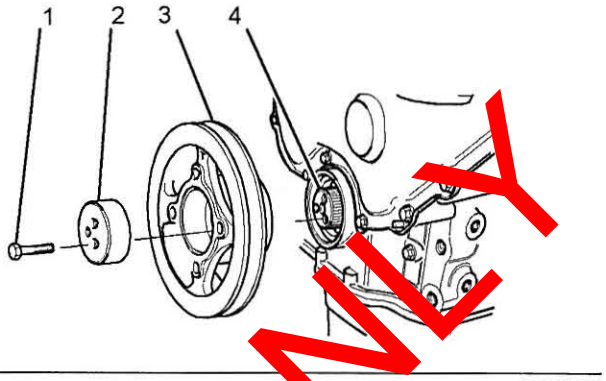

Illustration 141 g01127338

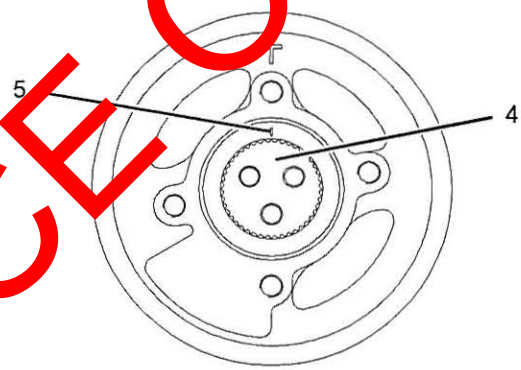

Illustration 142 g01127411

1. Remove the setscrews (1) and then remove the thrust block (2).
2. Apply a mark on the front face of the crankshaft (4) that is aligned with the mark on the pulley (5).
3. Remove the pulley (3) from the crankshaft (4).

Install the Non-standard Pulley when the Crankshaft is Not Replaced

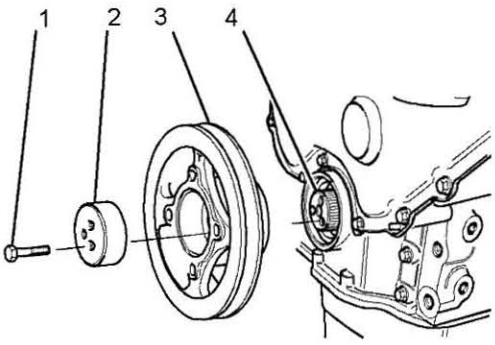

Illustration 143 g01127338

1. Clean the pulley (3) and clean the thrust block (2). Inspect the pulley (3) and the thrust block (2) for wear and for damage. If necessary, replace any damaged component. Inspect the area on the pulley that is normally in contact with the crankshaft front seal. If there is excessive wear then a wear sleeve can be installed. Refer to the Disassembly and Assembly Manual, "Crankshaft Wear Sleeve (Front) - Remove and Crankshaft Wear Sleeve (Rear) - Install" for further details.

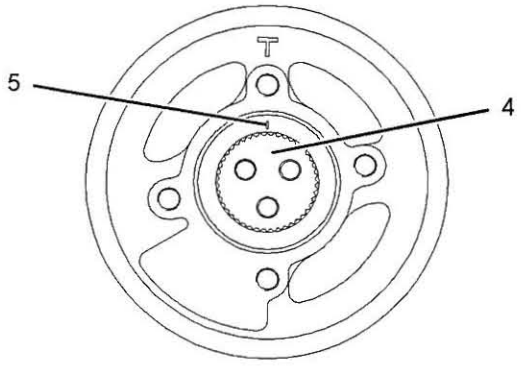

Illustration 144 g01127411

2. Align the mark on the pulley (5) with the mark on the front face of the crankshaft (4) and then install the pulley on the crankshaft.

3. Lubricate the threads and the shoulder of the setscrews (1) with clean engine oil. Position the thrust block (2) and install the setscrews (1). Tighten the setscrews evenly to a final torque of 115 N·m (85 lb ft).

4. Tighten each of the setscrews (1) again to the same torque in order to ensure that the setscrews are still at the required torque.

Remove the Non-standard Pulley when the Crankshaft is Replaced

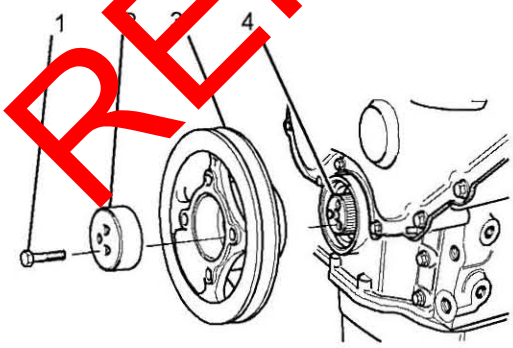

Illustration 145 g01127338

1. Remove the setscrews (1) and then remove the thrust block (2).

2. Remove the pulley (3) from the crankshaft (4).

Install the Non-standard Pulley when the Crankshaft is Replaced

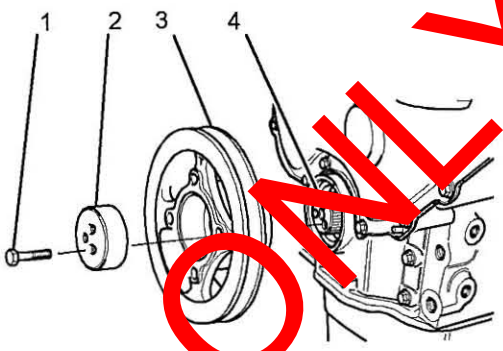

Illustration 146 g01127338

1. Clean the pulley (3) and clean the thrust block (2). Inspect the pulley (3) and the thrust block (2) for wear and for damage. If necessary, replace any damaged component. Inspect the area on the pulley that is normally in contact with the crankshaft front seal. If there is excessive wear then a wear sleeve can be installed. Refer to the Disassembly and Assembly Manual, "Crankshaft Wear Sleeve (Front) - Remove and Crankshaft Wear Sleeve (Rear) - Install" for further details.

2. Put the No. 1 piston at the top center position. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Piston".

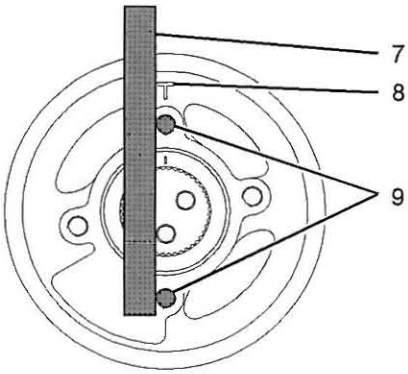

Illustration 147 g01127795

3. Align the front pulley with the "T" mark (8) at the top. Install temporary guide pins (9) in the top and bottom threaded holes in the pulley. Refer to illustration 147.

4. Align the pulley with the "T" mark (8) at the top and in line with the center line of the engine and then install the pulley on the crankshaft. Use a suitable straight edge (7) against the guide pins (9) to aid alignment of the pulley.

Note: The pulley can be rotated by a maximum of 4 degrees in a clockwise direction or a counterclockwise direction in order to align the splines in the pulley with the splines on the crankshaft. This is within acceptable limits.

5. Remove the straight edge (7) and the two guide pins (9).

6. Lubricate the threads and the shoulder of the setscrews (1) with clean engine oil. Position the thrust block (2) and install the setscrews (1). Tighten the setscrews evenly to a final torque of 115 N·m (85 lb ft).

7. Tighten each of the setscrews (1) again to the same torque in order to ensure that the setscrews are still at the required torque.

End By:

a. Install the V-Belts. Refer to this Disassembly and Assembly, "V-Belts - Remove and Install".

i0196[illegible]39

Crankshaft Front Seal - Remove

Removal Procedure

Table 13

Required Tool		
Part Number	**Part Description**	**Qty**
2761023	Three legged puller	1

Start By:

a. Remove the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

b. Thoroughly clean the area around the housing for the crankshaft front seal.

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: Do not remove the crankshaft front seal at this time if the housing (front) will also be removed. It is easier to remove the crankshaft front seal when the housing (front) has been removed from the engine. Refer to this Disassembly and Assembly Manual, "Housing (Front) - Remove".

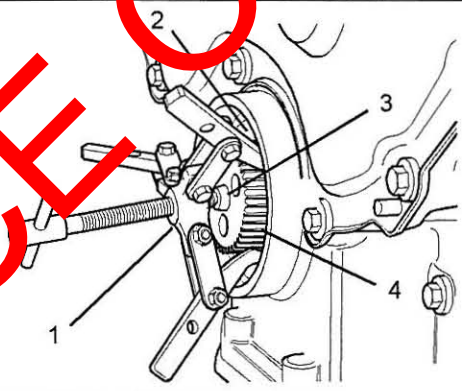

Illustration 148 g01020672

1. Install the legs of the puller (1) under the crankshaft front seal (2) and lock the legs into position.

2. Install a suitable adapter (3) between the crankshaft (4) and the puller (1).

NOTICE
Ensure that the main lip is used in order to remove the crankshaft front seal. Do not damage the edge of the housing for the crankshaft front seal.

3. Use the puller (1) in order to remove the crankshaft front seal (2). Discard the crankshaft front seal (2).

i01964540

Crankshaft Front Seal - Install

Installation Procedure

Table 14

Required Tools		
Part Number	Part Description	Qty
21825577	Crankshaft Front Seal Replacer	1
21825580	Fastener Plate	1
21825578	Pressure Plate	1
27610217	Adapter	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: This procedure assumes that the housing (front) is still on the engine. Do not follow this procedure if the housing (front) has been removed from the engine. Refer to this Disassembly and Assembly Manual, "Housing (Front) - Install" if the housing (front) has been removed from the engine.

1. Clean the oil seal housing (8) and inspect the oil seal housing for damage. If necessary, replace the housing (front). Refer to this Disassembly and Assembly Manual, "Housing (Front) - Remove and Housing (Front) - Install".

2. Check the face on the pulley that contacts the crankshaft front seal for wear. If necessary, repair the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Wear Sleeve (Front) - Remove and Crankshaft Wear Sleeve (Front) - Install" for further details.

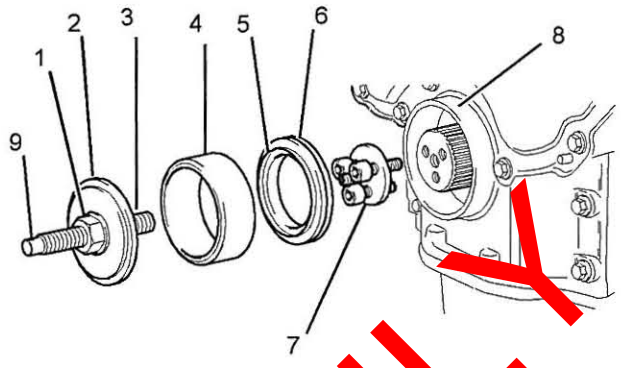

Illustration 149 g01020716

Note: A sleeve (5) is attached to the new crankshaft front seal (6). Do not remove the sleeve (5) at this time. Discard the new crankshaft front seal (6) if the sleeve (5) is not installed on the new crankshaft front seal.

3. Install the 21825580 Fastener Plate (7) to the front of the crankshaft.

4. Install the nut (1) and 21825578 Pressure Plate (2) onto the threaded bar (3).

Do not lubricate the crankshaft front seal (6). Do not lubricate the oil seal housing (8).

5. Align the assembly of the sleeve (5) and the crankshaft front seal (6) to the front of the oil seal housing (8).

6. Install the 27610217 Adapter (4) onto the sleeve (5).

7. Install the pressure plate (2) onto the adapter (4) and tighten the threaded bar (3) onto the fastener plate (7). Check the alignment of the assembly and the crankshaft front seal (6) to the oil seal housing (8).

8. Insert a suitable rod through the hole (9) in the threaded bar (3) in order to prevent the threaded rod from turning as the nut (1) is tightened. Tighten the nut (1) in order to push the crankshaft front seal (6) into the oil seal housing (8). Continue to tighten the nut (1) until contact is made with the bottom face of the oil seal housing (8).

9. Remove items (1), (2), (3), and (4).

10. Turn the sleeve (5) counterclockwise and pull the sleeve at the same time in order to remove the sleeve from the oil seal housing (8). Remove the adapter (7).

11. Immediately install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

i01964526

Crankshaft Wear Sleeve (Front) - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

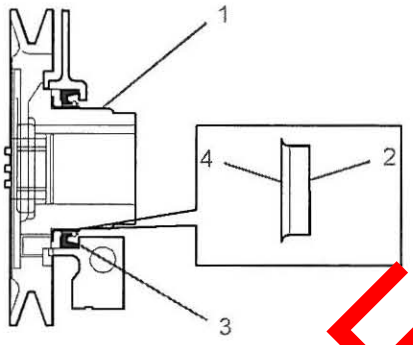

Illustration 150

1. Install a new crankshaft front seal (3). Refer to this Disassembly and Assembly Manual, "Crankshaft Front Seal - Install".

2. Thoroughly clean the crankshaft pulley (1).

3. Install the crankshaft wear sleeve (front) (2). Refer to the installation information in the packaging for the crankshaft wear sleeve (front) (2).

Note: It is not necessary to remove the flange (4) from the crankshaft wear sleeve (front) (2) after the crankshaft wear sleeve (front) has been installed onto the crankshaft pulley (1).

End By:

a. Install the crankshaft pulley. Refer to this Disassembly and Assembly Manual, "Crankshaft Pulley - Remove and Install".

i02254888

Front Cover - Remove and Install

Removal Procedure

Start By:

a. Remove the water pump. Refer to this Disassembly and Assembly Manual, "Water Pump - Remove and Install".

Note: In order to remove the front cover, it is not necessary to remove the cooling fan, the fan drive, the crankshaft pulley, or the alternator. Removal of the fan and fan drive will assist the access to the front cover. For illustration purposes, these components have been removed.

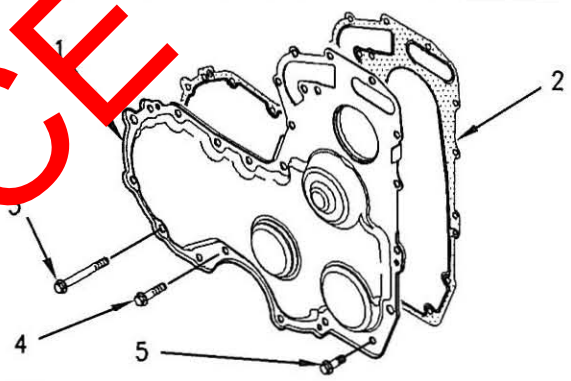

Illustration 151 g00955548

1. Remove the setscrews (3), the setscrews (4), and the setscrew (5) from the front cover (1).

2. Remove the front cover (1) from the front housing.

3. Remove the joint (2) from the front cover (1). Discard the joint (2).

Installation Procedure

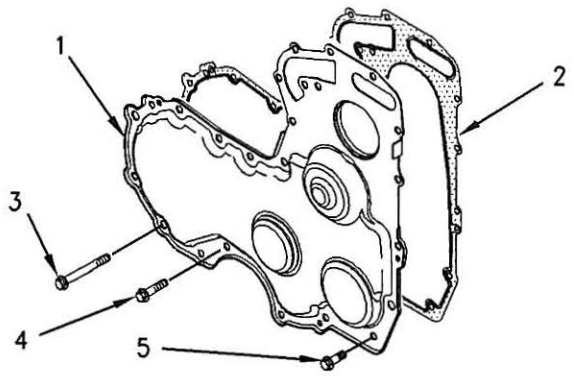

Illustration 152 g00955548

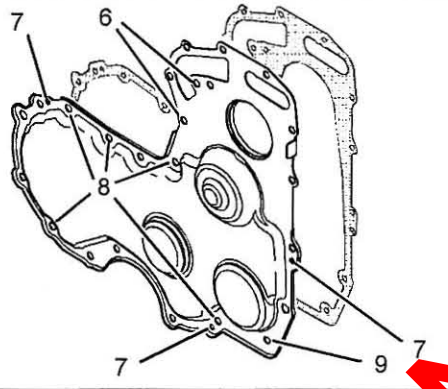

Illustration 153

1. Thoroughly clean all the surfaces of the front cover (1) and clean the joint face of the housing (front).

2. Install two guide studs into the appropriate holes (6) within the housing (front).

3. Position the joint (2) onto the front cover (1).

Note: The joint is located by the three locating dowels (7) on the front cover.

4. Position the front cover (1) and the joint (2) on the front housing. Install setscrews (3) into holes (8). Install setscrew (5) into hole (9). Remove the two guide studs from the holes (6). Install the remainder of the setscrews (4). Tighten all of the setscrews finger tight.

5. Loosely install the water pump. Refer to this Disassembly and Assembly Manual, "Water Pump - Remove and Install".

6. Tighten all of the setscrews (3, 4, and 5) for the front cover (1) and tighten all of the setscrews for the water pump to a torque of 22 N·m (16 lb ft).

End By:

a. If necessary, install the fan drive. Refer to this Disassembly and Assembly, "Fan Drive - Remove and Install".

b. If necessary, install the fan. Refer to this Disassembly and Assembly Manual, "Fan - Remove and Install".

i03217477

Gear Group (Front) - Remove

Removal Procedure

Table 15

Required Tools		
Part Number	**Part Description**	**Qty**
27[illegible]0211	Crankshaft timing pin	1
2761[illegible]12	Camshaft timing pin	1

Start By:

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

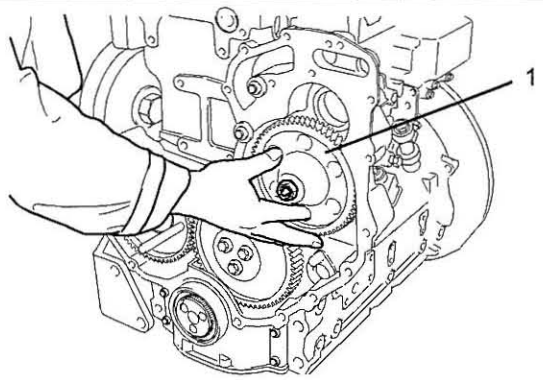

Illustration 154 g01021972
Typical example (Bosch drive gear)

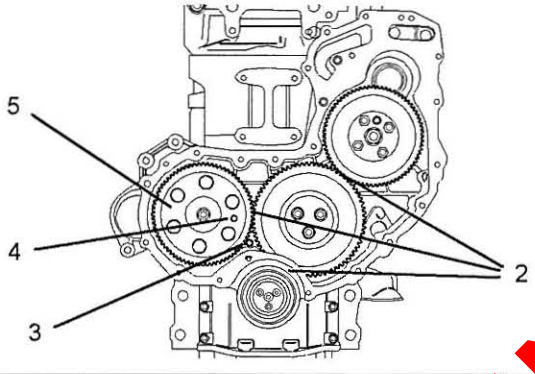

Illustration 155 g01021971
Typical example (Delphi fuel pump drive gear)

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

Note: If necessary, remove the glow plugs in order to allow the crankshaft to rotate more freely. Refer to this Disassembly and Assembly Manual, "Glow Plugs - Remove and Install".

1. Rotate the crankshaft to top dead center. Refer to the Testing and Adjusting Manual, "Finding Top Center for No. 1 Piston". Apply hand pressure to the fuel injection pump gear (1) in a counterclockwise direction in order to remove the backlash (2) in the gears. Mark the orientation of each of the gears for installation purposes.

Note: Timing pins are used in order to time the engine at top dead center. The timing pins are a slip fit. Do not use excessive force to install the timing pins. Do not use the timing pins to lock the engine during repairs.

2. Insert the 27610211 Crankshaft timing pin (3) through the housing (front) and into the web of the crankshaft. Insert the 27610212 Camshaft timing pin (4) through the camshaft gear (5) and into the housing (front).

3. Remove the rocker shaft. Refer to this Disassembly and Assembly Manual, "Rocker Shaft and Pushrod - Remove".

Note: The fuel injection pump must be locked before proceeding further.

Note: The three cylinder engine can be equipped with either the Delphi DP210 or the Delphi DPG fuel injection pump.

Note: The four cylinder engine can be equipped with the Delphi DP210, the Delphi DPA or the Bosch EPVE fuel injection pump. The various types of fuel injection pump have a different procedure for locking the fuel injection pump shaft.

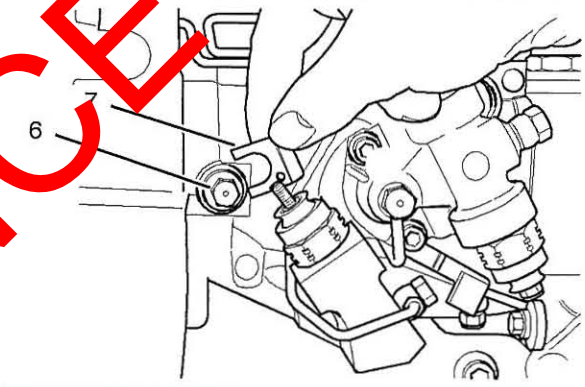

Illustration 156 g01022971
Four cylinder engine only

4. In order to lock the Bosch EPVE fuel injection pump, loosen the locking screw (6) and remove the washer (7). Tighten the locking screw (6) to a torque of 31 N·m (23 lb ft).

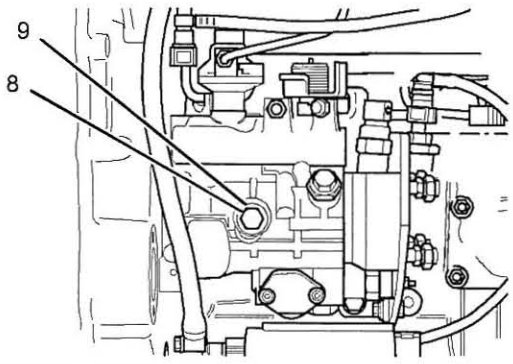

Illustration 157 g01022972
Three cylinder and four cylinder engines

5. In order to lock the Delphi DP210 fuel injection pump, loosen the locking screw (8) and move the washer (9). Ensure that the washer (9) can now turn about the locking screw (8) and tighten the locking screw to a torque of 17 N·m (12 lb ft).

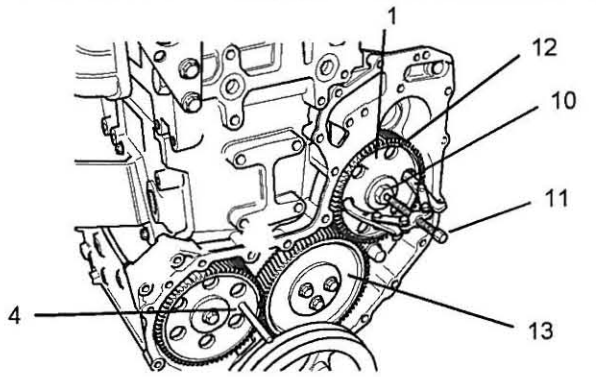

Illustration 158 g01022973

6. Release the nut (10). Install a suitable puller with two legs (11) through two holes (12) in the fuel injection pump gear (1). Tighten the puller (11) in order to release the gear (1) from the fuel injection pump. Remove the nut (10), the gear (1), and the puller (11).

7. Remove the camshaft gear (5). Refer to this Disassembly and Assembly Manual, "Camsh[illegible] Gear - Remove and Install".

8. Remove the idler gear (13). Refer to this Disassembly and Assembly Manual, "Idler Gear - Remove and Install".

9. If necessary, remove the crankshaft gear. Refer to this Disassembly and Assembly Manual, "Crankshaft Gear - Remove and Install".

i02217478

Gear Group (Front) - Install

Installation Procedure

Table 1

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

1. If necessary, install the crankshaft gear. Refer to this Disassembly and Assembly Manual, "Crankshaft Gear - Remove and Install".

2. Thoroughly clean the [illegible]nt).

3. Thoroughly clean all of the components and inspect all of the components of the front gear group. If necessary, replace any worn components and/or any damaged components of the front gear group.

4. Ensure that no. 1 piston is still at top dead center. Refer to the Testing and Adjusting Manual, "Finding Top Center for No. 1 Piston".

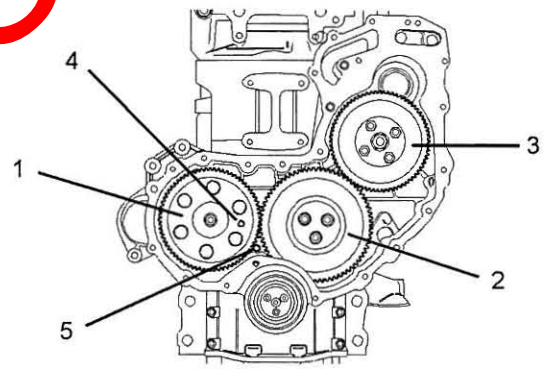

Illustration 159 g01023249
Typical example (Delphi fuel injection pump drive gear)

5. Install the camshaft gear (1). Refer to this Disassembly and Assembly Manual, "Camshaft Gear - Remove and Install".

6. Install the idler gear (2). Refer to this Disassembly and Assembly Manual, "Idler Gear - Remove and Install".

7. Ensure that the mesh of the idler gear (2) is correct with the camshaft gear (1).

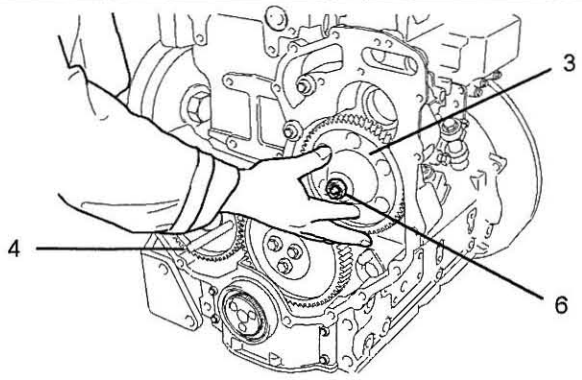

Illustration 160 g01023250

Typical example (Bosch fuel injection pump drive gear)

8. Install the fuel injection pump gear (3) onto the fuel injection pump shaft. Ensure that the mesh of the fuel injection pump gear (3) is correct with the idler gear (2). Install the washer and the nut (6) finger tight.

9. Apply hand pressure to the fuel injection pump gear (3) in a counterclockwise direction in order to remove the backlash in the gears (1), (2), and (3). Tighten the nut (6) to a torque of 24 N·m (18 lb ft).

10. Ensure that all of the timing marks on the gears (1), (2), and (3) are in alignment.

Note: The three cylinder engine can be equipped with either the Delphi DP210 or the Delphi DPG fuel injection pump.

Note: The four cylinder engine can be equipped with the Delphi DP210, the Delphi DPA, or the Bosch EPVE fuel injection pump. The various types of fuel injection pump have a different procedure for locking the fuel injection pump shaft.

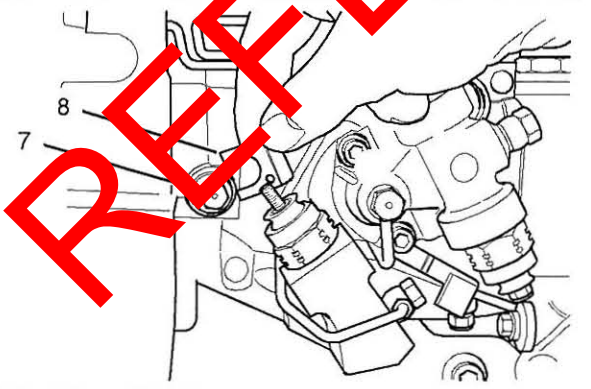

Illustration 161 g01023252

Four cylinder engine only

11. Release the locked fuel injection pump shaft. In order to unlock the Bosch EPVE fuel injection pump shaft, loosen the locking screw (7) and install the washer (8). Tighten the locking screw (7) onto the washer (8) to a torque of 12 N·m (9 lb ft).

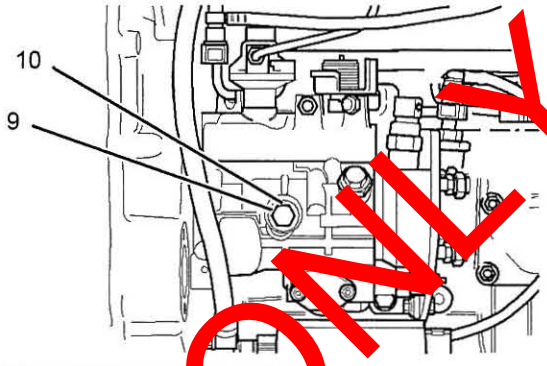

Illustration 162 g01023253

Three cylinder and four cylinder engines

12. In order to unlock the Delphi DP210 fuel injection pump shaft, loosen the locking screw (9) and move the washer (10). Tighten the locking screw (9) onto the washer (10) to a torque of 12 N·m (9 lb ft).

13. Tighten the nut (6) to an increased torque of 90 N·m (66 lb ft). Refer to illustration 160.

14. Remove the timing pins (4) and (5). Refer to illustration 159.

15. Check the backlash value for the fuel injection pump gear (3). Refer to the Specifications Manual, "Gear Group (Front)" for further information.

16. Check the end play of the idler gear (2). Refer to this Disassembly and Assembly Manual, "Idler Gear - Remove and Install" and refer to the Specifications Manual, "Gear Group (Front)" for further information.

17. Check the backlash value for the idler gear (2). Refer to this Disassembly and Assembly Manual, "Idler Gear - Remove and Install" and refer to the Specifications Manual, "Gear Group (Front)" for further information.

18. Check the end play of the camshaft gear (1). Refer to this Disassembly and Assembly Manual, "Camshaft Gear - Remove and Install".

19. Check the backlash value for the camshaft gear (1). Refer to this Disassembly and Assembly Manual, "Camshaft Gear - Remove and Install" and refer to the Specifications Manual, "Gear Group (Front)" for further information.

20. Lightly lubricate each gear with clean engine lubricating oil.

End By:

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

b. Install the glow plugs. Refer to this Disassembly and Assembly Manual, "Glow Plugs - Remove and Install".

c. Install the rocker shaft. Refer to this Disassembly and Assembly Manual, "Rockershaft and Pushrod - Install".

i02217480

Idler Gear - Remove and Install

Removal Procedure

Table 17

Required Tools		
Part Number	**Part Name**	**Qty**
27610212	Camshaft (Timing Pin)	1
27610211	Crankshaft (Timing Pin)	1

Start By:

a. Remove the front cover if the front cover has not previously been removed. Refer to this Disassembly and Assembly Manual, "Front Cover - 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: There are two types of idler gear that may be installed on these engines. The standard idler gear is supported on the hub by two bushes. The heavy-duty idler gear is supported on the hub by two roller bearings.

Note: If necessary, remove the glow plugs in order to allow the crankshaft to rotate more freely. Refer to this Disassembly and Assembly Manual, "Glow Plugs - Remove and Install".

Note: The three cylinder engine can be equipped with either the Delphi DP210 or the Delphi DPG fuel injection pump.

Note: The four cylinder engine can be equipped with the Delphi DP210, the Delphi DPA or the Bosch EPVE fuel injection pump. The various types of fuel injection pump have a different procedure for locking the fuel injection pump shaft.

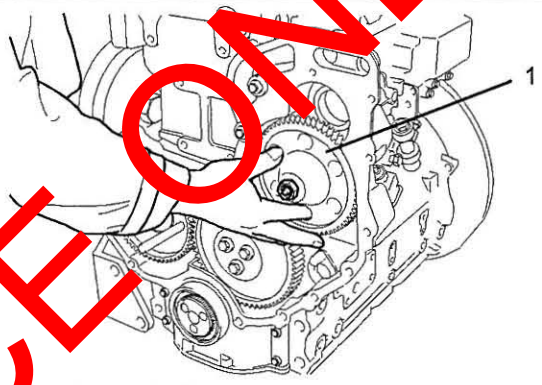

Illustration 163 g01021972
Typical example (Bosch fuel injection pump drive gear)

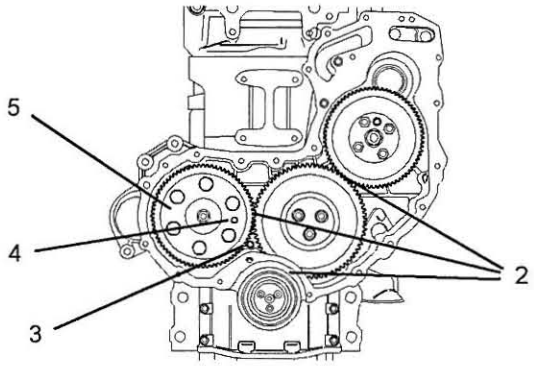

Illustration 164 g01021973
Typical example (Delphi fuel injection pump drive gear)

1. Ensure that the No. 1 cylinder is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston". Apply hand pressure to the fuel injection pump gear (1) in a counterclockwise direction in order to remove backlash (2) in the gears. Mark the orientation of each of the gears for installation purposes.

Note: Timing pins are used in order to time the engine at top dead center. The timing pins are a slip fit. Do not use excessive force to install the timing pins. Do not use the timing pins to lock the engine during repairs.

2. Insert the 27610211 Crankshaft timing pin (3) through the housing (front) and into the web of the crankshaft if the timing pin has not previously been installed. Insert the 27610212 Camshaft timing pin (4) through the camshaft gear (5) and into the housing (front) if the timing pin was not previously installed.

3. Remove the rocker shaft if the rocker shaft was not previously removed. Refer to this Disassembly and Assembly Manual, "Rocker Shaft and Pushrod - Remove".

4. Remove the fuel injection pump gear (1) if the gear has not previously been removed. Refer to this Disassembly and Assembly Manual, "Gear Group (Front) - Remove".

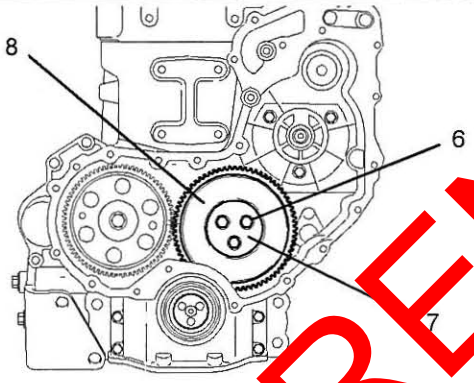

Illustration 165 g01038900

5. Remove the three setscrews (6) from the idler gear (8). Remove the plate (7) from the idler gear (8).

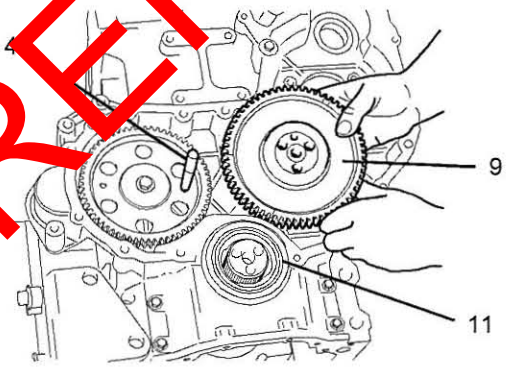

Illustration 166 g01023843

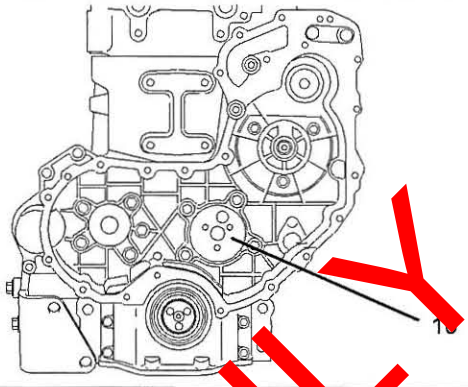

Illustration 167 g01038902

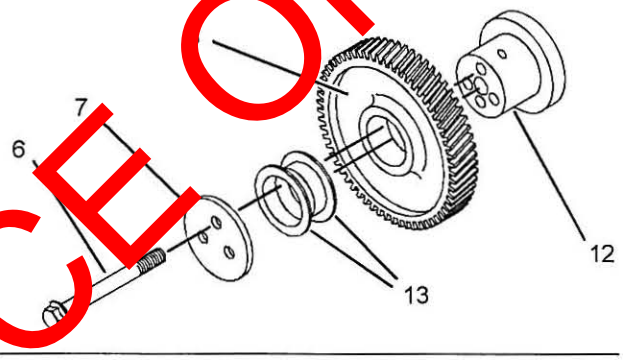

Illustration 168 g01023845
Standard idler gear assembly

6. Remove the assembly (9) of the idler gear (8) and the hub from the recess (10) in the cylinder block. The assembly (9) must be lifted over the housing for the crankshaft front seal (11) as the assembly is moved forward.

7. Disassemble the assembly (9) of the idler gear (8) and the hub. In order to disassemble the standard assembly (9), slide the hub (12) out of the idler gear (8). Inspect the bushes (13) in the idler gear (8) for wear and/or damage. If necessary, remove the bushes (13) from each side of the idler gear (8).

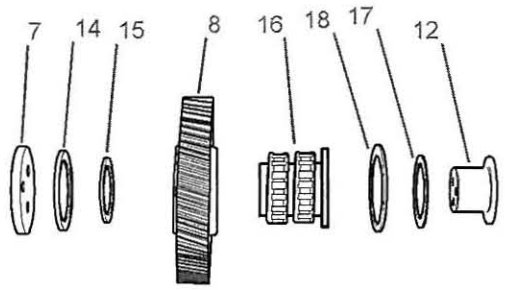

Illustration 169 g01023942

Heavy-duty idler gear assembly

8. In order to disassemble the heavy-duty idler gear, press the hub (12) out of the bearing assembly (16). Remove the circlip (14) and the thrust washer (15) from the idler gear (8). If the bearing assembly (16) is worn and/or damaged, slide the bearing assembly out of the idler gear (8). Discard the bearing assembly (16). Remove the circlip (17) and the thrust washer (18).

Installation Procedure

Table 18

Required Tools		
27610212	Timing Pin (Camshaft)	1
27610211	Timing Pin (Crankshaft)	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean all of the components and inspect all of the components that were removed in the previous procedure. If necessary, replace any worn component and/or any damaged component.

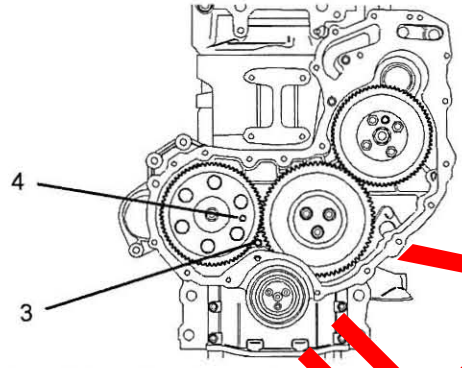

Illustration 170 g01024162

Typical example (Delphi fuel injection pump drive gear)

Note: Timing pins are used in order to time the engine at top dead center. The timing pins are a slip fit. Do not use excessive force to install the timing pins. Do not use the timing pins to lock the engine during repairs.

2. Ensure that the No. 1 cylinder is still at top dead center on the compression stroke. If necessary, refer to the Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston". Ensure that the timing pin (3) for the crankshaft is installed and that the timing pin (4) for the camshaft is installed.

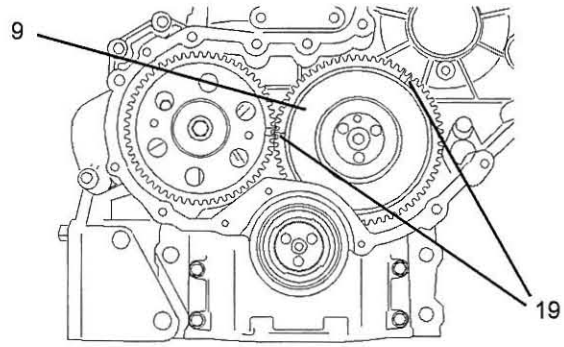

Illustration 171 g01024165

Note: Ensure that the marks (19) on the idler gear (8) face toward the front of the engine when the assembly (9) of the idler gear and the hub is being assembled.

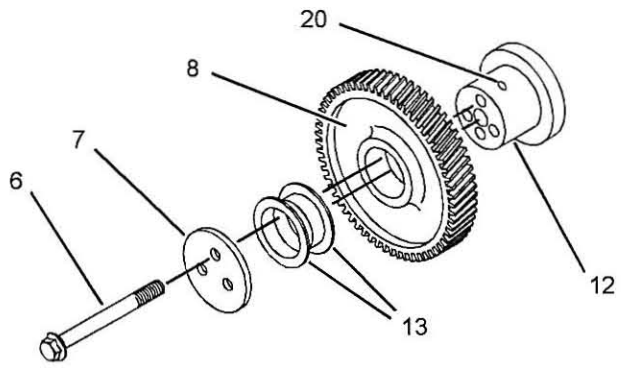

Illustration 172 g01024432

Standard idler gear assembly

3. Assemble the assembly (9) of the idler gear and the hub. In order to assemble the standard assembly, press new bushes (13) into the idler gear (8) if the bushes were previously removed. Lubricate the hub (12) with clean engine lubricating oil. Slide the hub (12) into the idler gear (8). Ensure that the oil hole (20) is to the top of the hub (12) and ensure that the marks (19) are to the front of the idler gear (8).

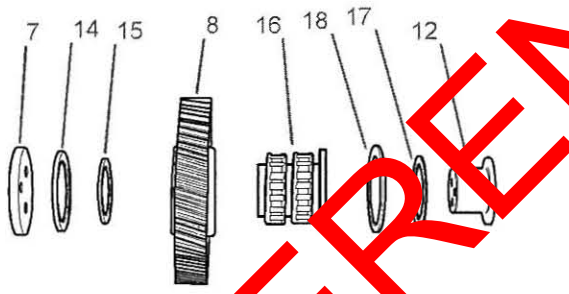

Illustration 173 g01023942

Heavy-duty idler gear assembly

Note: The new bearing assembly (16) is supplied with a protective sleeve. Do not remove this protective sleeve. The protective sleeve prevents the rollers from falling out of the roller bearings.

4. In order to assemble the heavy-duty idler gear, install the circlip (17) into the back face of the idler gear (8). Place the back face of the idler gear (8) onto a clean, flat surface. Insert the thrust washer (18) through the idler gear (8) and onto the circlip (17). Ensure that the flange face of the bearing assembly (16) is toward the bottom and that the protective sleeve is still in place. Insert the new bearing assembly (16) into the idler gear (8). Push the new bearing assembly (16) into the idler gear (8) until the bearing assembly comes into contact with the thrust washer (18). As the bearing assembly (16) is pushed into the idler gear (8) the protective sleeve will remain on the top face of the idler gear. Discard the protective sleeve. Install the thrust washer (15) and install the circlip (14). Lightly lubricate the hub (12) with clean engine lubricating oil. Press the hub (12) into the idler gear (8).

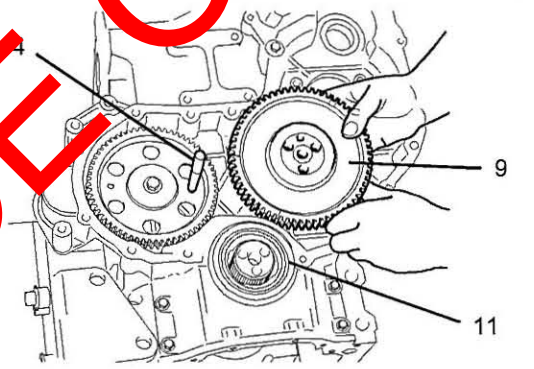

Illustration 174 g01023843

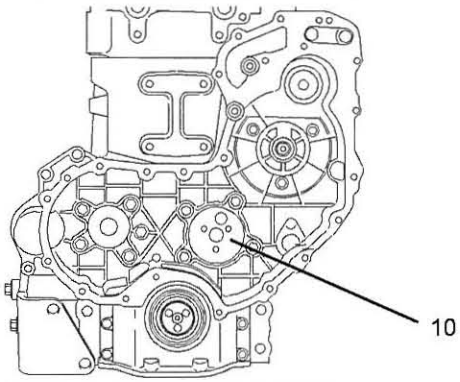

Illustration 175 g01038902

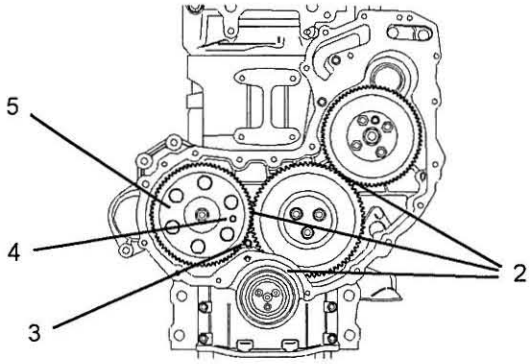

Illustration 176 g01021973

5. Lift the assembly (9) of the idler gear and the hub over the housing for the crankshaft front seal (11) and insert the hub into the recess (10) in the cylinder block.

Note: Ensure that the oil hole (20) is to the top of the hub (12).

Note: Ensure that the marks (19) on the idler gear assembly (9) align with the marks on the camshaft gear and with the crankshaft gear. Refer to the illustration 171.

6. Align the holes in the plate (7) with the holes in the hub (12). Insert the setscrews (6) through the plate (7) and into the hub (12).

7. Evenly tighten the setscrews (6) to a torque of 44 N·m (32 lb ft).

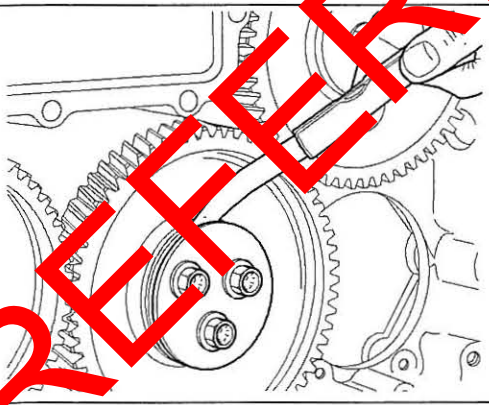

Illustration 177 g00944081

8. Check the end play for the idler gear. Refer to the illustration 177 and refer to the Specifications Manual, "Gear Group (Front)" for more information.

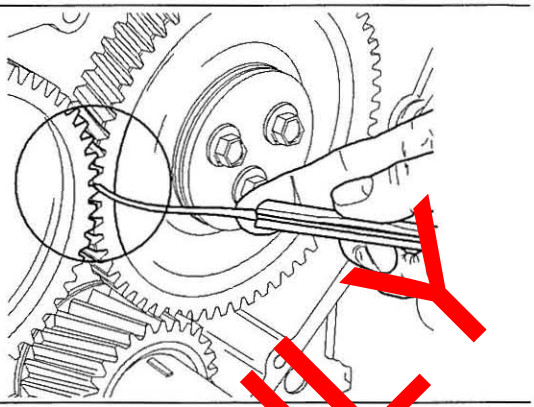

Illustration 178 g00944084

9. Check the backlash between the idler gear and the camshaft gear. Refer to the illustration 178 and refer to the Specifications Manual, "Gear Group (Front)" for more information.

10. Check the backlash between the idler gear and the crankshaft gear. Refer to the Specifications Manual, "Gear Group (Front)" for more information.

Note: The three cylinder engine can be equipped with either the Delphi DP210 or the Delphi DPG fuel injection pump.

Note: The four cylinder engine can be equipped with the Delphi DP210, the Delphi DPA or the Bosch EPVE fuel injection pump. The various types of fuel injection pump have a different procedure for locking the fuel injection pump shaft.

11. Install the fuel injection pump gear. Refer to this Disassembly and Assembly Manual, "Gear Group (Front) - Install".

12. Remove the timing pin for the crankshaft (3) and remove the timing pin for the camshaft (4).

13. Lightly lubricate all of the gears with clean engine lubricating oil.

End By:

a. Install the rocker shaft. Refer to this Disassembly and Assembly Manual, "Rocker Shaft and Pushrod - Install".

b. Install the glow plugs if the glow plugs were previously removed. Refer to this Disassembly and Assembly Manual, "Glow Plugs - remove and Install".

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

i01964553

Housing (Front) - Remove

Removal Procedure

Start By:

a. Drain the coolant into a suitable container for storage or disposal.

b. Remove the fan drive. Refer to this Disassembly and Assembly Manual, "Fan Drive - Remove and Install".

c. If necessary, remove the alternator. Refer to this Disassembly and Assembly Manual, "Alternator - Remove".

d. Remove the fuel injection pump. Refer to the appropriate fuel injection pump within this Disassembly and Assembly Manual, "Fuel Injection Pump - Remove".

e. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

f. Remove the gear group (front). Refer to this Disassembly and Assembly Manual, "Gear Group (Front) - 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.

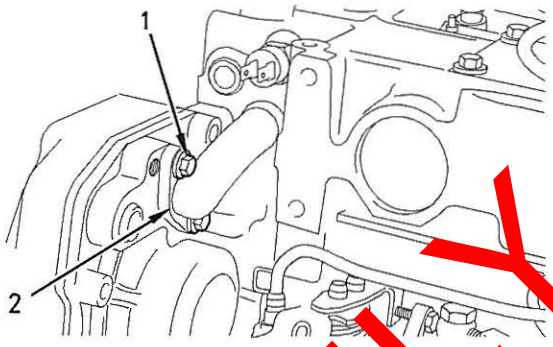

Illustration 179 g00995185

1. Remove the setscrews (1). Remove the bypass tube (2) from the cylinder head. Remove the O-rings from the bypass tube (2). Discard the O-rings.

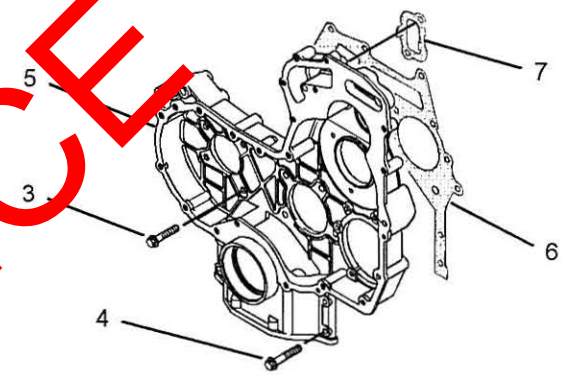

Illustration 180 g01024469

2. Remove the setscrews (3) and the setscrews (4) that fasten the front housing (5) to the cylinder block.

3. Remove the front housing (5). Remove the joint (6) from the cylinder block and the front housing (5).

4. Remove the joint (7) from the back side of the front housing (5).

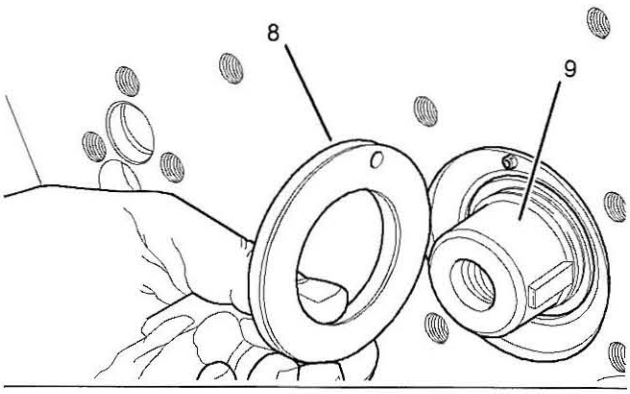

Illustration 181 g01024472

5. Remove the thrust washer (8) from the camshaft (9).

i01964552

Housing (Front) - Install

Installation Procedure

Table 19

Required Tools		
Part Number	**Part Name**	**Qty**
27610216	Alignment Tool	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

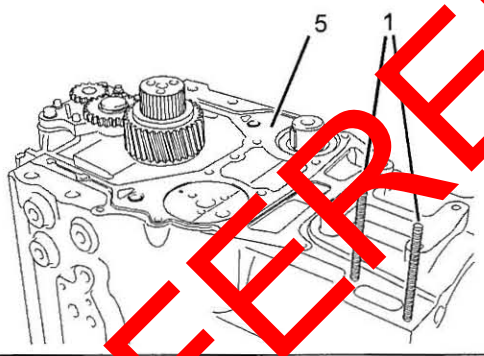

Illustration 182 g01024529
Typical example

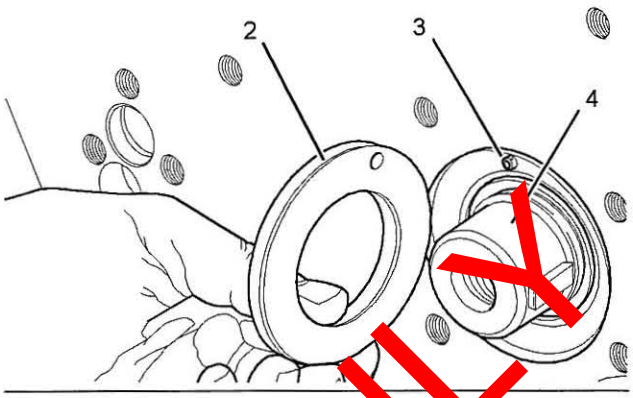

Illustration 183 g01024492

1. Thoroughly clean the mating surfaces on the cylinder block for the front housing. Install two temporary studs (1) into the cylinder block. Ensure that the thrust washer (2) is aligned with the hollow dowel (3). Install the thrust washer onto the camshaft (4). Install a new joint (5) onto the cylinder block.

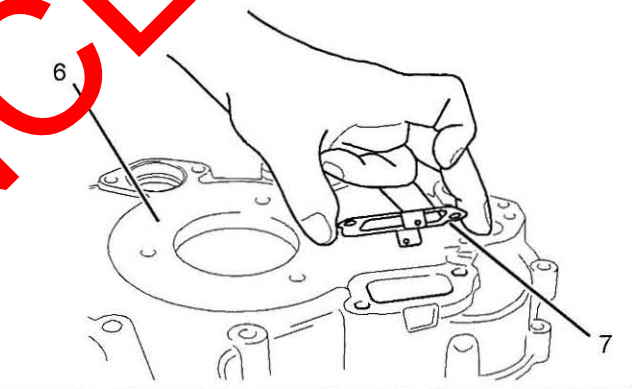

Illustration 184 g01024547

2. Thoroughly clean the front housing (6). Especially clean the mating surfaces of the front housing (6). Inspect the front housing (6) for wear and for damage. If necessary, replace the front housing (6).

Note: If it is necessary to replace the front housing (6), it may also be necessary to install blanking plugs which should be sealed with a suitable sealant into the front housing.

3. Install a new joint (7) to the front housing (6).

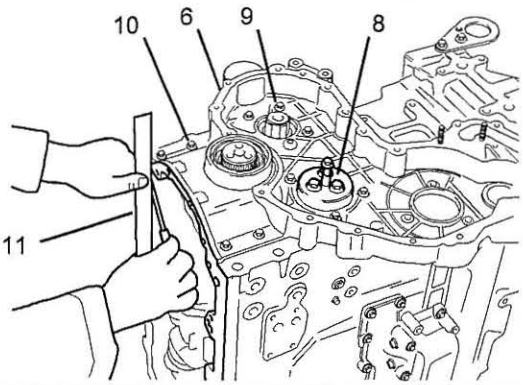

Illustration 185 g01024551
Typical example

4. Install the 27610216 Alignment Tool (8) into the recess within the cylinder block. Install the front housing (6) onto the cylinder block.

5. Install the setscrews (9). Tighten the setscrews (9) finger tight. Except for the two holes with the temporary studs (1), install the setscrews (10). Tighten the setscrews (10) finger tight. Remove the two temporary studs (1). Install the remainder of the setscrews (10). Tighten the remaining two setscrews (10) finger tight.

6. Align the front housing (6) to the lower machined face of the cylinder block (11). Use a suitable straight edge and a feeler gauge to check the tolerance for the alignment (11). Refer to the Specifications Manual, "Front Housing & Covers" for further information.

7. With the alignment within tolerance, tighten the setscrews (9) and the setscrews (10) to a torque of 22 N·m (16 lb ft). Remove the alignment tool (8).

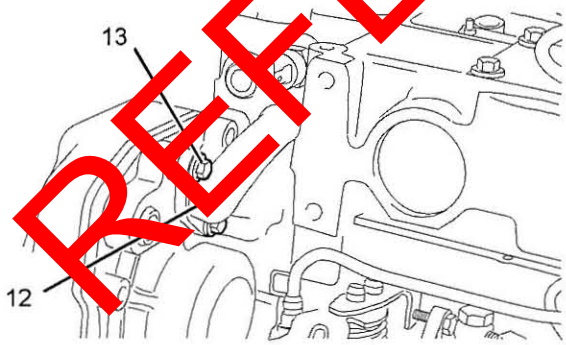

Illustration 186 g01024687

8. Install new O-rings onto the bypass tube (12). Apply POWERPART 21820221 Red Rubber Grease to the O-rings. Install the bypass tube (12) into the cylinder head. Install the setscrews (13).

End By:

a. Install the gear group (front). Refer to this Disassembly and Assembly Manual, "Gear Group (Front) - Install".

b. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

c. Install the fuel injection pump. Refer to the appropriate fuel injection pump within this Disassembly and Assembly Manual, "Fuel Injection Pump - Install".

d. Install the alternator if the alternator was removed previously. Refer to this Disassembly and Assembly Manual, "Alternator - Install".

e. Install the fan drive. Refer to this Disassembly and Assembly Manual, "Fan Drive - Remove and Install".

f. At the appropriate time, fill the cooling system.

i02641608

Accessory Drive - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

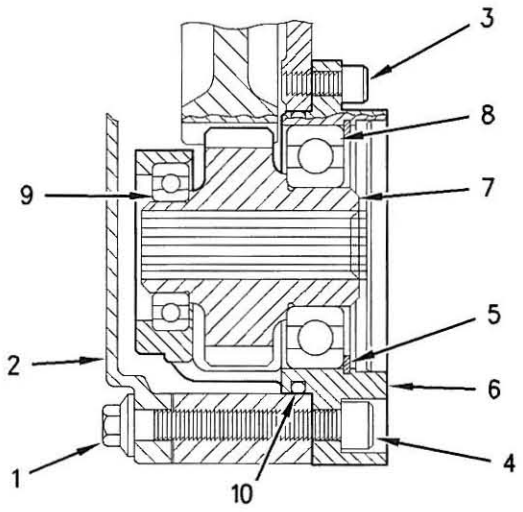

Illustration 187 g01004414

1. Remove the setscrews (1) and the front cover (2).
2. Remove the Allen head screws (3) and (4). Remove the accessory drive assembly from the rear face of the front housing (6).
3. Remove the circlip (5).
4. Place the flange of the front housing (6) onto a suitable support. Press the assembly of the gear (7) and the bearings (8 and 9) out of the front housing (6). Use a suitable puller in order to remove the bearings (8 and 9) from the gear (7).
5. Remove the O-ring (10) from the front housing (6) and discard the O-ring.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

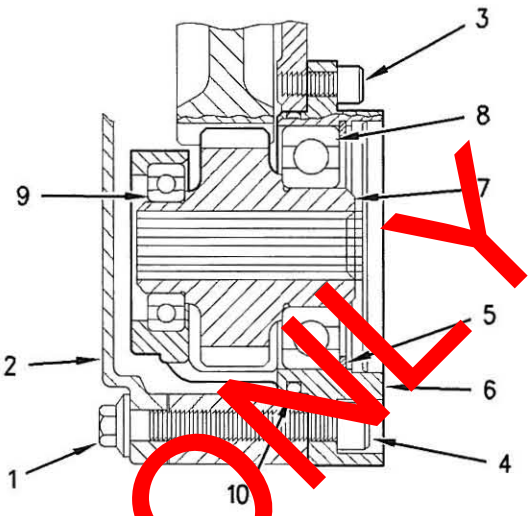

Illustration 188 g01004414

1. Inspect the condition of the teeth and the splines of the gear (7), the bearings (8 and 9), the circlip (5), and the groove for the circlip in the front housing (6) for wear and for damage. Replace any worn component or any damaged component.

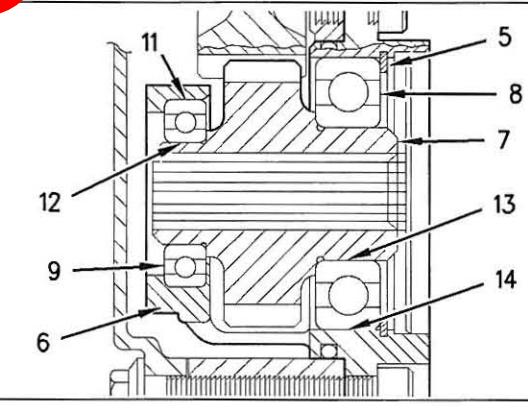

Illustration 189 g01004637

2. Apply a small continuous bead (11) of 21820603 POWERPART Retainer (oil tolerant) to the outer surface of the bearing (9). Place the front flange of the front housing (6) onto a suitable support. Press on the outer race of the bearing (9) until the bearing is against the front face of the recess for the bearing in the front housing (6). Remove any excess sealant.
3. Apply a small continuous bead (12) of 21820603 POWERPART Retainer (oil tolerant) to the inner surface of the bearing (9). Place the front face of the inner race of the bearing (9) onto a suitable support. Press the smaller shaft of the gear (7) into the bearing (9) until the shoulder of the gear is against the bearing. Remove any excess sealant.

4. Apply a small continuous bead (14) of 21820603 POWERPART Retainer (oil tolerant) to the outer surface of the bearing (8). Apply a small continuous bead (13) of 21820603 POWERPART Retainer (oil tolerant) to the inner surface of the bearing (8). Ensure that the front face of the inner race of the bearing (9) is still on a suitable support. Press the bearing (8) onto the larger shaft of the gear (7) until the bearing (9) is against the shoulder of the gear. Remove any excess sealant.

5. Install the circlip (5) into the groove in the front housing (6). Ensure that the circlip (5) is correctly positioned in the groove.

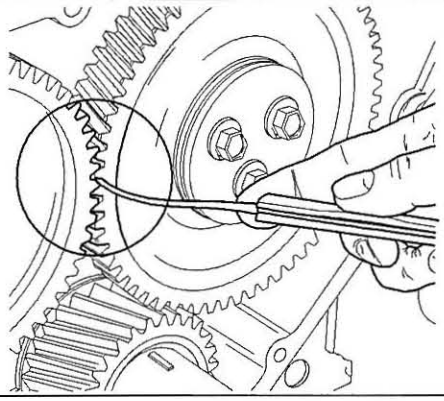

Illustration 190 g00946787
Typical Example

6. Refer to the illustration 190 and check the backlash between the idler gear and gear (7). The backlash should be within 0.11 mm (0.004 inch) to 0.17 mm (0.007 inch).

7. Lightly lubricate a new O-ring (10) with 21820221 POWERPART Red Rubber Grease and install the O-ring into the recess in the front housing (6). Lightly lubricate the bearing (8), the bearing (9), and the gear (7) with clean engine lubricating oil.

8. By using the Allen head screws (3 and 4), install the assembly of the accessory drive to the rear of the front housing (6). Torque the Allen head screws to a torque of 22 N·m (16 lb ft).

9. By using the screws (1), install the front cover (2). Refer to this Disassembly and Assembly Manual, "Front Cover - Remove and Install.".

i02217688

Crankcase Breather - Remove and Install

Removal Procedure for the Diaphragm Valve

Note: All naturally aspirated three cylinder and four cylinder engines in the 1100 Series except for models DJ and RR are equipped with a closed breather system. A closed breather system is optional for turbocharged three cylinder and four cylinder engines in the 1100 Series.

Note: 1103 engines, models DJ and DK that are equipped with an open crankcase breather do not have a diaphragm valve in the valve mechanism cover.

Note: 1103 engines, models DC, DD, DF, DG and all 1104 engines that are equipped with a closed breather system have a diaphragm valve in the valve mechanism cover.

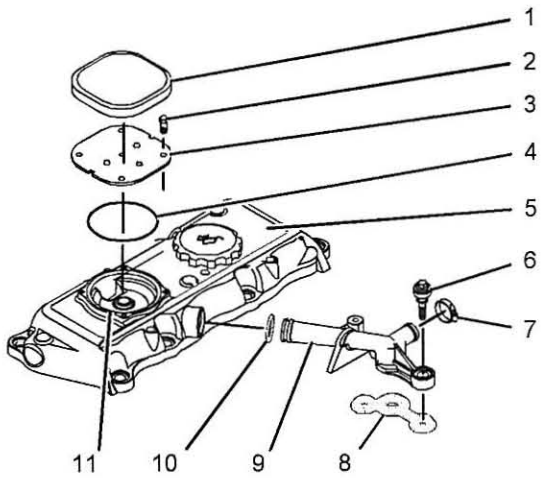

Illustration 191 g01122584
1103 engine, models DJ and DK

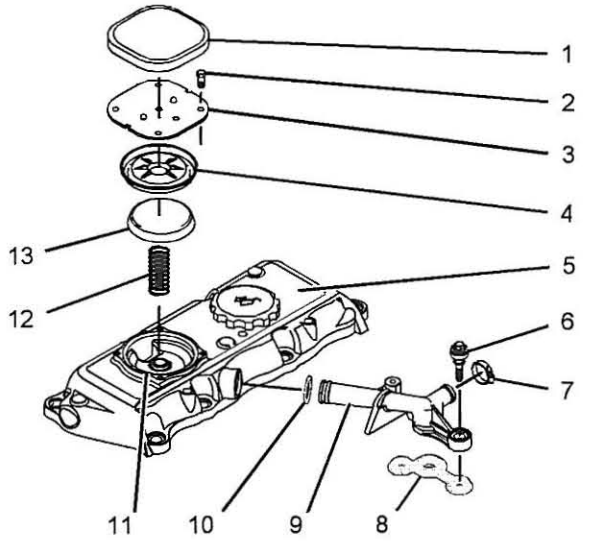

Illustration 192 g01122835

1103 engine, models DC, DD, DF and DG

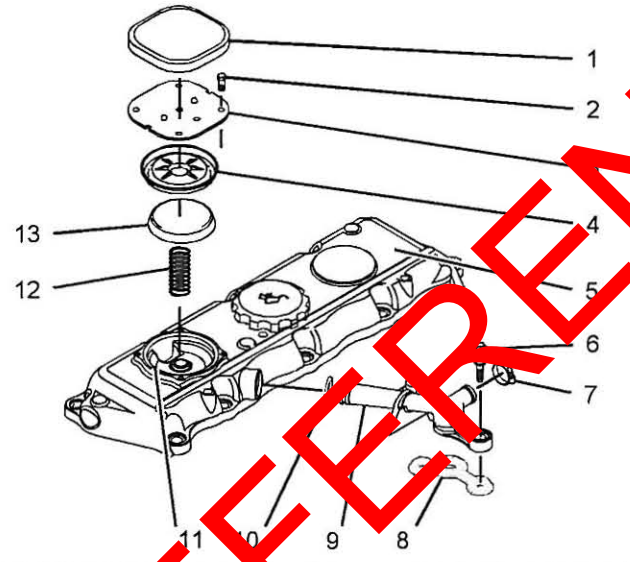

Illustration 19 g01122836

1104 engine

1. Refer to the appropriate illustration 191, 192 or 193. Loosen the hose clamp (7) and release the hose from the connector (9).

2. Remove the fasteners (6) and remove the connector (9) from the cylinder head and from the valve mechanism cover (5). Remove the O-ring (10) from the connector (9). Discard the O-ring (10). Remove the joint (8). Discard the joint (8).

3. Remove the plastic cover (1) from the valve mechanism cover (5).

⚠ 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.

4. Remove the screws (2). Remove the plate (3).

5. If equipped, remove the seal ring (4). Refer to illustration 191.

6. If equipped, remove the diaphragm (4) and the cap (13). Remove the spring (12). Refer to illustration 192 or 193.

7. If the recess (11) for the assembly of the diaphragm valve needs to be cleaned, remove the valve mechanism cover (5). Refer to this Disassembly and Assembly Manual, "Valve Mechanism Cover - Remove and Install". If necessary, thoroughly clean the valve mechanism cover (5) and especially clean the recess (11).

Installation Procedure for the Diaphragm Valve

Note: 1103 engines, models DJ and DK that are equipped with a closed breather system do not have a diaphragm valve in the valve mechanism cover.

Note: 1103 engines, models DC, DD, DF, DG and all 1104 engines that are equipped with a closed breather system have a diaphragm valve in the valve mechanism cover.

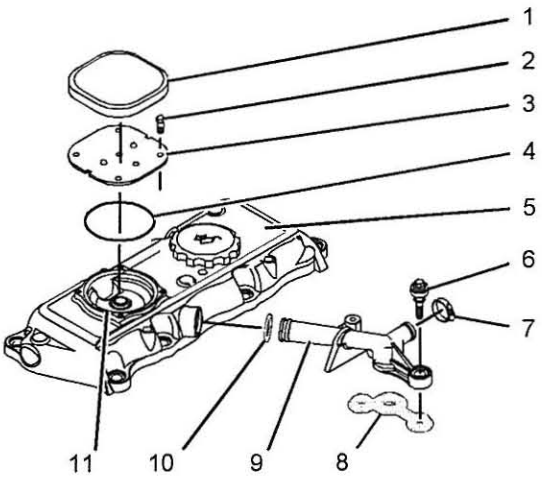

Illustration 194 g01122584
1103 engine, models DJ and DK

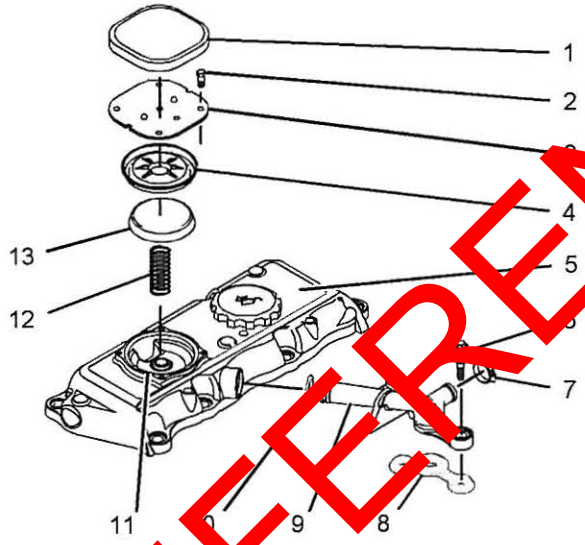

Illustration 19 g01122835
1103 engine, models DC, DD, DF and DG

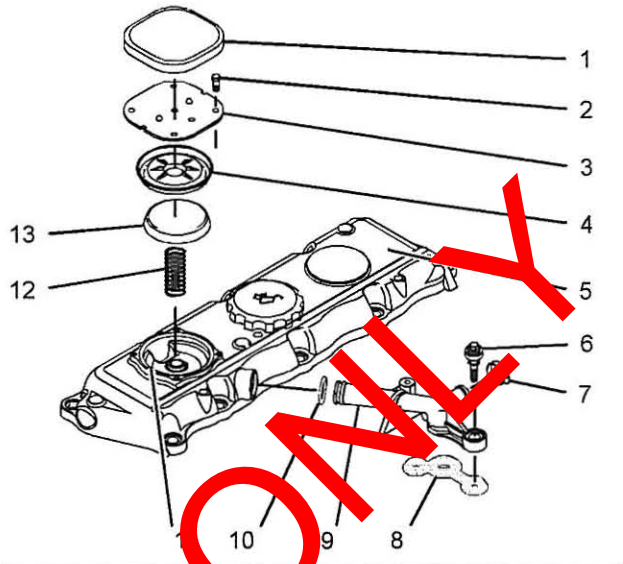

Illustration 196 g01122836
1104 engine

1. Refer to the appropriate illustration 194, 195 or 196. Thoroughly clean all of the previously removed components. Inspect all of the components for wear and for damage. Especially check the condition of the hose for the connector (9) and the diaphragm or the seal ring (4) for damage. Replace any component that is worn and/or damaged.

2. If the valve mechanism cover (5) was removed, install the valve mechanism cover. Refer to this Disassembly and Assembly Manual, "Valve Mechanism Cover - Remove and Install".

3. If equipped, install the seal ring (4) in the recess (11) in the valve mechanism cover (5).

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. If equipped, install the spring (12), the cap (13), and the diaphragm (4) into the recess (11) in the valve mechanism cover (5).

5. If equipped, ensure that the two domes on the plate (3) are uppermost and ensure that the offset hole is toward the connector (9) of the valve mechanism cover (5). Install the plate (3). Install the screws (2). Tighten the screws (2) to a torque of 1.3 N·m (11.5 lb in).

6. Push the plastic cover (1) onto the valve mechanism cover (5).

7. Install a new O-ring (10) onto the connector (9).

8. Install a new joint (8) to the connector (9). Install the connector (9) into the valve mechanism cover (5) and onto the cylinder head.

9. Install the fasteners (6). Tighten the fasteners (6) to a torque of 9 N·m (80 lb in).

10. Install the hose onto the connector (9). Ensure that the hose is clear of all hot surfaces, clear of all components that move, and clear of all components that vibrate when the engine is operating. Tighten the hose clamp (7) to a torque of 5 N·m (44 lb in).

i01947656

Valve Mechanism Cover - Remove and Install

Removal Procedure

Start By:

a. Remove the heat shields, if equipped.

b. Remove the cover for the fuel injector. Refer to this Disassembly and Assembly Manual, "Fuel Injector Cover - 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: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustration shows the four cylinder engine.

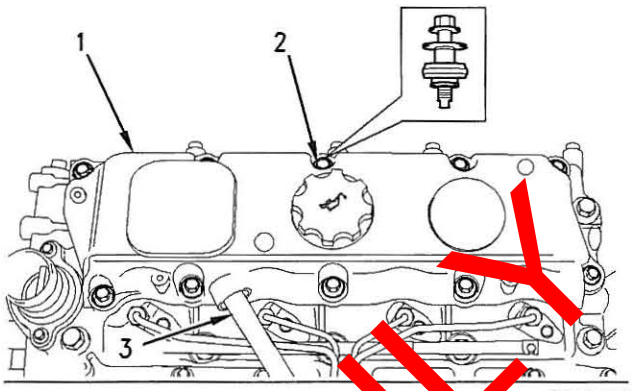

Illustration 197 g00951080
Typical example

1. Remove the breather tube (3) from the valve mechanism cover (1). Refer to this Disassembly and Assembly Manual, "Crankcase Breather - Remove and Install".

2. Remove the fasteners (2). Remove the valve mechanism cover (1). Remove the joint for the valve mechanism cover and discard the joint.

Installation Procedure

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. Only the sequence for tightening the fasteners for the valve mechanism cover is different. Refer to the appropriate illustration for further information.

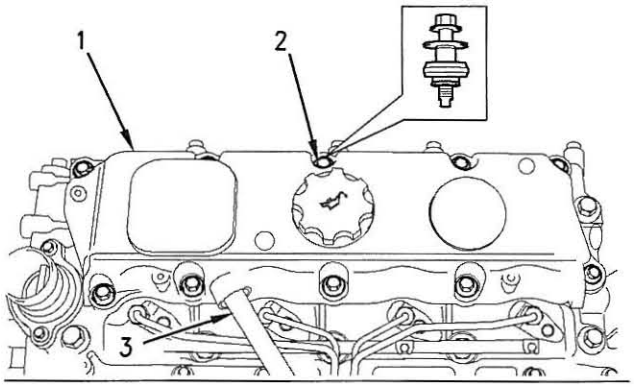

Illustration 198 g00951080
Typical example

1. Thoroughly clean the valve mechanism cover (1). Ensure that the groove for the joint for the valve mechanism cover (1) is clean and dry. Ensure that the mating face on the cylinder head is clean and dry.

2. If the valve mechanism cover (1) is equipped with an oil filler cap, check the condition of the O-ring for the oil filler cap. If necessary, replace the O-ring.

3. Install a new joint to the valve mechanism cover (1) and install the valve mechanism cover onto the cylinder head.

4. Check the condition of the fasteners (2). Replace the fasteners (2), if necessary. Install the fasteners (2).

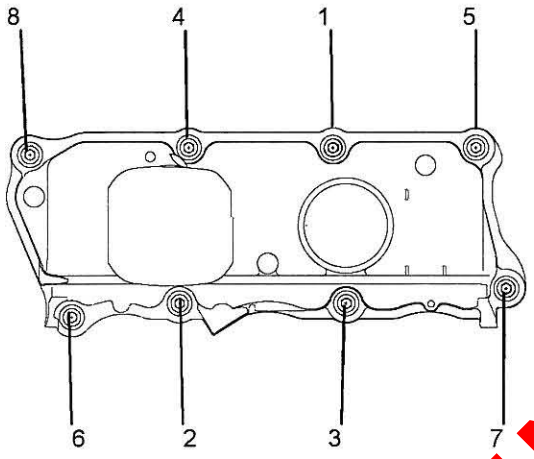

Illustration 199 g01018519

Sequence for tightening the fasteners for the three cylinder engine

5. If you are working on a four cylinder engine, go to Step 6. If you are working on a three cylinder engine, tighten the fasteners for the valve mechanism cover in the sequence that is shown in Illustration 199. Tighten the fasteners to a torque of 9 N·m (80 lb in). Go to Step 7

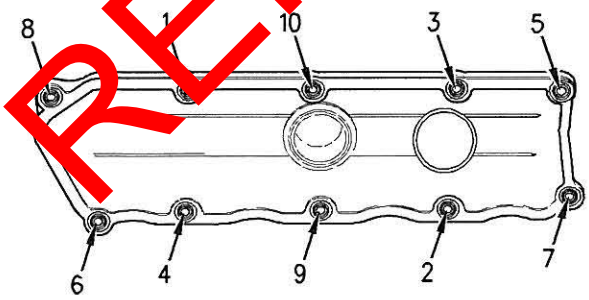

Illustration 200 g00908011

Sequence for tightening the fasteners for the four cylinder engine

6. If you are working on a four cylinder engine, tighten the fasteners for the valve mechanism cover in the sequence that is shown in Illustration 200. Tighten the fasteners to a torque of 9 N·m (80 lb in).

7. Connect the breather tube (3) to the valve mechanism cover (1). Refer to this Disassembly and Assembly Manual, "Crankcase Breather - Remove and Install".

End By:

a. Install the cover for the fuel injectors. Refer to this Disassembly and Assembly Manual, "Fuel Injector Cover - Remove and Install".

b. If equipped, ensure that the heat shields are clean and free from dust, oil, and paint. Install the heat shields.

i01947657

Rocker Shaft and Pushrod - Remove

Removal Procedure

Table 20

Required Tools		
Part Number	**Part Description**	**Qty**
27610227	Rocker Assembly Tool	4

Start By:

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

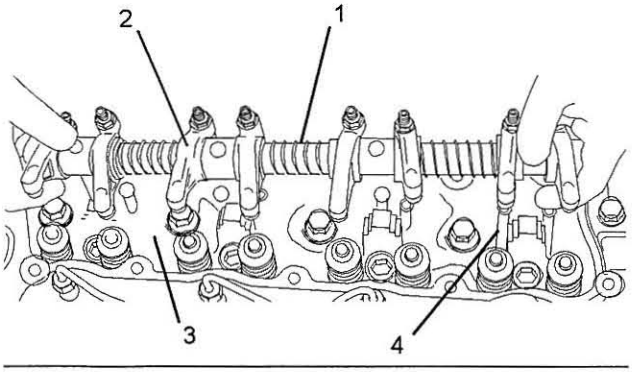

Illustration 201 g01014000
Typical example

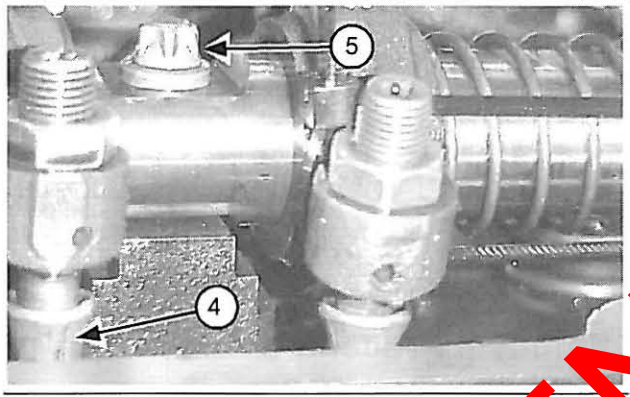

Illustration 202 g0101399

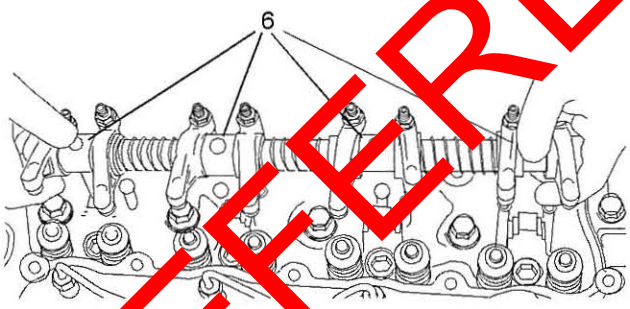

Illustration 203 g01015730
Typical example

1. If the rocker shaft will not be disassembled, install the rocker assembly tools (6) between each pair of rocker arms (2). The rocker arms (2) must be held away from the machined face of the cylinder head (3) during reassembly.

2. Start from the ends of the rocker shaft assembly (1) and work toward the center of the rocker shaft assembly in order to remove the torx screws (5). Evenly loosen the torx screws (5) in order to remove the rocker shaft assembly (1).

3. Remove the rocker shaft assembly (1) from the cylinder head (3).

4. Place an identification mark on the pushrods (4) for installation. Remove the pushrods (5) from the cylinder head (3).

i01947658

Rocker Shaft - Disassemble

Disassembly Procedure

Table 21

Required Tools	
Part Description	Qty
Suitable Pliers for External Circlips	1

Start By:

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

⚠ WARNING

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

Make sure to wear all necessary protective equipment.

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

Note: The disassembly procedure is identical for the three cylinder and the four cylinder engines. The illustration shows the four cylinder engine.

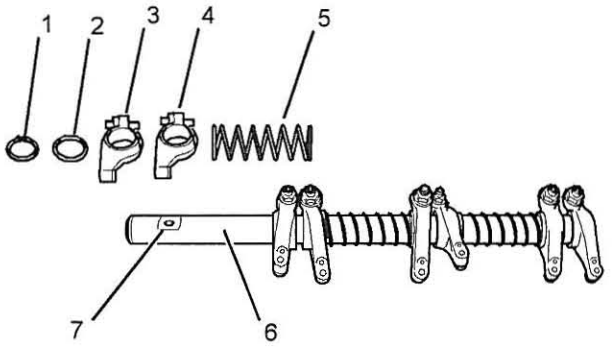

Illustration 204 g01014249
Typical example

1. Remove the circlip (1) and remove the washer (2) from both ends of the rocker shaft assembly.

Note: The rocker shaft (6) is not symmetrical as there is a machined flat (7) toward one end of the shaft.

2. Place an identification mark on each of the components for installation. Ensure that you note the component's relationship to the machined flat (7).

3. Remove the rocker arm assembly (3) for the inlet valve from the rocker shaft (6). Remove the rocker arm assembly (4) for the exhaust valve from the rocker shaft (6).

4. Remove the spring (5) from the rocker shaft (6).

5. Repeat Step 3 and Step 4 in order to completely disassemble the rocker shaft assembly.

i01947659

Rocker Shaft - Assemble

Assembly Procedure

Table 22

Required Tools	
Part Description	**Qty**
Suitable Pliers for External Circlips	1

Note: The assembly procedure is identical for the three cylinder and the four cylinder engines. The illustration shows the four cylinder engine.

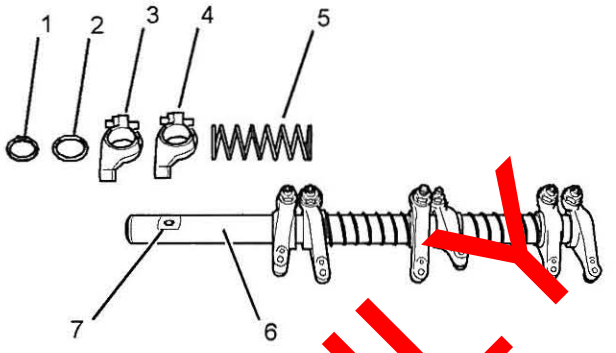

Illustration 205 g01014249
Typical example

1. Clean all of the components and inspect all of the components. Inspect the grooves for the circlips (1) and ensure that all of the oil holes in the rocker shaft (6) and in the rocker arms (3 and 4) are not plugged before you begin the assembly procedure. If necessary, replace any worn components and any damaged components.

2. Check the clearance between the rocker shaft (6) and the bushing of every rocker arm (3 and 4). Refer to the Specifications Manual, "Rocker Shaft" for further information. If necessary, replace any worn components.

3. Lubricate all of the components with clean engine oil before assembly.

Note: Ensure that the machined flat (7) on the rocker shaft (6) is facing upward.

4. Install a circlip (1) onto the end of the rocker shaft (6) that is closest to the machined flat (7). Install a washer (2) onto the rocker shaft (6).

5. Install the rocker arm assembly (3) for the inlet valve onto the rocker shaft (6). Install the rocker arm assembly (4) for the exhaust valve onto the rocker shaft (6).

6. Install the spring (5) onto the rocker shaft (6).

7. Repeat Step 5 and Step 6 in order to assemble the rocker shaft assembly.

⚠ 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.

8. Install the remaining washer (2) and the remaining circlip (1) onto the rocker shaft (6).

End By:

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

i01947661

Rocker Shaft and Pushrod - Install

Installation Procedure

Table 23

Required Tools		
Part Number	**Part Description**	**Qty**
27610227	Rocker Assembly Tool	4

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten component life.

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

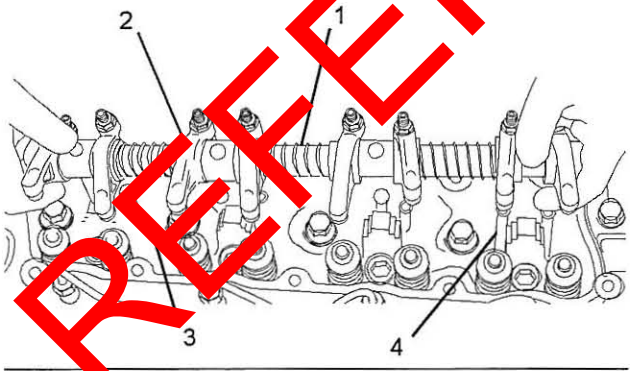

Illustration 206 g01014000
Typical example

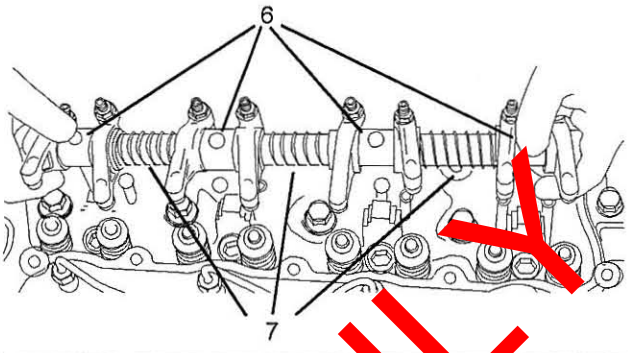

Illustration 207 g01015738
Typical example

1. Apply clean engine lubricating oil to both ends of the pushrods (4). Install the pushrods (4).

Note: Ensure that the pushrods (4) are installed in the original location and that the pushrods are seated in the valve lifters correctly.

2. If the rocker shaft assembly was disassembled, install 27610227 Rocker Assembly Tool (6) around the rocker arms (2) in order to slightly compress the spring (7). The rocker arms (2) must be held away from the machined face of the cylinder head (3) during reassembly.

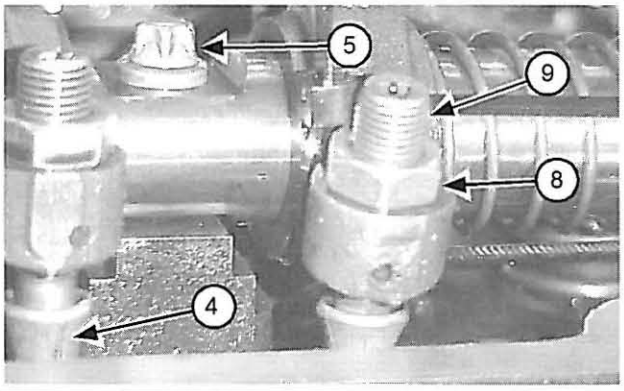

Illustration 208 g01015827

3. Loosen the nut (8) and the adjustment screw (9) on each rocker arm (2). This will help prevent a bent valve or a bent pushrod during the installation of the rocker shaft.

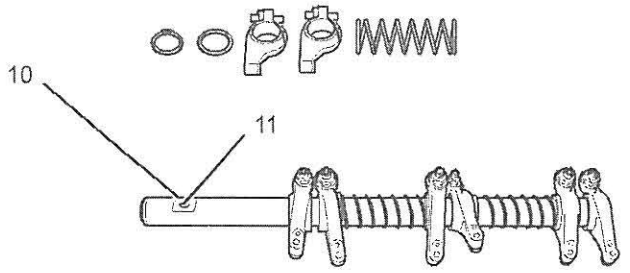

Illustration 209 g01015836
Typical example

Note: The rocker shaft of the rocker shaft assembly (1) is not symmetrical. The rocker shaft has a machined flat (10) at the front end of the shaft. Ensure that the machined flat (10) is toward the top and toward the front end of the engine.

4. Position the rocker shaft assembly (1) onto the cylinder head (3).

5. Install the torx screws (5) in the rocker shaft (3).

Note: The longest torx screw (5) must be installed at the front of the cylinder head in hole (11).

6. Ensure that the adjustment screws (9) are properly seated in the ends of pushrods (4).

7. Alternately tighten the torx screws (5). Start from the center and work toward the outside. Tighten torx screws (5) to a torque of 35 N·m (26 lb ft).

8. Remove the rocker assembly tool (A) from the rocker shaft assembly (1).

9. Adjust the inlet valve lash to 0.20 mm (0.008 inch) and adjust the exhaust valve lash to 0.45 mm (0.018 inch). Refer to the Testing and Adjusting Manual "Engine Valve Lash - Inspect/Adjust" for more information on adjusting the valve lash.

End By:

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

i01947662

Cylinder Head - Remove

Removal Procedure

Start By:

a. Drain the coolant from the engine into a suitable container for storage or disposal. Drain the engine oil from the engine into a suitable container. Refer to the Operation and Maintenance Manual for the procedure on draining the engine coolant and the engine oil.

b. Remove the hose from the air filter to the integral air inlet. Refer to the OEM information for further details.

c. Remove the fuel priming pump. Refer to this Disassembly and Assembly Manual, "Fuel Priming Pump - Remove and Install".

d. Remove the pipe for the boost control, if equipped.

e. Remove the fuel injectors. Refer to this Disassembly and Assembly Manual, "Fuel Injector - Remove".

f. Remove the exhaust manifold. Refer to this Disassembly and Assembly Manual, "Exhaust Manifold - Remove and Install".

g. Remove the rocker shaft assembly and the pushrods. Refer to this Disassembly and Assembly Manual, "Rocker Shaft and Pushrod - Remove".

h. Remove the glow plugs. Refer to this Disassembly and Assembly Manual, "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: The removal procedure is identical for the three cylinder and the four cylinder engines.

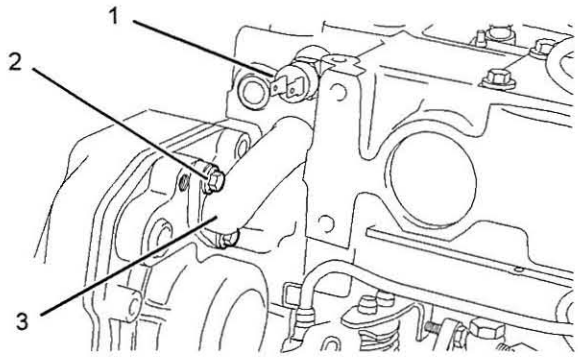

Illustration 210 g01039425
Typical example

1. Disconnect the harness assembly from the coolant temperature sensor (1).

2. Remove the setscrews (2). Remove the bypass tube (3) from the cylinder head (4). Remove the O-rings from the bypass tube (3).

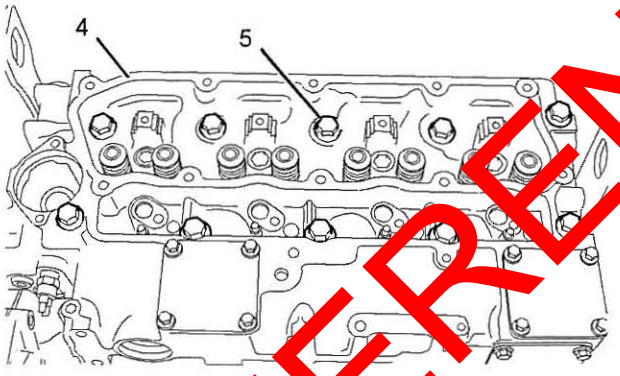

Illustration 211 g01039484
Typical example

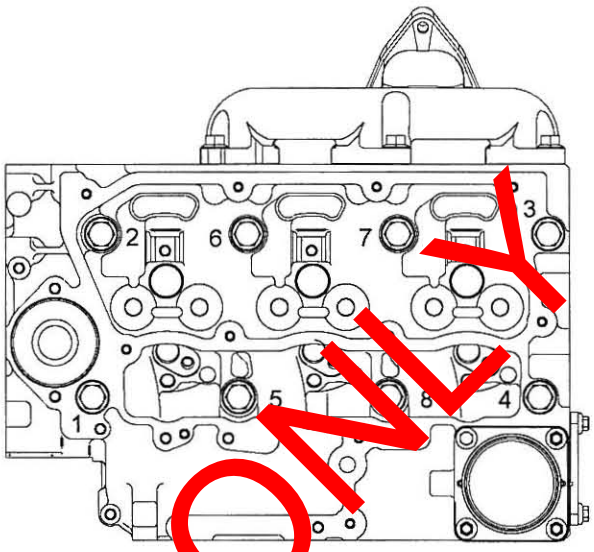

Illustration 212 g01039487
Sequence for tightening the setscrews for the three cylinder engine

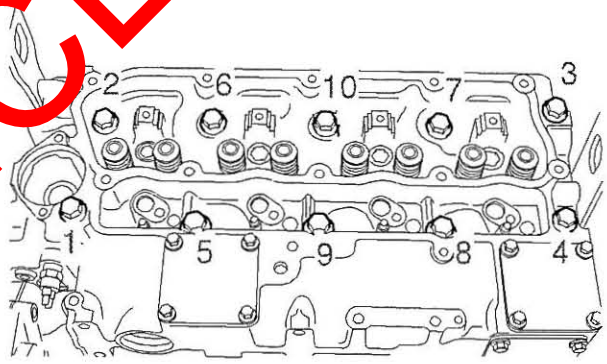

Illustration 213 g01039483
Sequence for tightening the setscrews for the four cylinder engine

3. Refer to the illustration 212 for three cylinder engines or illustration 213 for four cylinder engines. Gradually loosen the setscrews (5) in the reverse numerical order. This will help prevent distortion of the cylinder head (4).

4. Remove the setscrews (5) from the cylinder head (4).

Note: The cylinder head (4) is heavy. To avoid injury, take care when the cylinder head (4) is lifted. Also take care not to damage the machined surfaces of the cylinder head (4) during lifting and lowering the cylinder head.

Note: Do not use a lever to separate the cylinder head (4) from the cylinder block.

NOTICE
Place the cylinder head on a surface that will not scratch the face of the cylinder head.

5. Use a suitable lifting device and carefully lift the cylinder head (4) off the cylinder block.
6. Remove the cylinder head gasket and discard the cylinder head gasket.
7. Note the location of the dowels in the cylinder block for installation purposes.

i01947663

Cylinder Head - Install

Installation Procedure

Table 24

Required Tools		
Part Number	**Part Description**	**Qty**
21825607	Angle Gauge	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. Unless the illustration is otherwise indicated, the illustrations show the four cylinder engine.

Note: Thoroughly clean the top of the cylinder block (1) and the bottom of the cylinder head (2). Ensure that there is no debris in the cylinder bores, the coolant passages, and the lubricant passages.

Note: Thoroughly clean the hole in the cylinder head for the gas that is ventilated from the crankcase. Ensure that the hole is not restricted by debris and/or oil deposits.

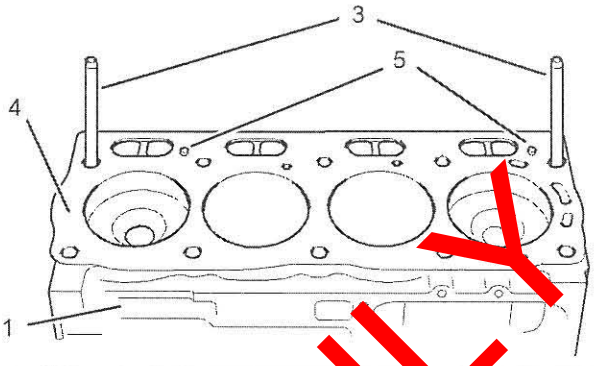

Illustration 214 g01039834
Typical example

1. Install suitable studs (3) into the cylinder block (1) in the set screw holes 2 and 3. Refer to the illustration 214 for the three cylinder and refer to the illustration 214 for the four cylinder head.

Note: Do not use any sealant or compound on the cylinder head gasket (4).

2. Install the cylinder head gasket (4) onto the studs (3) and onto the dowels (5) in the top of the cylinder block (1).

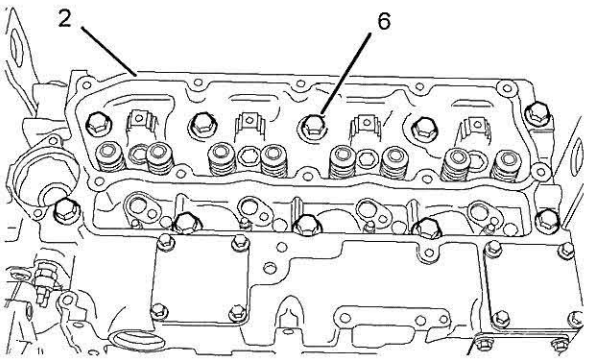

Illustration 215 g01039835
Typical example

Note: The cylinder head (2) is heavy. To avoid injury, take care when the cylinder head (2) is lifted. Also take care not to damage the machined surfaces of the cylinder head (2) during lifting and lowering the cylinder head.

3. Use a suitable lifting device to install the cylinder head (2).

Note: Ensure that the cylinder head (2) is positioned onto the dowels (5).

4. Remove the studs (3).

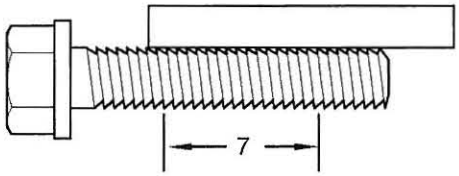

Illustration 216 g01039873

5. Clean the threads of the setscrews (6) for the cylinder head (2). Inspect the setscrews (6) for the cylinder head (2).

Note: Do not use the setscrews (6) if there is any visual reduction in the diameter of the threads (7) that have not been engaged with the cylinder block (1). Use a straight edge to check the setscrews (6). Refer to illustration 216.

6. Lubricate the threads and the shoulder of the setscrews (6) for the cylinder head (2) with clean engine oil before installation.

Note: There are two different lengths of setscrew (6) for the cylinder head (2).

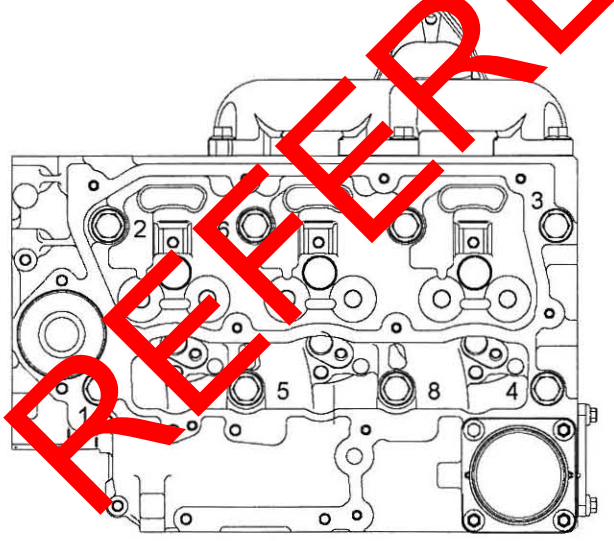

Illustration 217 g01039487
Three cylinder engine

Note: For the three cylinder engine, the short setscrews (6) are installed into the holes that are marked 2, 5, 6, 7, and 8. The long setscrews (6) are installed into the holes that are marked 1, 3, and 4. Refer to the illustration 217.

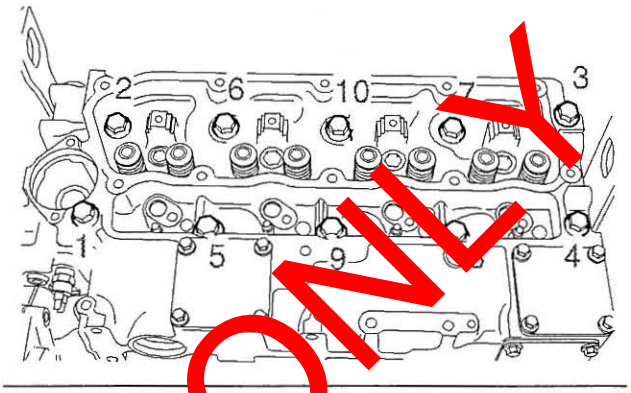

Illustration 218 g01039483
Four cylinder engine

Note: For the four cylinder engine, the short setscrews (6) are installed into holes that are marked 2, 5, 6, 7, 8, 9, and 10. The long setscrews (6) are installed into the holes that are marked 1, 3, and 4. Refer to illustration 218.

7. Install the appropriate setscrews (6) into the cylinder head (2).

8. Tighten the setscrews (6) for the cylinder head (2) in numerical order to a torque of 50 N·m (37 lb ft). Refer to the illustration 217 for the three cylinder and refer to illustration 218 for the four cylinder engine.

9. Tighten the setscrews (6) for the cylinder head (2) again in the appropriate numerical order to a torque of 100 N·m (74 lb ft). Refer to the illustration 217 for the three cylinder and the illustration 218 for the four cylinder engine.

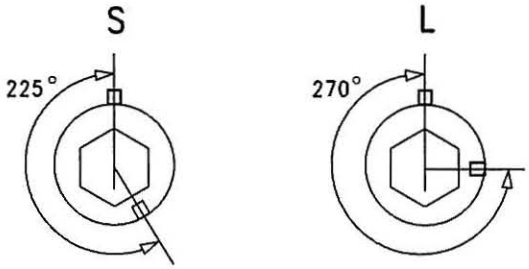

Illustration 219 g00951562

10. Finally tighten the setscrews (6) for the cylinder head (2) in the appropriate numerical order by an additional amount of degrees.

    a. Turn the short setscrews (2, 5, 6, 7, and 8) for the three cylinder or turn the short setscrews (2, 5, 6, 7, 8, 9, and 10) for the four cylinder engine for an additional 225 degrees.

    b. Turn the long setscrews (1, 3, and 4) for an additional 270 degrees.

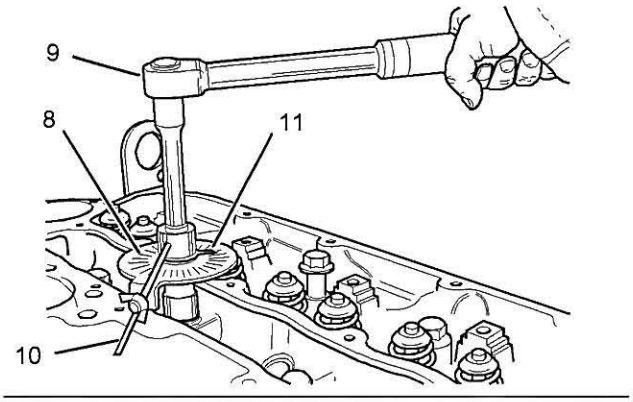

Illustration 220 g01040089
Typical example

11. Use 21825607 Angle Gauge in order to achieve the correct final torque.

12. Install the angle gauge (8) onto a suitable ratchet wrench (9). Refer to the appropriate illustration for the first setscrew (6) of the tightening sequence. Refer to illustration 217 for the three cylinder and illustration 218 for the four cylinder engine. Position the stop (10) against a suitable protrusion on the cylinder head (2) in order to prevent movement of the angle gauge (8) in a counterclockwise direction. Align the pointer (11) of the angle gauge (8) with the appropriate angle on the dial of the angle gauge. Tighten the appropriate setscrew (6) until the pointer aligns with the zero on the dial of the angle gauge (8).

13. Repeat Step 12 for all of the cylinder head setscrews (6) in the correct tightening sequence. Refer to illustration 217 for the three cylinder and illustration 218 for the four cylinder engine.

Note: The following alternative method can be used if 21825607 Angle Gauge is not available.

Note: For reference, 225 degrees of rotation is equal to 3.75 flats on the setscrew and 270 degrees of rotation is equal to 4.5 flats on the setscrew.

14. Place an index mark on the cylinder head (2) in line with a corner of each setscrew (6). Make another mark in a counter clockwise direction and at the correct angle for the length of setscrew (6) on the edge of the setscrew.

15. Tighten the setscrews (6) for the cylinder head (2) in numerical order. Refer to the illustration 217 for the three cylinder and illustration 218 for the four cylinder engine.

16. Turn the short setscrews (2, 5, 6, 7, and 8) or turn the short setscrews (2, 5, 6, 7, 8, 9, and 10) through an additional 225 degrees.

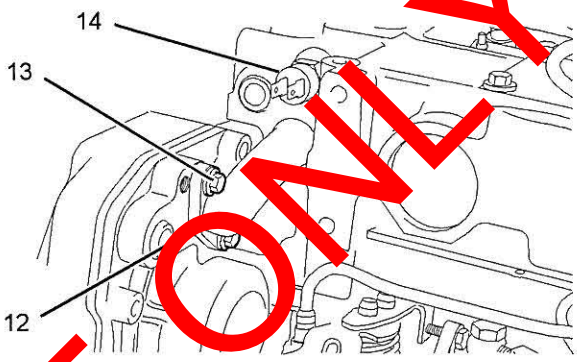

Illustration 221 g01040100
Typical example

17. Apply 21820221 POWERPART Red Rubber Grease to the new O-rings before the O-rings are installed onto the bypass tube (12). Install the new O-rings onto the bypass tube (12). Install the bypass tube (12) into the cylinder head (2). Install the setscrews (13).

18. Connect the harness assembly onto the coolant temperature sensor (14).

End By:

a. Install the glow plugs. Refer to this Disassembly and Assembly Manual, “Glow Plugs - Remove and Install”.

b. Install the rocker shaft and the pushrods. Refer to this Disassembly and Assembly Manual, “Rocker Shaft and Pushrod - Install”.

c. Install the exhaust manifold. Refer to this Disassembly and Assembly Manual, “Exhaust Manifold - Remove and Install”.

d. Install the fuel injectors. Refer to this Disassembly and Assembly Manual, “Fuel Injector - Install”.

e. Install the pipe for the boost control, if equipped.

f. Install the fuel priming pump. Refer to this Disassembly and Assembly Manual, “Fuel Priming Pump - Remove and Install”.

g. Install the hose from the integral air inlet to the air filter. Refer to the OEM information for further details.

h. Refill the engine with coolant and engine oil. Refer to the Operation and Maintenance Manual for the correct procedure, the quantities, the coolant specification, and the specification for the engine oil.

i01977577

Lifter Group - Remove and Install

Removal Procedure

Start By:

a. Remove the cylinder head if the cylinder head has not previously been removed. Refer to this Disassembly and Assembly Manual, "Cylinder Head - Remove".

b. Remove the engine oil pan if the engine oil pan has not previously been removed. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

c. Remove the camshaft. Refer to this Disassembly and Assembly Manual, "Camshaft - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

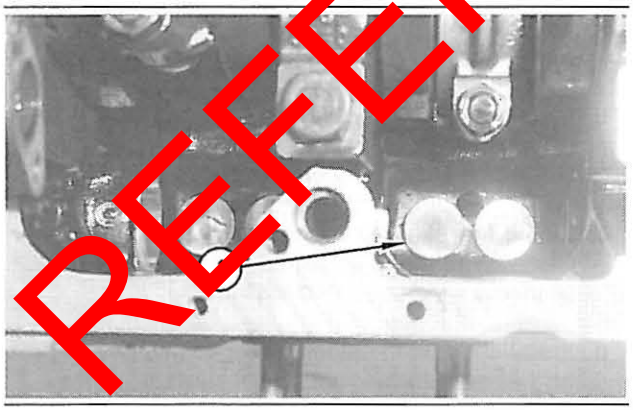

Illustration 222 g00540954

1. Use a suitable magnet to remove each cam follower (1).

Note: Place an identification mark on each cam follower for installation purposes.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Lubricate each cam follower (1) with clean engine oil.

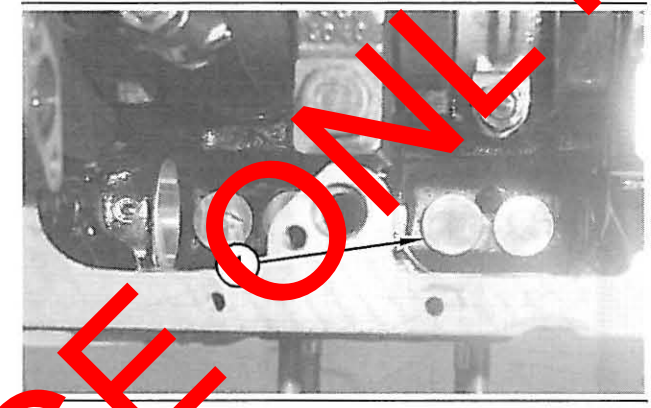

Illustration 2 g00540954

2. Install each cam follower (1) into the appropriate housing in the cylinder block.

Note: Ensure that each cam follower (1) is installed in the original location and that each cam follower is seated correctly.

End By:

a. Install the camshaft. Refer to this Disassembly and Assembly Manual, "Camshaft - Remove and Install".

b. Install the engine oil pan if this is the appropriate time. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

c. Install the cylinder head if this is the appropriate time. Refer to this Disassembly and Assembly Manual, "Install".

i01977579

Camshaft - Remove and Install

Removal Procedure

Start By:

a. Remove the cylinder head if the cylinder head has not previously been removed. Refer to this Disassembly and Assembly Manual, "Cylinder Head - Remove".

b. Remove the front housing if the front housing has not previously been removed. Refer to this Disassembly and Assembly, "Housing (Front) - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the engine upside-down so that the cam followers are held in a position away from the camshaft.

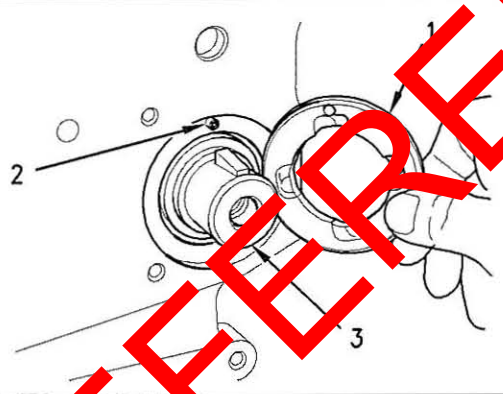

Illustration 22 g00951938

2. Remove the thrust washer (1) if the thrust washer has not previously been removed. Make a note of the location of the hollow dowel (2) for installation purposes.

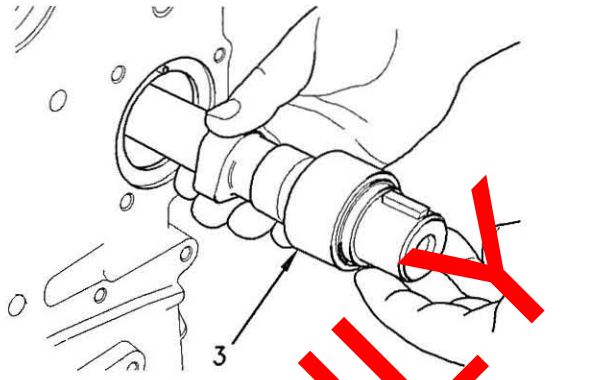

Illustration 225 g00951934

NOTICE
Do not damage the lobes or the bearings when the camshaft is removed or installed.

3. Carefully remove the camshaft (3) from the cylinder block.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: Ensure that the camshaft (3) is clean. Lubricate the camshaft (3) with clean engine oil prior to installation.

NOTICE
Do not damage the lobes or the bearings when the camshaft is removed or installed.

1. Carefully install the camshaft (3) into the cylinder block.

2. Put the thrust washer (1) in position if this is the appropriate time. Make sure that the thrust washer (1) is aligned with the hollow dowel (2).

End By:

a. Install the front housing if this is the appropriate time. Refer to this Disassembly and Assembly Manual, "Housing (Front) - Install".

b. Install the cylinder head if this is the appropriate time. Refer to this Disassembly and Assembly Manual, "Cylinder Head - Install".

i01977601

Camshaft Gear - Remove and Install

Removal Procedure

Start By:

a. Remove the front cover if the front cover has not previously been removed. Refer to this Disassembly and Assembly Manual, "Front Cover - Remove and Install".

b. Remove the idler gear if the idler gear has not previously been removed. Refer to this Disassembly and Assembly Manual, "Idler Gear - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

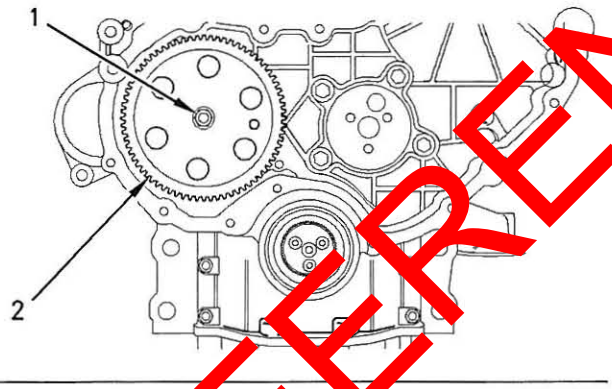

Illustration 226 g00954352

1. Remove the setscrew (1) and the washer from the camshaft gear (2).

2. Remove the camshaft gear (2) from the camshaft.

Note: Do not lose the key that is located in the camshaft for the camshaft gear (2).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Inspect the camshaft gear (2) and the key in the camshaft for wear or damage.

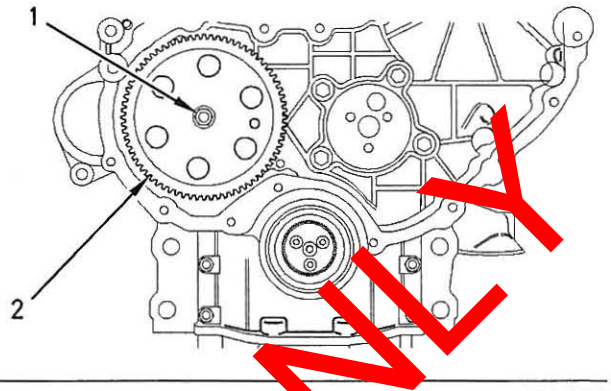

Illustration 227 g00954352

2. Ensure that the marked teeth on the camshaft gear (2) are facing toward the front and that the key is installed in the camshaft. Install the camshaft gear (2) onto the camshaft. If necessary, tap the camshaft gear (2) with a soft hammer in order to seat the key in the keyway.

3. Install the setscrew (1) and the washer onto the camshaft gear (2). Tighten the setscrew (1) to a torque of 95 N·m (70 lb ft).

End By:

a. Install the idler gear if this is the appropriate time. Refer to this Disassembly and Assembly Manual, "Idler Gear - Remove and Install".

b. Install the front cover if this is the appropriate time. Refer to this Disassembly and Assembly Manual, "Front Cover - Remove and Install".

i02242609

Camshaft Bearings - Remove and Install

Removal Procedure

Start By:

a. Remove the camshaft. Refer to this Disassembly and Assembly Manual, "Camshaft - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

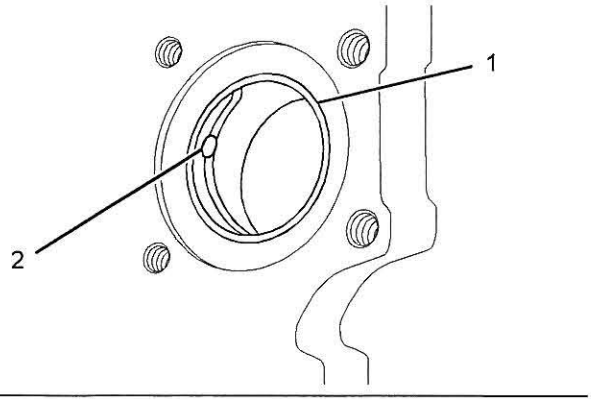

Illustration 228 g01130526
Typical example

1. If the camshaft bearing (1) is worn or damaged use a suitable adapter in order to press the bearing out of the cylinder block.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the bearing housing in the cylinder block is clean. Ensure that the oil hole in the bearing housing is clean and free from debris.

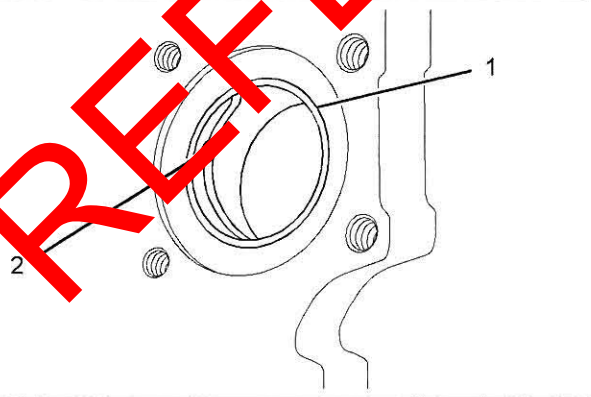

Illustration 229 g01130526
Typical example

Note: Align the oil hole in camshaft bearing (2) with the oil hole in the cylinder block.

2. Use a suitable adapter in order to press the camshaft bearing (1) into the cylinder block. Continue to press the camshaft bearing (1) into the cylinder block until the bearing is flush with the face of the recess in the cylinder block. Ensure that the oil holes are still in alignment.

End By:

a. Install the camshaft. Refer to this Disassembly and Assembly Manual, "Camshaft - Remove and Install".

i01958105

Engine Oil Pan - 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: Ensure that the engine oil pan is fully supported before the oil pan is removed. Particular care must be taken with the cast iron version of the engine oil sump as this version is heavy.

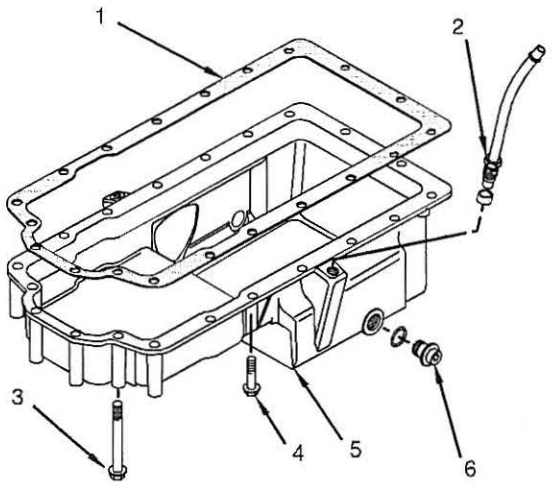

Illustration 230 g01042307

1. Remove all dirt, oil, and grease from the exterior surfaces of the oil pan (5).
2. Operate the engine until the engine is warm. Stop the engine.
3. If necessary, remove the nut (2), the seal, and the tube assembly from the engine oil pan (5).
4. Remove the oil drain plug (6) and the O-ring. Drain the engine oil into a suitable container for storage or disposal.
5. Remove the setscrews (3) and the setscrews (4) from the engine oil pan (5).
6. Remove engine oil pan (5) and remove the joint (1) from the cylinder block. Discard the joint (1).
7. Clean the engine oil pan (5) with a suitable cleaning fluid. Ensure that all of the cleaning fluid is removed.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: If the bridge for the cylinder block and/or the timing case have just been installed the engine oil pan must be installed before the silicon sealant has cured.

Note: Ensure that any old silicon rubber sealant is removed from the mating surfaces of the engine oil pan when the sump is installed.

1. Clean the flange face of the engine oil pan (5) and the flange face of the cylinder block.

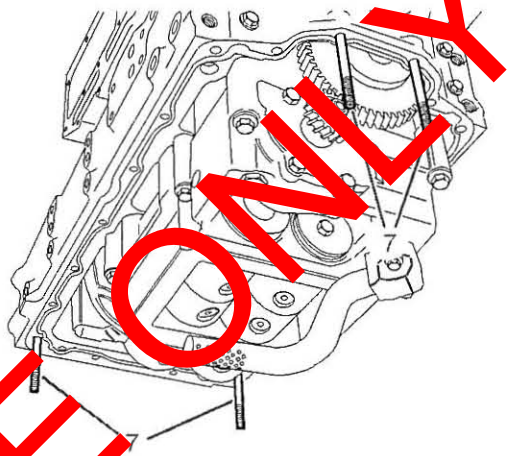

Illustration 231 g01042312

2. Install four temporary studs (7) as guides. Refer to illustration 231for the correct location of the temporary studs (7).

Note: When the joint for the engine oil pan is removed, damage may occur to the existing sealant in the bridge of the cylinder block.

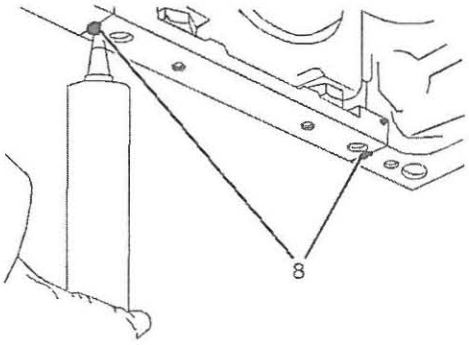

Illustration 232 g01042275

3. If the silicon sealant is damaged, apply a sufficient amount of 21826038 POWERPART Silicone Rubber Sealant in order to fill the groove (8).

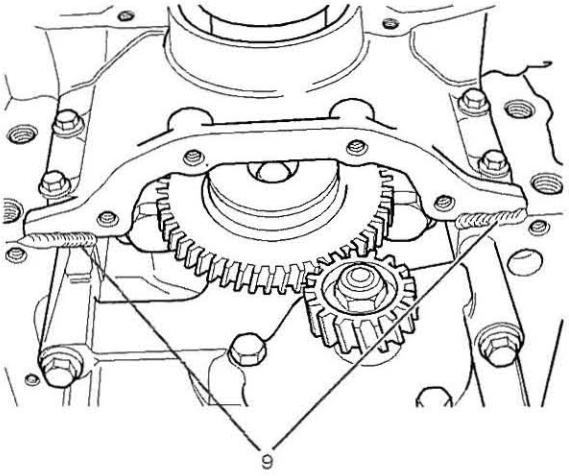

Illustration 233 g01042276

4. Also, apply a sufficient amount of new silicon rubber sealant if the silicon rubber sealant (9) between the cylinder block and the front cover is damaged.

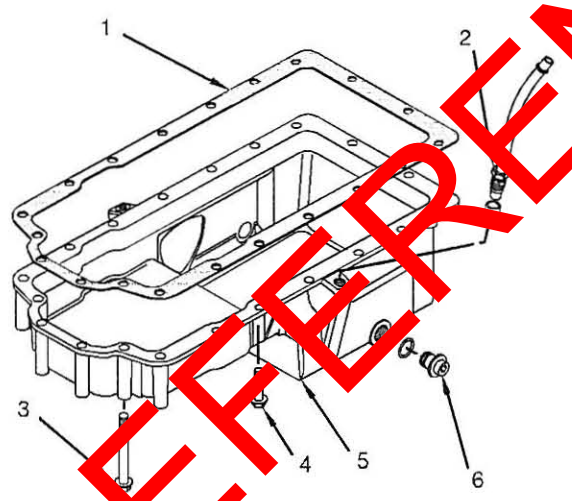

Illustration 234 g01042307

5. Carefully position the joint (1) over the temporary studs (7). Ensure that the engine oil pan is properly supported while the engine oil pan (5) is installed onto the temporary studs (7). The cast iron sump is heavy.

Note: New setscrews have sealant on the first 13 mm (0.5 inch) of the threads. In order to reuse the old setscrews, clean the old sealant from the setscrews and apply 21820117 POWERPART Threadlock and Nutlock to the setscrews.

6. Install the setscrews (4) in order to secure the engine oil pan (5) to the cylinder block. Tighten the setscrews (4) finger tight.

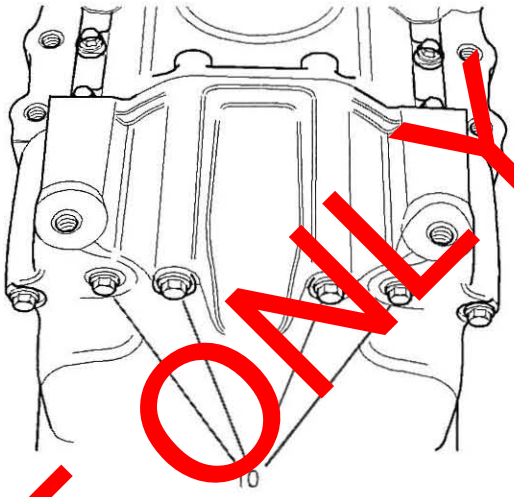

Illustration 235 g01042277

7. Remove the temporary studs (7) and install the remaining setscrew (3 and 4). Tighten the four setscrews (10) to a torque of 22 N·m (16 lb ft).

8. Tighten remaining setscrews (3) and setscrews (4) to a torque of 22 N·m (16 lb ft).

9. Inspect the O-ring for the drain plug (6). Replace the O-ring if it is necessary. Install the O-ring seal and drain plug (6). Tighten the drain plug (6) to a torque of 34 N·m (25 lb ft).

10. If necessary, install the seal and the tube assembly in the engine oil pan. Tighten the nut (2) to a torque of 18 N·m (13 lb ft).

11. Fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to the Operation and Maintenance Manual, “Refill Capacities” for the lubrication system capacity of the engine.

i02242016

Balancer - Remove (Some 1104 Engines Only)

Removal Procedure

Table 25

Required Tools		
Part Number	**Part Name**	**Qty**
27610225	Timing Pin (Balancer)	1

Start By:

a. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

b. Remove the engine oil relief valve. Refer to this Disassembly and Assembly Manual, "Engine Oil Relief Valve - Remove and Install (Balancer Unit for the Engine)".

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. Put the No. 1 cylinder at top dead center on the compression stroke. Refer to this Testing and Adjusting Manual, "Fuel Injection Timing - Check".

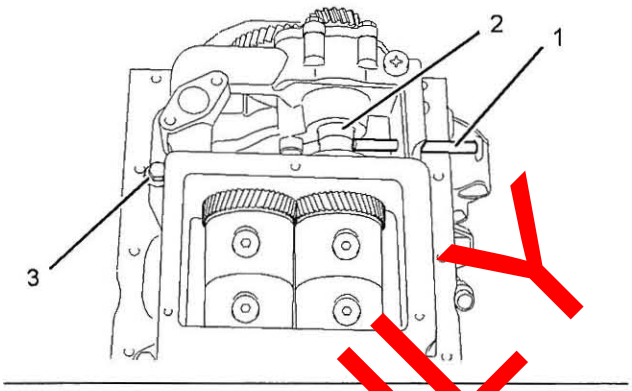

Illustration 236 g01026243

2. Install the 27610225 Timing Pin into the balancer. Ensure that the timing pin (1) is fully located into the drive shaft (2).

Note: The balancer is heavy. Take care when the balancer is lifted and/or when the balancer is lowered. If the engine is not inverted, support the balancer before removing the setscrews (3).

3. Refer to the Note above and remove the setscrews (3). Use a suitable lifting device to remove the balancer.

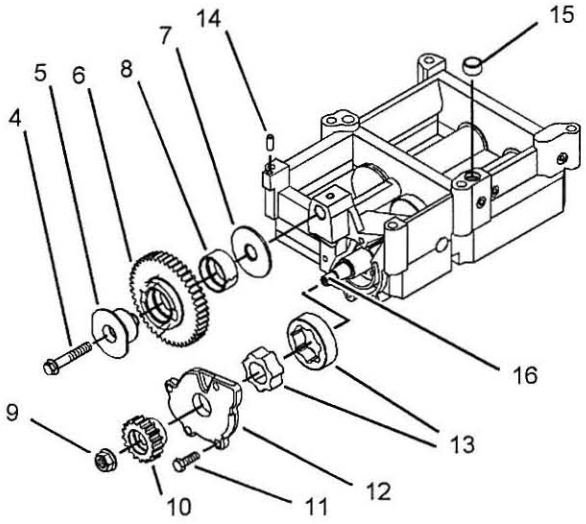

Illustration 237 g01026290

Note: The balancer is a nonserviceable item. Use the following procedure in order to remove the engine oil pump from the balancer.

4. Remove the setscrew (4) and the shaft (5). Remove the idler gear (6) and the thrust washer (7). Use a suitable adapter in order to press the bearing (8) from the idler gear (6). Discard the bearing (8).

5. Remove the nut (9). Use a suitable puller in order to remove the gear (10) from the shaft.

6. Remove the setscrews (11). Remove the cover (12).

7. Remove the rotor assembly (13).

8. If necessary, remove the dowel (14) and the hollow dowel (15).

i01979489

Balancer - Install (Some 1104 Engines Only)

Installation Procedure

Table 26

Required Tools		
Part Number	Part Name	Qty
27610225	Timing Pin (Balancer)	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean all of the components and inspect all of the components that were removed previously. Replace any component that is worn or damaged.

2. Clean the mating surfaces of the cylinder block and the balancer.

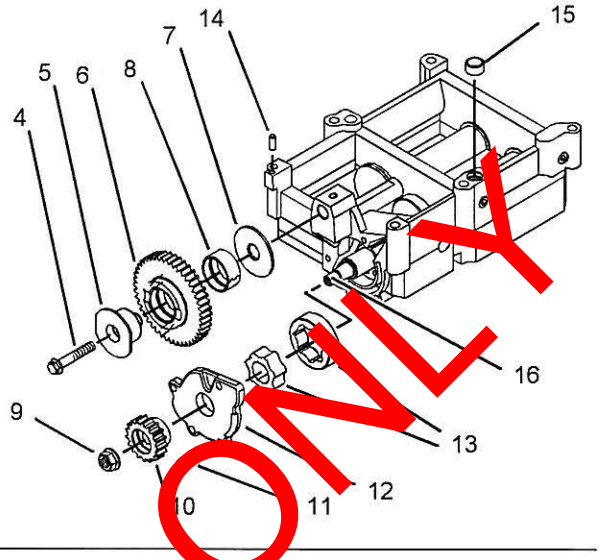

Illustration 238 g01026290

3. Install the rotor assembly (13). Check the clearance between the outer rotor and the body. Check the clearance between the inner rotor and the outer rotor. Check the end play for the rotor assembly. Refer to the Specifications Manual, "Engine Oil Pump" for information.

4. Lubricate the rotor assembly (13) with clean engine oil. Install the cover (12). Install the setscrews (11). Tighten the setscrews (11) to a torque of 28 N·m (21 lb ft).

5. Ensure that the threads (16) of the shaft are clean and dry. Position the oil pump gear (10) onto the shaft. Install the nut (9). Tighten the nut (9) to a torque of 95 N·m (70 lb ft).

6. Install a new bearing (8) into the idler gear (6).

7. Lubricate the bearing (8) with clean engine oil. Install the shaft (5) into the idler gear (6).

8. Position the idler gear (6) and the thrust washer (7) onto the balancer. Ensure that the threads of the setscrew (4) are clean and dry. Apply 21820117 POWERPART Threadlock and Nutlock to the threads of the setscrew (4) and install the setscrew. Tighten the setscrew (4) to a torque of 26 N·m (19 lb ft).

9. Check the end play for the idler gear (6). Refer to the Specifications Manual, "Engine Oil Pump".

10. Check the backlash between the gear (10) for the engine oil pump and the idler gear (6). Refer to the Specifications Manual, "Engine Oil Pump".

11. Ensure that the dowel (14) and the hollow dowel (15) are installed in the balancer.

12. Ensure that the No. 1 piston is at top dead center on the compression stroke. Refer to the Testing and Adjusting Manual, "Fuel Injection Timing - Check".

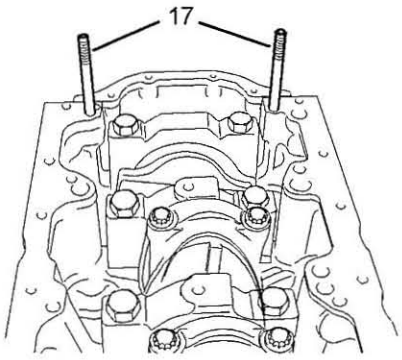

Illustration 239 g01026330

13. Install two temporary studs (17) into the cylinder block.

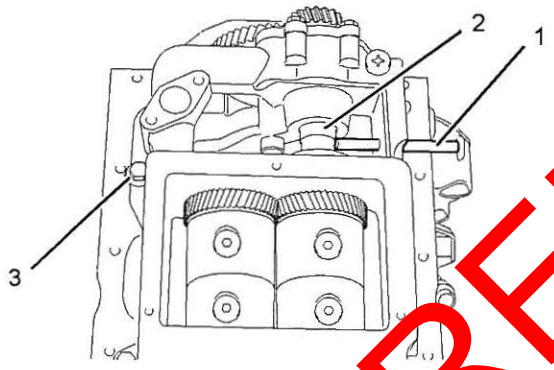

Illustration 240 g01026243

14. Install the 27610225 Timing Pin (1) into the shaft (2).

15. Carefully position the balancer onto the temporary studs (17). Ensure that the teeth of the idler gear (6) and the crankshaft gear are aligned.

16. Install two setscrews (3) into the center of the balancer. Tighten the setscrews (3) to a torque of 54 N·m (40 lb ft).

17. Remove the temporary studs (17) and install the remaining setscrews (3). Tighten the remaining setscrews to a torque of 54 N·m (40 lb ft).

18. Remove the timing pin (1). Rotate the crankshaft in order to ensure that the balancer turns freely.

End By:

a. Install the engine oil relief valve. Refer to this Disassembly and Assembly Manual, "Engine Oil Relief Valve - Remove and Install (Balancer Unit for the Engine)".

b. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i01979959

Piston Cooling Jets - Remove and Install

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

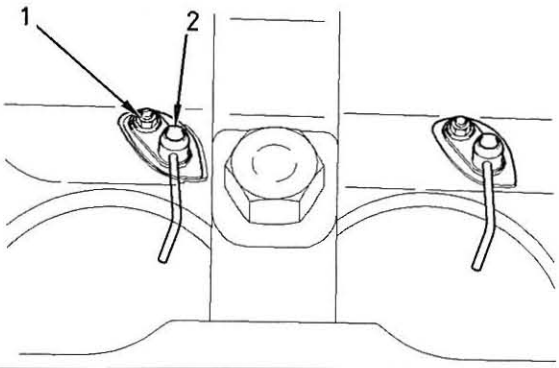

Illustration 241 g00952340

1. Remove the setscrew (1). Remove the piston cooling jet assembly (2) from the cylinder block.

Note: The engine crankshaft may be rotated in order to access all of the piston cooling jet assemblies.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

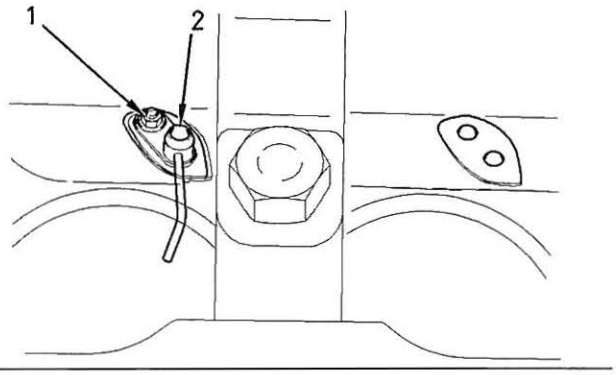

Illustration 242 g00952363

1. Clean each piston cooling jet assembly (2). Inspect each assembly for damage and especially check that the tube of the piston cooling jet assembly (2) has not been damaged. Ensure that the ball moves freely within each valve assembly of the piston cooling jet (2). Replace any damaged assembly.

2. Install each piston cooling jet assembly (2) into the cylinder block. Install the setscrew (1). Tighten the setscrew (1) to a torque of 9 N·m (80 lb in).

Note: Ensure that piston cooling jet assembly (2) is properly located on the cylinder block. Refer to the Specifications Manual, "Piston Cooling Jet" for the correct procedure for the alignment of the piston cooling jet.

End By:

a. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i01939118

Pistons and Connecting Rods - Remove

Removal Procedure

Start By:

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

b. 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: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustration shows the four cylinder engine.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Position the pistons that are being removed at the bottom center position.

2. Remove the carbon buildup from the inner surface of the top of the cylinder liner.

3. Ensure that the connecting rod and the cap are correctly marked to the cylinder.

Note: Do not punch the connecting rod or stamp the connecting rod assembly as this may cause damage.

4. Remove the torx screws (1) from the connecting rod.

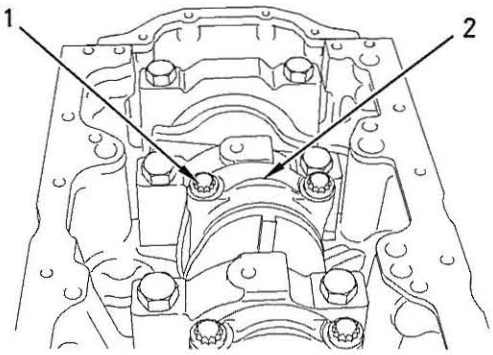

Illustration 243 g00970465
Typical example

5. Remove the connecting rod cap (2) with the bearing shell.

6. Push the piston and the connecting rod through the top of the cylinder block.

Note: Make a mark under the piston on the pin boss in order to identify the cylinder. Always mark the front pin boss to aid installation.

7. The bearing shell for the connecting rod and the bearing shell for the connecting rod cap must be placed with the correct rod and the correct connecting rod cap.

8. 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).

i02280401

Pistons and Connecting Rods - Disassemble

Disassembly Procedure

Start By:

a. Remove the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Remove".

NOTICE
Removal of the piston pin bushing must be carried out by personnel with the correct training. Also special machinery is required. For more information, refer to your authorized Perkins dealer or your Perkins distributor.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

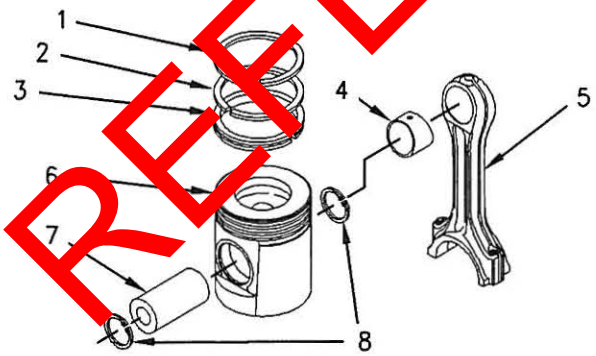

Illustration 244 g00964585

1. Use a suitable ring expander in order to remove the three piston rings (1) and (2), and the oil control ring (3) from the piston (6). Remove the lower connecting rod bearing from the connecting rod cap. Remove the upper connecting rod bearing from the connecting rod.

Note: If necessary, note the orientation of the old piston rings for assembly.

2. Use suitable pliers in order to remove the circlips (8).

3. Remove the piston pin (7) from the piston (6).

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 oxyacetylene torch to heat the piston.

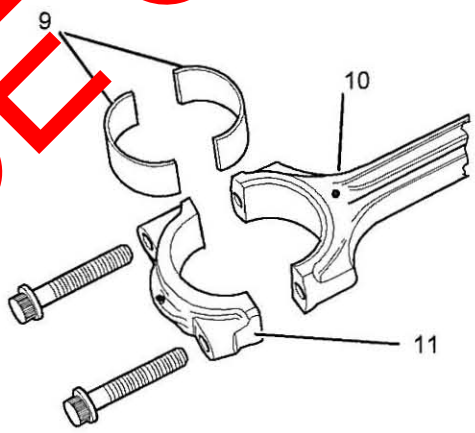

Illustration 245 g01015731

4. Remove the bearing shells (9) from the connecting rod (10) and the connecting rod cap (11).

5. Use a suitable press and a suitable adapter in order to remove the piston pin bushing (4) from the connecting rod (5).

i01939858

Pistons and Connecting Rods - Assemble

Assembly Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Installation of the piston pin bushing must be carried out by personnel with the correct training. Also special machinery is required.

Note: A new piston pin bushing is in a shape of a wedge. For further information on installation of the piston pin bushing, refer to your authorized Perkins dealer or your Perkins distributor for assistance.

1. Refer to Testing and Adjusting, "Connecting Rod - Inspect" for the correct height grade for the fractured split connecting rod.

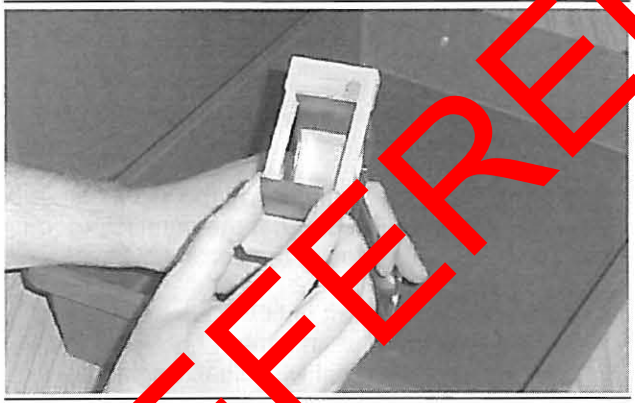

Illustration 2[illegible] g01000785
Alignm[illegible]of the [illegible]hell

2. The bearing shells for the connecting rod and the connecting rod cap must be aligned by a tool before the bearing shells are installed. Refer to illustration 246. Check the alignment of the bearing shells and remove the alignment tool from the assembly. The bearing shell must be an equal distance from each end. Refer to illustration 247.

Note: The alignment tool is supplied with new bearing shells .

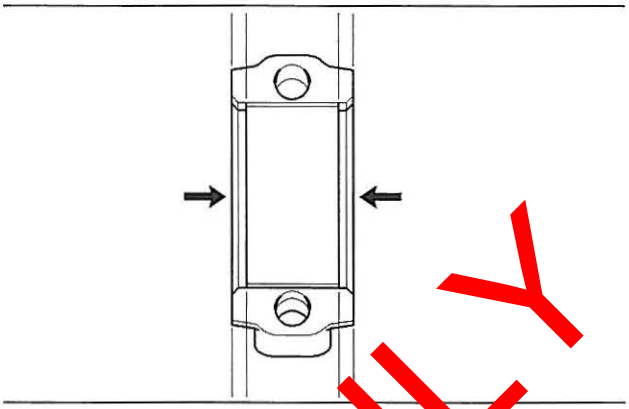

Illustration 247 g01001160
Aligned shell

3. Align the mark (1) on the connecting rod to the boss cutout (2) of the piston. Also check that the arrow (3) that is marked on top of the piston is aligned. Install the piston pin into the piston and through the connecting rod.

Note: If the piston pin cannot be installed by hand, use hot water in order to heat the piston to a temperature of 45° ± 5°C (113° ± 9°F).

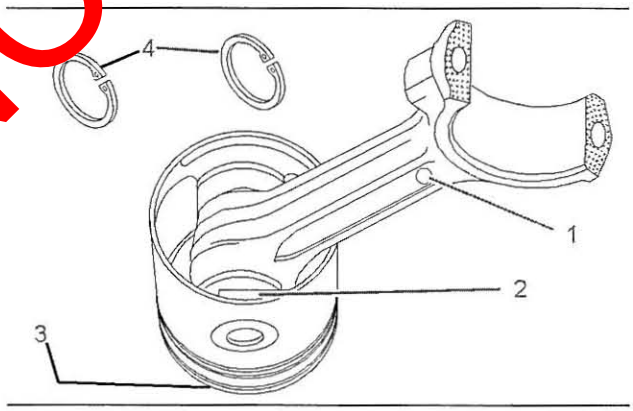

Illustration 248 g01009410
Align the connecting rod to the piston.

4. Use suitable pliers in order to install the circlips (4) that hold the piston pin in position.

5. Use a suitable ring expander in order to install the piston rings on the piston with the following steps.

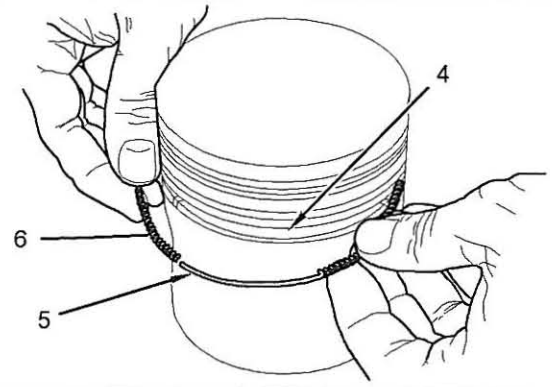

Illustration 249 g01010864

a. Install the spring (6) for the oil control piston ring (7) in the groove (4) that is lowest on the piston. The latch pin (5) must be located inside the ends of the spring. Locate the oil control ring (7) over the internal spring (6).

Note: Ensure that the latch pin is 180 degrees from the oil control ring gap.

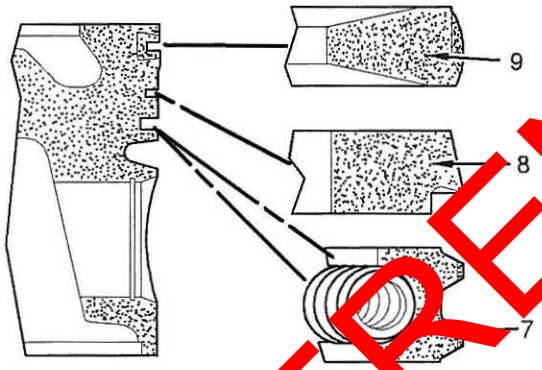

Illustration 250 g01010865

b. Install the intermediate piston ring (8) with the tapered face into the second groove on the piston. The stamp "TOP" must be toward the top of the piston.

Note: Intermediate piston rings that are new have a green mark which must be on the left of the piston ring gap when the piston ring is installed.

c. Install the top piston ring (9) with the barrel face and the molybdenum insert into the top groove on the piston. The top piston ring has a keystone ring. The stamp "TOP" must be toward the top of the piston.

Note: Top piston rings that are new have a red mark which must be on the left of the ring gap when the ring is installed.

d. Position the piston ring gaps at 120 degrees away from each other.

End By:

a. Install the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Install".

i02280830

Pistons and Connecting Rods - Install

Installation Procedure

Table 27

Required Tools		
Part Number	Part Description	Qty
2[illegible]256[illegible]	Piston sleeve (installation tool)	1

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean all of the components.

2. Lubricate the piston and the cylinder bore with clean engine oil.

Note: The piston and connecting rod are matched to a specific cylinder. Ensure that the connecting rod and pistons are installed in the correct cylinder.

3. Rotate the crankshaft until the connecting rod journal is at the bottom center. Lubricate the connecting rod journal with clean engine oil.

4. Ensure that the piston assembly is correctly marked to the cylinder.

5. Lubricate the bearing shells for the connecting rod with clean engine oil.

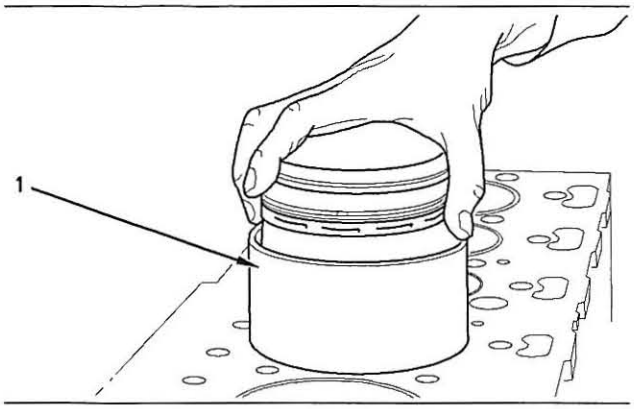

Illustration 251 g00999752

6. Lubricate the piston sleeve (1) with clean engine oil and install the piston sleeve.

Note: The arrow or the "FRONT" mark that is on the top of the piston must be toward the front of the engine. Ensure that the piston rings are 120 degrees away from each other.

Note: Ensure that the piston sleeve is installed correctly and that the piston can easily slide from the tool and into the cylinder.

7. Push the piston and the connecting rod assembly into the cylinder and onto the connecting rod journal.

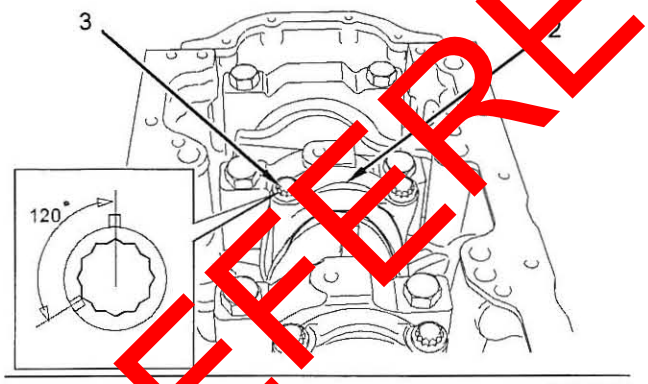

Illustration 252 g01141423
Typical example

Note: New setscrews must be installed.

Note: Ensure that the etched number on connecting rod bearing cap (2) matches the etched number on connecting rod.

8. Install the cap (2) with the bearing shell onto the connecting rod journal and the new setscrews for the cap.

9. Tighten the new setscrews to 20 N·m (14 lb ft).

Refer to Testing and Adjusting, "Piston Height - Inspect" for the correct procedure on checking the height of the piston above the cylinder block.

10. Tighten the setscrews (3) to 70 N·m (51 lb ft). Again tighten the setscrews by 120 degrees. Refer to the insert in the illustration 252. Check that there is no binding after this tightening sequence in step 9 and step 10.

End By:

a. Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

b. 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".

i01954554

Connecting Rod Bearings - Remove

Removal Procedure

Start By:

a. 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: Remove one pair of connecting rod caps at a time and install one pair at a time. Damage can occur when the fractured split connecting rods are separated.

1. In order to remove the connecting rod caps, rotate the crankshaft in a clockwise direction until one pair of pistons is at the bottom center position.

Note: Check that the connecting rod and the cap are correctly marked to the cylinder. If the connecting rod assembly requires marking do not punch the connecting rod assembly or stamp the connecting rod assembly as this may cause damage.

2. Remove the torx screws from the caps and remove both pair of caps with the bearing shells. Push both pair of connecting rods into the cylinder. Do not allow the connecting rods to contact the piston cooling jets.

3. Carefully rotate the crankshaft in order to give access to both pair of connecting rods.

4. Remove the bearing shells from the connecting rods and the caps.

5. Before continuing with the next pair of connecting rods, install all the new bearing shell into the connecting rods and caps. Refer to Disassembly and Assembly , "connecting rod bearing - install".

i01953533

Connecting Rod Bearings - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten bearing component life.

1. Carefully rotate the crankshaft in order to give access to the connecting rod.

2. Ensure that the components are clean before the components are assembled.

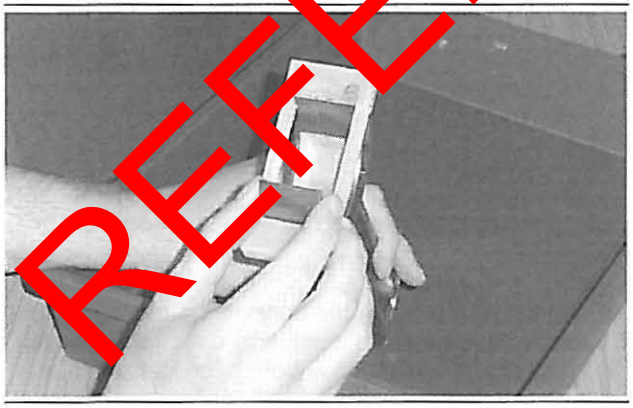

Illustration 253 g01000785
Alignment of the shell

Note: The alignment tool is supplied with the new bearing shells.

3. The bearing shell for the connecting rod must be aligned by a tool before the bearing shells are installed. Refer to illustration 253. Check the alignment of the shell and remove the tool from the assembly. The bearing shell must be an equal distance from each end. Refer to illustration 254. Lubricate both the bearing shells and lubricate the crankshaft journal.

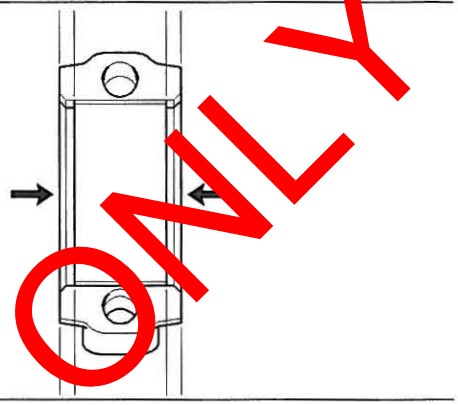

Illustration 254 g01001160
Aligned shell

4. Pull the connecting rod onto the crankshaft journal and install the correctly marked cap with the bearing shell onto the connecting rod.

Note: Do not allow the connecting rod into contact with the piston cooling jet.

5. Install new torx screws into the connecting rod assembly. Tighten the torx screws to 20 N·m (14 lb ft). Rotate the crankshaft in order to check for binding. Again tighten the torx screws to 70 N·m (51 lb ft).

   Finally rotate the torx screws by 120 degrees.

Note: Rotate the crankshaft in order to recheck that there is no binding.

End By:

a. Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

b. 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".

i01980468

Crankshaft Main Bearings - Remove

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

b. Only if the engine is not equipped with a balancer, remove the engine oil pump. Refer to this Disassembly and Assembly Manual, "Engine Oil Pump - Remove".

c. If the engine is equipped with a balancer, remove the balancer. Only remove the engine oil pump if it is necessary. Refer to this Disassembly and Assembly Manual, "Balancer - Remove".

d. Remove the flywheel housing in order to remove the rear main bearing with the crankshaft in position. Refer to this Disassembly and Assembly Manual, "Flywheel Housing - Remove and Install".

e. Remove the crankshaft rear seal in order to remove the rear main bearing with the crankshaft in position. Refer to this Disassembly and Assembly Manual, "Crankshaft Rear Seal - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

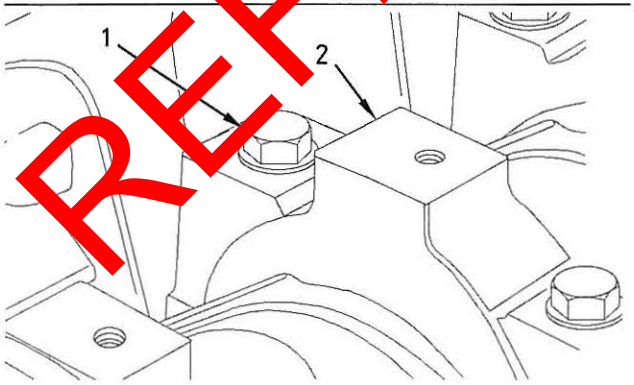

Illustration 255 g00947823

Note: The main bearings and the main bearing caps (2) must be installed in the same location when the engine is reassembled.

1. Make sure that the main bearing caps (2) are marked for the location and direction for installation.

2. Remove the setscrews (1) and the main bearing cap (2).

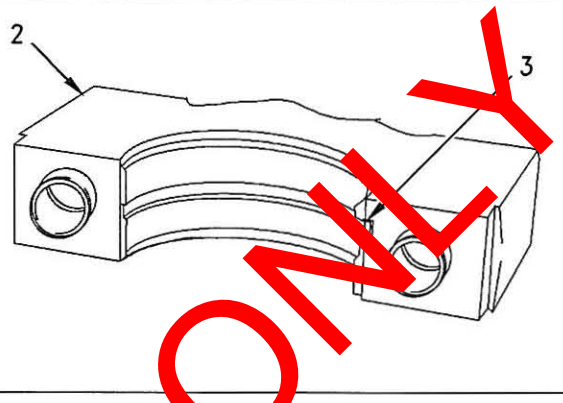

Illustration 256 g00934803

3. Remove the lower bearing shell (3) from the main bearing cap (2). Keep the respective bearing shell (3) and the main bearing cap (2) together for proper installation.

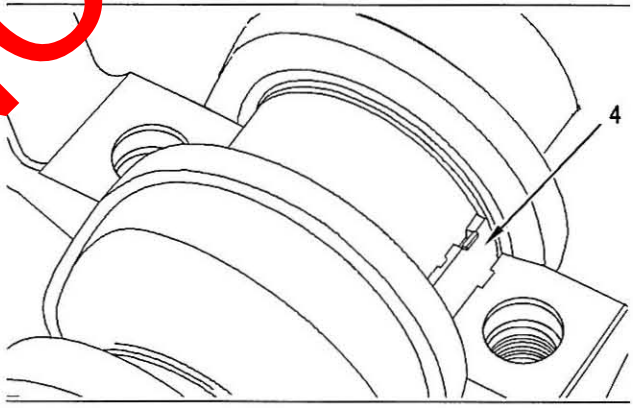

Illustration 257 g00934767

4. Push the upper bearing shell (4) from the opposite side of the bearing tab with a suitable tool. Carefully rotate the crankshaft while you push on the bearing shell (4). Remove the upper bearing shell (4) from the cylinder block. Keep all of the upper halves of the bearing shells (4) together in order to ensure proper installation.

5. Repeat Step 2 through Step 4 for the remaining main bearings.

Note: Thrust washers (5) and (6) are installed onto one main bearing in order to limit crankshaft end play. These thrust washers are installed onto the No. 3 main bearing of the three cylinder and onto the center main bearing of the four cylinder engine. The removal procedure is identical for the three cylinder and the four cylinder engines. The appropriate illustrations show the four cylinder engine.

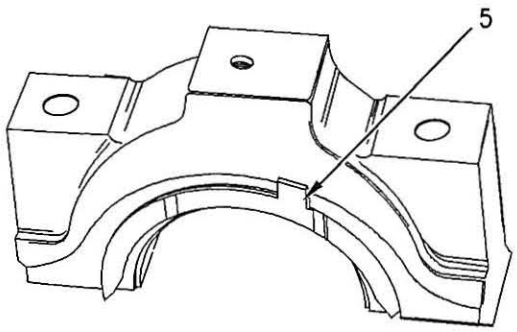

Illustration 258 g00934744
Typical example

6. Remove the lower half of the thrust washer (5) from each side of the appropriate main bearing cap.

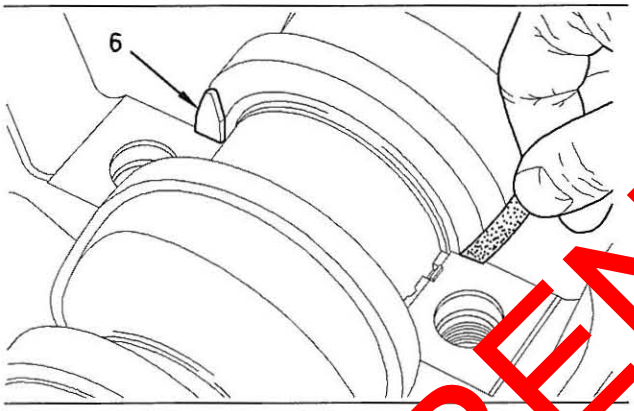

Illustration 259 g[illegible]753
Typical example

7. Remove the upper half of the thrust washer (6) from each side of the appropriate main bearing in the cylinder block with a suitable tool. Carefully rotate the crankshaft while you push on the thrust washer (6). If necessary, move the crankshaft to the front or to the rear of the engine in order to loosen or tight thrust washer (6).

i01980478

Crankshaft Main Bearings - Install (Crankshaft in Position)

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

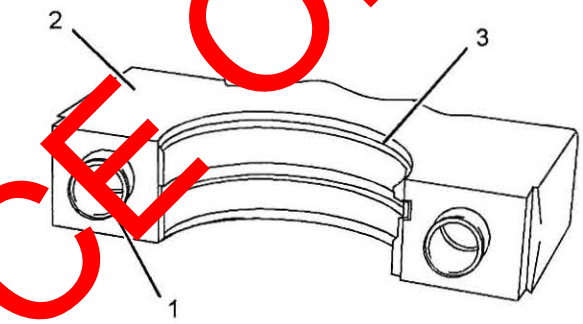

Illustration 260 g01026621

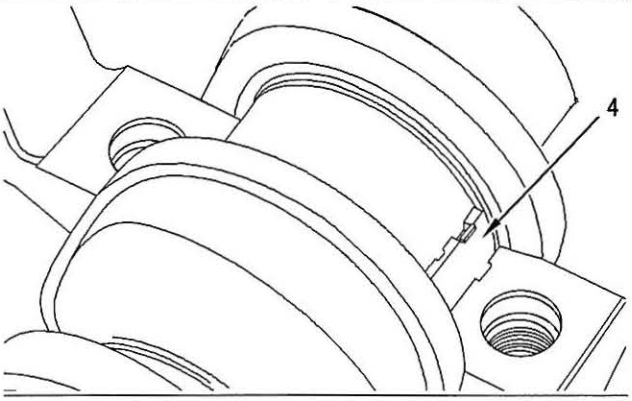

Illustration 261 g00934767

Note: Ensure that the lower bearing shells (3), the upper bearing shells (4), and the appropriate main bearing caps (2) are kept in sets and in the correct sequence for installation.

1. Ensure that all of the main bearing caps (2) are clean and dry. Ensure that both of the hollow dowels (1) are not damaged and that the hollow dowels are securely in place within the main bearing cap (2).

2. Gently wipe the lower bearing shells (3) and the upper bearing shells (4) in order to ensure that the bearing shells are clean and dry. Inspect the lower bearing shells (3) and the upper bearing shells (4). If necessary, replace the bearing shells that are worn or damaged.

Note: Bearing shells must be replaced in pairs. If a pair of bearing shells need to be replaced, consider replacing all of the bearing shells at the same time.

Note: The upper bearing shell for the No. 1 crankshaft journal has a lubricating oil slot. The remaining upper bearing shells have an oil hole for lubrication. All new upper bearing shells will have the slot for lubrication.

3. Gently wipe the main journals of the crankshaft in order to ensure that the main journals are clean and dry.

4. Lubricate the bearing surface of the upper bearing shell (4) and lubricate the appropriate main journal with clean engine oil.

Note: Ensure that the upper bearing shell (4) is installed so that the bearing tabs fit into the notch in the cylinder block.

NOTICE
Only the upper half of the main bearing has lubrication holes. Make sure the upper half of the main bearing is installed correctly in the cylinder block to ensure proper lubrication.

5. Slide the upper bearing shell (4) into position between the appropriate crankshaft journal and the cylinder block.

6. Lubricate the bearing face of the appropriate lower bearing shell (3) with clean engine oil.

Note: Ensure that the lower bearing shell (3) is installed so that the bearing tab fits into the notch in the appropriate main bearing cap.

7. Install the lower bearing shell (3) into the appropriate main bearing cap (2). Install the main bearing cap (2) into the appropriate position and ensure that the hollow dowels (1) are located within the main bearing cap and within the recesses in the cylinder block.

8. Repeat Step 4 through Step 7 for the remaining main bearings.

Note: Thrust washers (5) and (6) are installed onto one main bearing in order to limit crankshaft end play. These thrust washers are installed onto No. 3 main bearing of the three cylinder and onto the center main bearing of the four cylinder engine. The installation procedure is identical for the three cylinder and the four cylinder engines. The appropriate illustrations show the four cylinder engine.

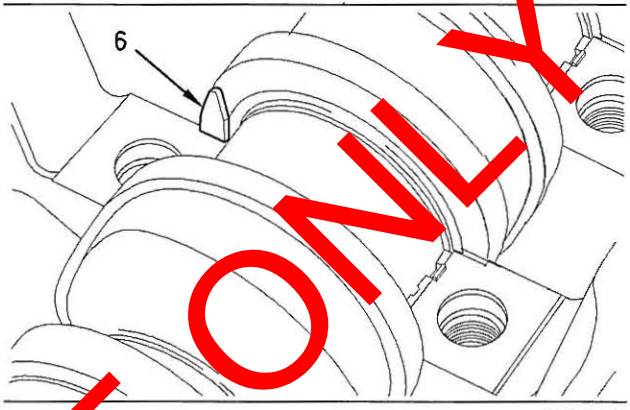

Illustration 262 g00947861
Typical example

9. Gently wipe the upper thrust washers (6) and the lower thrust washers (5) in order to ensure that the thrust washers are clean and dry. Inspect the upper thrust washers (6) and the lower thrust washers (5). If necessary, replace any damaged thrust washers.

10. Lightly lubricate the upper thrust washers (6) with clean engine oil. Install the upper thrust washers (6) onto each side of the appropriate main bearing in the cylinder block. The grooves on the upper thrust washers (6) must be located against the crankshaft. If necessary, move the crankshaft to the front or to the rear in order to install the thrust washers (6).

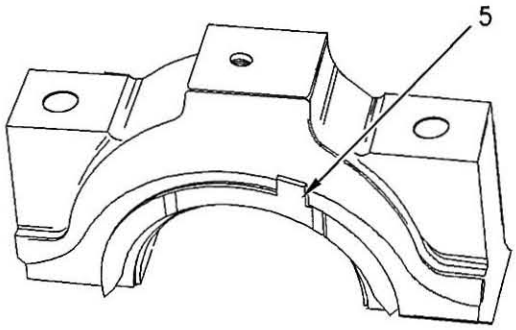

Illustration 263 g00934744
Typical example

11. Lightly lubricate the lower thrust washers (5) with clean engine oil. Install the lower thrust washers (5) onto each side of the appropriate main bearing cap. The grooves on the lower thrust washers (5) must be located against the crankshaft.

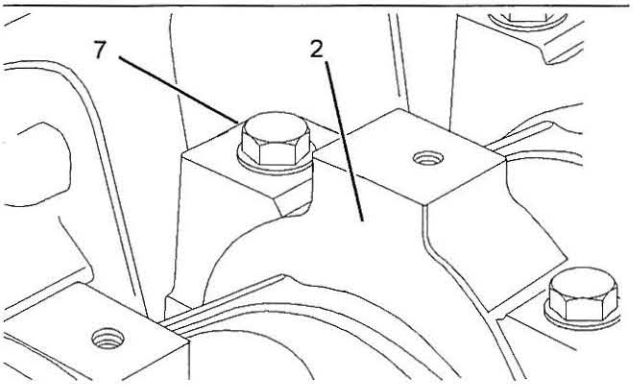

Illustration 264 g01026633

12. Lubricate the threads of the setscrews (7) with clean engine oil.

13. Install the setscrews (7). Tighten the setscrews (7) to a torque of 245 N·m (181 lb ft).

14. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

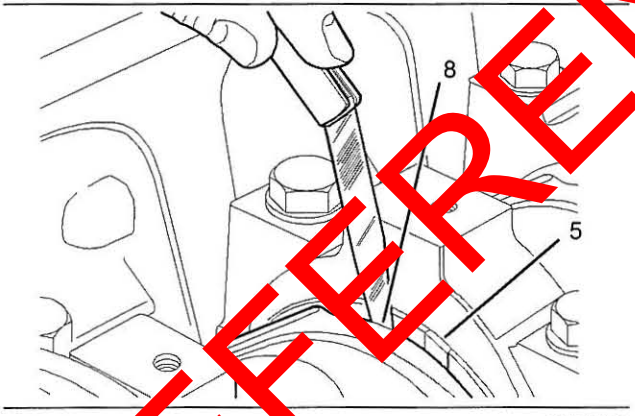

Illustration 2[illegible] g01026647

15. Check the crankshaft end play. Use a prybar to move the crankshaft toward the front of the engine. Use a suitable feeler gauge to measure the end play (8) between rear thrust washer (5) and the crankshaft. The maximum permissible crankshaft end play is 0.51 mm (0.020 inch).

End By:

a. Install the rear bridge. Refer to this Disassembly and Assembly Manual, "Crankshaft - Install".

b. Install the crankshaft rear seal. Refer to this Disassembly and Assembly Manual, "Crankshaft Rear Seal - Install".

c. Install the flywheel housing. Refer to this Disassembly and Assembly Manual, "Flywheel Housing - Remove and Install".

d. If the engine is equipped with a balancer and the engine oil pump was removed from the balancer, install the engine oil pump. Install the balancer. Refer to this Disassembly and Assembly Manual, "Balancer - Install".

e. If the engine is not equipped with a balancer, install the engine oil pump. Refer to this Disassembly and Assembly Manual, "Engine Oil Pump - Install".

f. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i01981186

Crankshaft - Remove

Removal Procedure

Start By:

a. Remove the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

b. Only if the engine is not equipped with a balancer, remove the engine oil pump. Refer to this Disassembly and Assembly Manual, "Engine Oil Pump - Remove".

c. If the engine is equipped with a balancer, remove the balancer. Only remove the engine oil pump if it is necessary. Refer to this Disassembly and Assembly Manual, "Balancer - Remove".

d. Remove the flywheel housing. Refer to this Disassembly and Assembly Manual, "Flywheel Housing - Remove and Install".

e. Remove the crankshaft rear seal. Refer to this Disassembly and Assembly Manual, "Crankshaft Rear Seal - Remove".

f. Remove the front housing. Refer to this Disassembly and Assembly Manual, "Housing (Front) - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

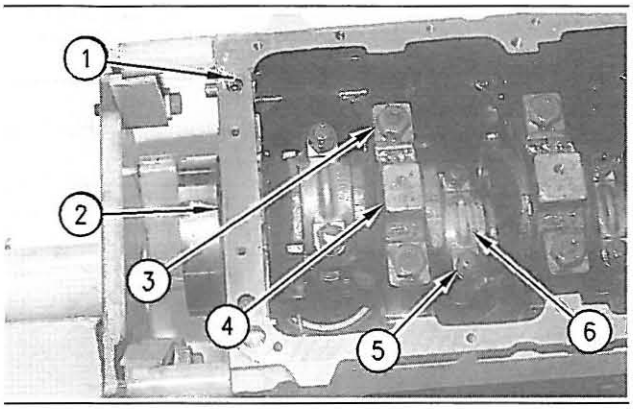

Illustration 266 g00975296
Typical example

1. Remove the Allen head screws (1) from the bridge (2).

2. Remove the bridge (2) from the cylinder block.

Note: Make sure that the main bearing caps (4) and the connecting rod caps (6) are marked for the location and direction for installation.

Note: This procedure assumes that the engine has been removed from the application and that the engine has been inverted. **If the engine is not inverted or if the bottom end of the engine has not been moved through at least 90 degrees horizontally, remove the connecting rods from the cylinder bores.** Refer to this Disassembly and Assembly Manual, "Pistons and Connecting Rods - Remove" for further information. Proceed to Step 6.

3. If the engine has been inverted or if the bottom end of the engine has been moved through at least 90 degrees horizontally, remove the setscrews (5) from the connecting rods. Discard the setscrews (5).

Note: Do not reuse the setscrews (5). Use new setscrews in order to secure the connecting rod cap for reassembly.

4. Remove the connecting rod bearing caps (6) from the connecting rods. Remove the bearing shells from the connecting rod bearing caps. Keep the bearing shell for the connecting rod cap with the appropriate connecting rod cap.

NOTICE
Do not allow the connecting rods to strike the piston cooling jets. Damage or misalignment may occur.

5. Push the piston assemblies into the cylinder bores.

Note: This procedure assumes that the engine has been removed from the application and that the engine has been inverted. **If the engine has not been inverted, ensure that the crankshaft is fully supported before removing the setscrews (3) for the main bearing caps (4).**

6. Remove the setscrews (3) from the main bearing caps (4).

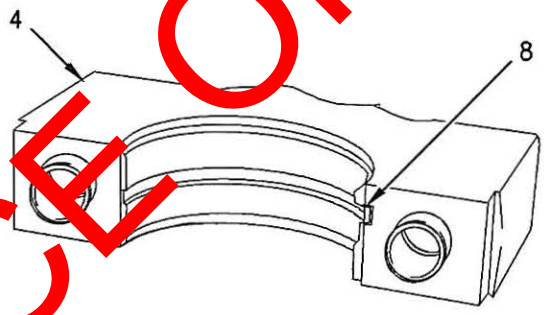

Illustration 267 g00975478

7. Remove the main bearing caps (4) from the cylinder block. Remove the bearing shells (8) from the main bearing caps (4). Keep the main bearing shells (8) with the respective main bearing cap (4).

8. Attach lifting straps and a suitable lifting device to the crankshaft. Lift the crankshaft out of the cylinder block. Take care to ensure that you do not scratch any of the finished surfaces on the crankshaft.

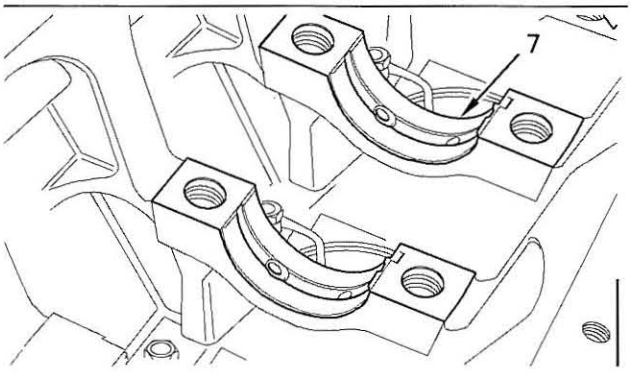

Illustration 268 g00975313

9. Remove the upper main bearing shells (7). Keep the upper main bearing shells with the respective main bearing caps (4).

Note: Thrust washers (9) and (10) are installed onto one main bearing in order to limit crankshaft end play. These thrust washers are installed onto the No. 3 main bearing of the three cylinder and the center main bearing of the four cylinder engine. The removal procedure is identical for the three cylinder and the four cylinder engines. The appropriate illustrations show the four cylinder engine.

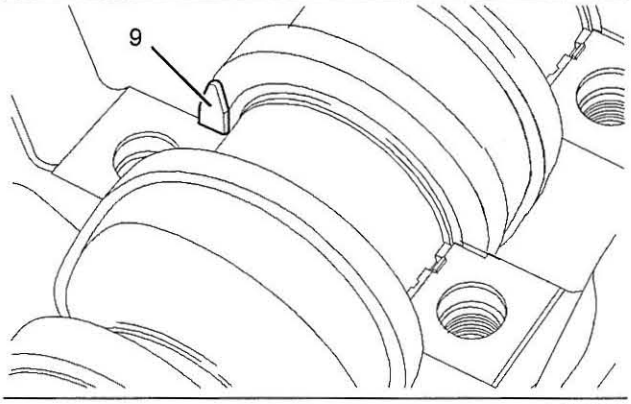

Illustration 269 g01026869
Typical example

10. Remove the upper thrust washers (9) from the appropriate main bearing block.

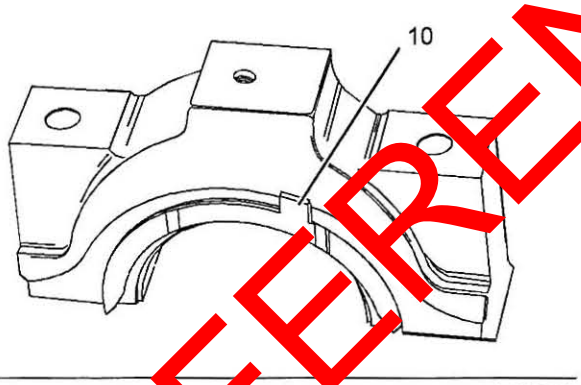

Illustration 270 g01026870
Typical example

11. Remove the lower thrust washers (10) from the appropriate main bearing cap.

i01981309

Crankshaft - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

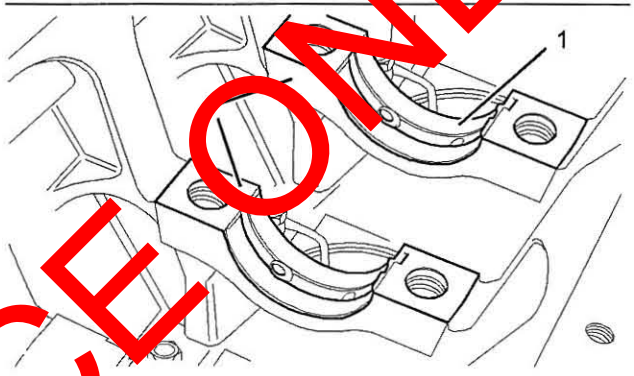

Illustration 271 g01027152

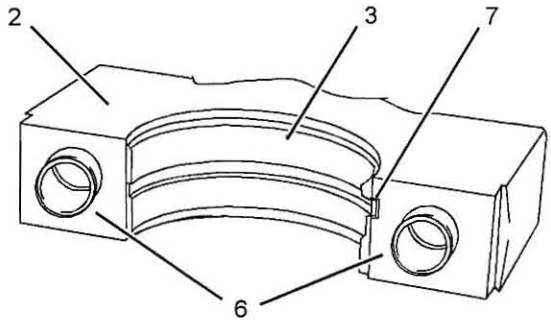

Illustration 272 g01027338
Typical example

Note: Ensure that the upper bearing shells (1), the appropriate main bearing caps (2), and the appropriate lower bearing shells (3) are kept in sets and in the correct sequence for installation.

1. Ensure that all of the housings (4) in the cylinder block for the upper bearing shells (1) are clean and dry. Ensure that all of the lubrication passages in the housings (4) are clean and free from debris.

2. Gently wipe the lower bearing shells (3) and the upper bearing shells (1) in order to ensure that the bearing shells are clean and dry. Inspect the lower bearing shells (3) and the upper bearing shells (1). If necessary, replace the bearing shells that are worn or damaged.

Note: Bearing shells must be replaced in pairs. If a pair of bearing shells need to be replaced, consider replacing all of the bearing shells at the same time.

Note: The upper bearing shell for the No. 1 crankshaft journal has a lubricating oil slot. The remaining upper bearing shells (1) have an oil hole for lubrication. All new upper bearing shells (1) will have the slot for lubrication.

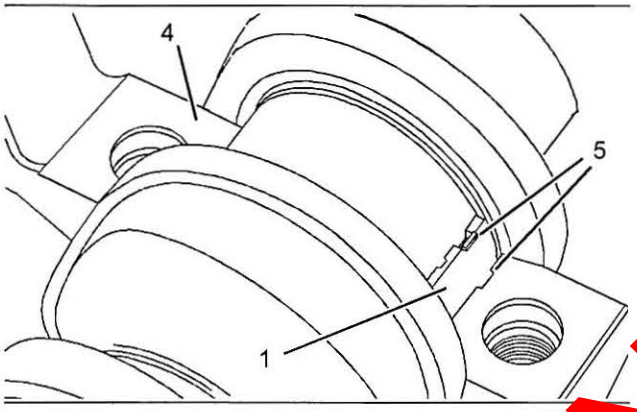

Illustration 273 g010[illegible]

3. Install the upper main bearing shells (1). The bearing tabs (5) for the upper main bearing shells (1) must be located in the correct position in the cylinder block (5). Lubricate the upper main bearing shells (1) with clean engine oil.

4. Ensure that all of the main bearing caps (2) are clean and dry. Ensure that both of the hollow dowels (6) are not damaged and that two hollow dowels are securely in place within each of the main bearing caps (2).

Note: This procedure assumes that the engine has been removed from the application and that the engine has been inverted. **If the engine has not been inverted, ensure that the crankshaft is completely supported until the main bearing caps (2) and the setscrews are completely installed.**

5. Gently wipe the main journals of the crankshaft in order to ensure that the main journals are clean and dry. Attach suitable lifting straps to the crankshaft.

6. Take care to ensure that you do not scratch any of the finished surfaces on the crankshaft and that you do not damage the upper main bearing shells (1) or dislodge the upper main bearing shells. The crankshaft is heavy. Use suitable lifting equipment to carefully lift the crankshaft into the upper main bearing shells (1).

7. Install the appropriate lower main bearing shells (3) into main bearing caps (2) with the bearing tabs (7) in the correct position. Lubricate the lower main bearing caps (2) with clean engine oil.

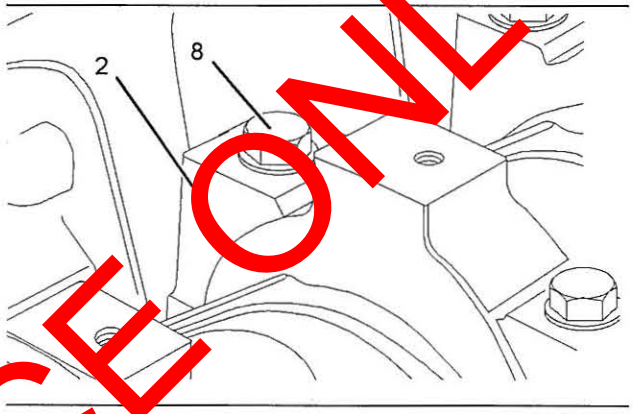

Illustration 274 g01027339

Note: Do not install the No. 3 main bearing cap of the three cylinder or the center main bearing cap of the four cylinder engine at this time.

8. Use the hollow dowels (6) in order to locate the appropriate main bearing caps (2) and install the main bearing caps into the appropriate housing (4) in the cylinder block. Insert the setscrews (8) finger tight.

Note: Thrust washers (9) and (10) are installed onto one main bearing in order to limit crankshaft end play. These thrust washers are installed onto the No. 3 main bearing of the three cylinder and the center main bearing of the four cylinder engine. The installation procedure is identical for the three cylinder and the four cylinder engines. The appropriate illustrations show the four cylinder engine.

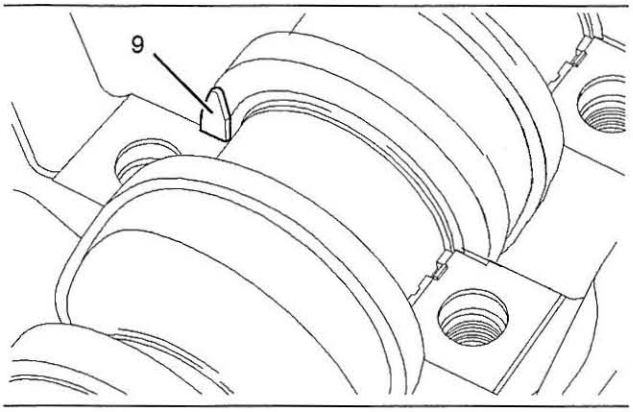

Illustration 275 g01026869
Typical example

9. Clean the upper half of the thrust washers (9) and lubricate the upper half of thrust washers. Place the upper half of the thrust washers (9) into both side recesses in the cylinder block next to the housing for the appropriate main bearing shell. The grooves on the thrust washer (9) must be located against the crankshaft.

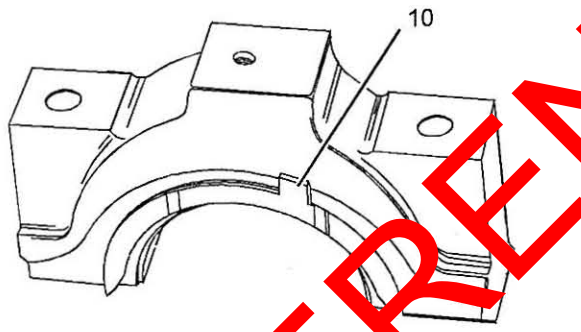

Illustration 276 g01026870
Typical example

10. Clean the lower half of the thrust washers (10) and lubricate the lower half of thrust washers. Place the lower half of the thrust washers (10) on both sides of the appropriate main bearing cap. The grooves on the thrust washers (10) must be located against the crankshaft.

11. Install the No. 3 main bearing cap onto the crankshaft of the three cylinder or the center main bearing cap onto the crankshaft of the four cylinder engine. Install the remaining setscrews (8).

12. Tighten all of the setscrews (8) to a torque of 245 N·m (181 lb ft).

13. If the piston assemblies were removed previously, install the piston assemblies. Refer to this Disassembly and Assembly Manual, "Pistons and Connecting Rods - Install". Go to Step 18.

14. If the piston assemblies are still inside the cylinder bores, ensure that the upper bearing shells for the connecting rods are centered in the connecting rods. Ensure that the lower bearing shells for the connecting rods are centered in the connecting rod caps (11). Lubricate the faces of the bearing shell with clean engine oil.

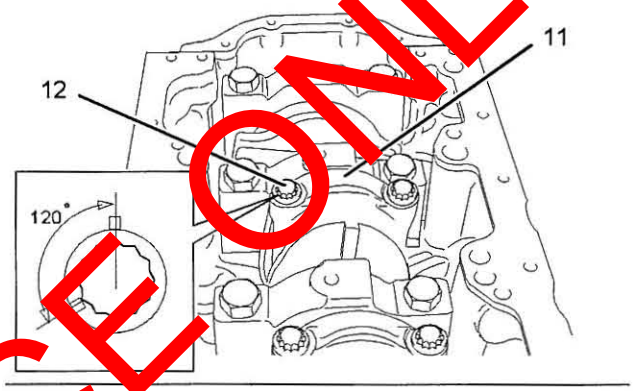

Illustration 277 g01027370
Typical example

15. Install the connecting rod caps (11). Install new setscrews (12) into the connecting rods. Tighten the setscrews (12) evenly to an initial torque of 18 N·m (13 lb ft).

Note: Do not reuse the old setscrews (12) in order to secure the connecting rod caps (11).

Note: Ensure that the etched number on the connecting rod bearing cap matches the etched number on the connecting rod. Ensure that the etched numbers are on the same side.

16. The setscrews must be tightened again to a higher torque. Tighten the setscrews (12) to a torque of 70 N·m (52 lb ft).

17. Finally tighten the setscrews (12) for an additional 120 degrees. Refer to the insert in the Illustration 277 in order to achieve the correct final torque.

18. Rotate the crankshaft in order to ensure that there is no binding.

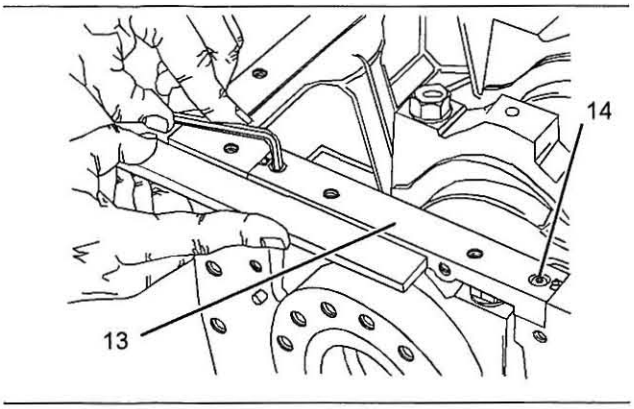

Illustration 278 g01027384

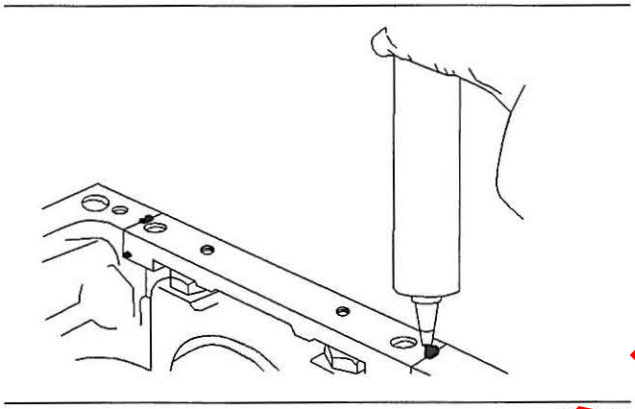

Illustration 279 g00

19. Clean the bridge (13) and the face of the cylinder block. Apply a thin bead of 2 326958 POWERPART Silicone Adhesive onto the corner of the seat for the bridge. Also apply POWERPART Silicone Adhesive around the thread holes in the seat for the bridge. Use the following steps when you apply POWERPART Silicone Adhesive to the cylinder block and the bridge.

a. Apply a 3.0 mm (0.12 inch) bead of the POWERPART Silicone Adhesive along the corner of the recess in the cylinder block.

Note: The maximum protrusion for the bridge (13) from the outside of the cylinder block is 0.075 mm (0.0029 inch).

Install the bridge (13). Use a straight edge to line up the bridge with the face of the cylinder block. Tighten the socket head screws (14) to a torque of 16 N·m (12 lb ft). Tighten the socket head screws (14) evenly.

c. When the bridge (13) is positioned and the socket head screws (14) have been tightened, inject POWERPART Silicone Adhesive into the groove that is at each end of the bridge. The groove must be completely filled.

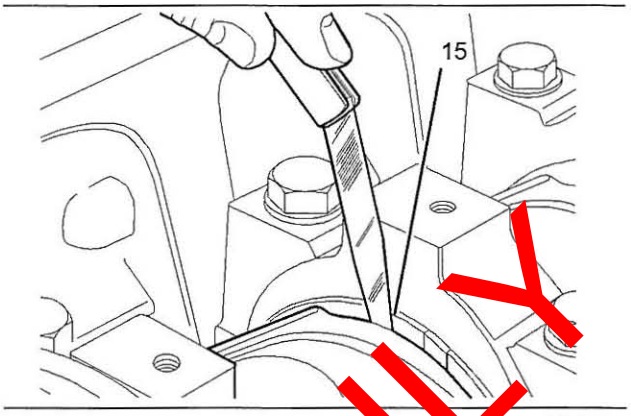

Illustration 280 g01027386

20. Check the crankshaft end play. Use a prybar to move the crankshaft toward the front of the engine. Use a feeler gauge to measure the end play (15) between the rear thrust washer and the crankshaft. Refer to the Specifications Manual, "Crankshaft" for the further information.

End By:

a. Install the front housing. Refer to this Disassembly and Assembly Manual, "Housing (Front) - Install".

Install the crankshaft rear seal. Refer to this Disassembly and Assembly Manual, "Crankshaft Rear Seal - Install".

c. Install the flywheel housing. Refer to this Disassembly and Assembly Manual, "Flywheel Housng - Remove and Install".

d. If the engine is equipped with a balancer, install the balancer. Refer to this Disassembly and Assembly Manual, "Balancer - Install".

e. If the engine is not equipped with a balancer, install the engine oil pump. Refer to this Disassembly and Assembly Manual, "Engine Oil Pump - Install".

f. Install the engine oil pan. Refer to this Disassembly and Assembly Manual, "Engine Oil Pan - Remove and Install".

i01981176

Crankshaft Gear - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

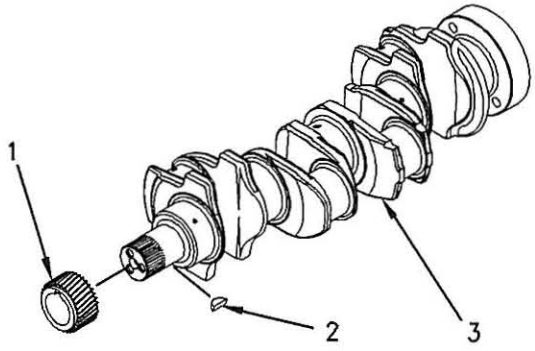

Illustration 281 g00
Typical example

Note: The crankshaft gear (1) may be a slip fit on the crankshaft (3). If the crankshaft (3) is installed in the engine, use a suitable tool to ensure that the crankshaft gear (1) is not a slip fit before the crankshaft is removed from the engine.

1. If the crankshaft gear (1) is a slip fit on the crankshaft (3), use a suitable tool to remove the crankshaft gear and proceed to Step 4.

2. If the crankshaft gear (1) is not a slip fit on the crankshaft (3), remove the crankshaft from the engine. Refer to this Disassembly and Assembly Manual, "Crankshaft - Remove".

3. Use suitable tooling to remove the crankshaft gear (1) from the crankshaft (3).

4. Remove the key (2) from the crankshaft (3).

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

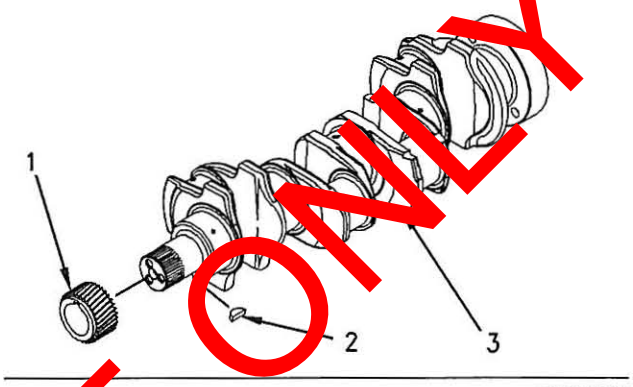

Illustration 282 g00970345
Typical example

1. Thoroughly clean the journal on the crankshaft (3) for the crankshaft gear (1) and the keyway slot for the key (2). Inspect the journal for the crankshaft gear (1), the keyway slot, and the key for wear and/or damage. If necessary, replace any damaged component.

2. Install the key (2) into the keyway slot in the crankshaft (3).

Note: The crankshaft gear (1) may be a slip fit on the crankshaft (3).

3. Check if the crankshaft gear (1) is a slip fit on the crankshaft (3). If the crankshaft gear (1) is a slip fit on the crankshaft (3), proceed to Step 5.

Note: Ensure that heat is applied to the crankshaft gear (1) only. Do not apply heat directly onto the crankshaft (3).

Note: Ensure that suitable clothing is worn in order to handle the heated crankshaft gear.

4. If the crankshaft gear is not a slip fit on the crankshaft, heat the crankshaft gear in an oven to 200 °C (392 °F).

5. Ensure that the shoulder on the crankshaft gear (1) is installed toward the front of the crankshaft (3). Install the crankshaft gear (1) onto the crankshaft (3) and the key (2).

End By:

a. If the crankshaft was removed from the engine, install the crankshaft (3) at an appropriate time. Refer to this Disassembly and Assembly Manual, "Crankshaft - Install".

i01981742

Bearing Clearance - Check

Measurement Procedure

Table 28

Required Tools	
Description	**Qty**
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 the possibility of damaging the bearing shell or the journal surfaces. Each Perkins bearing shell is quality checked by Perkins for specific wall thickness.

Note: These measurements should be within specifications and the correct bearing shells should be used. No further checks are necessary if the main journals and the bearing shells were measured during disassembly of the engine. No further checks are necessary if the crank pins of the crankshaft and the bearing shells were checked during the disassembly of the connecting rods. However, Plastic Gauge is an acceptable method if the technician still wants to measure the clearance of the bearing shell. Plastic Gauge 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 Plastic Gauge correctly. The following points must be remembered:

- Ensure that the backs of the bearing shells and the bores of the bearing shells are clean and dry.
- If the bearing shells have locking tabs ensure that the locking tabs are properly seated in the tab grooves.
- The crankshaft must be free of oil at the contact points of the Plastic Gauge.

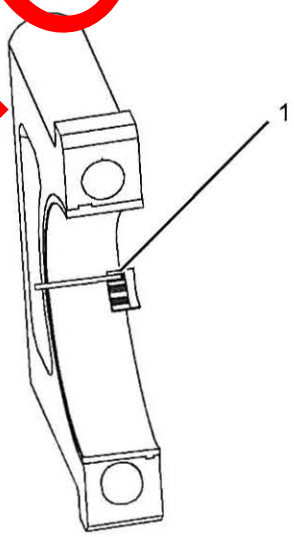

Illustration 283 g01010832
Typical example

1. Put a piece of the Plastic Gauge (1) on the crown of the bearing shell that is in the cap.

Note: Do not allow the Plastic Gauge (1) to extend over the edge of the bearing shell.

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 shell when the cap is installed.

Note: Do not turn the crankshaft when the Plastic Gauge (1) is installed.

3. Carefully remove the bearing cap, but do not remove the Plastic Gauge (1). Measure the width of the Plastic Gauge (1) while the Plastic Gauge is in the bearing cap or on the crankshaft journal. Refer to the Illustration 283.

4. Remove all of the Plastic Gauge (1) before you install the bearing cap.

Note: When Plastic Gauge is used, the readings can sometimes be unclear. For example, all parts of the Plastic Gauge are not the same width. Measure the major width in order to ensure that the parts are within the specification range. Refer to the Specifications Manual, "Connecting Rod Bearing Journal" and refer to the Specifications Manual, "Main Bearing Journal" for the correct clearances.

i02280117

Glow Plugs - Remove and Install (If Equipped)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

1. Turn the disconnect switch to the OFF position.

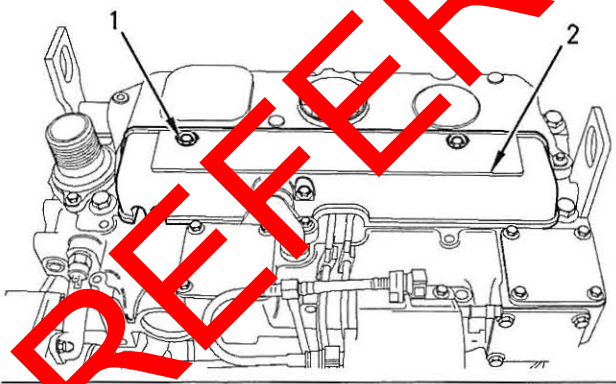

Illustration 284 g01001306
Typical example

2. Remove the setscrews (1). Remove the cover (2) from the cylinder head.

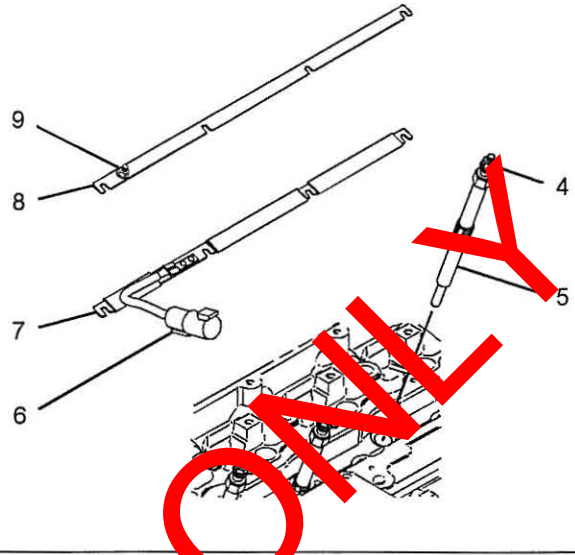

Illustration 285 g01119840

3. Disconnect the harness assembly from the Deutch connector(6) on the bus bar (7), if equipped.

4. Disconnect the harness assembly from the stud (9) on the bus bar (8), if equipped.

5. Loosen the nuts (4) that secure the bus bar (7) or (8) to the glow plugs (5).

6. Remove the bus bar from the glow plugs.

7. Remove the glow plugs from the cylinder head.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

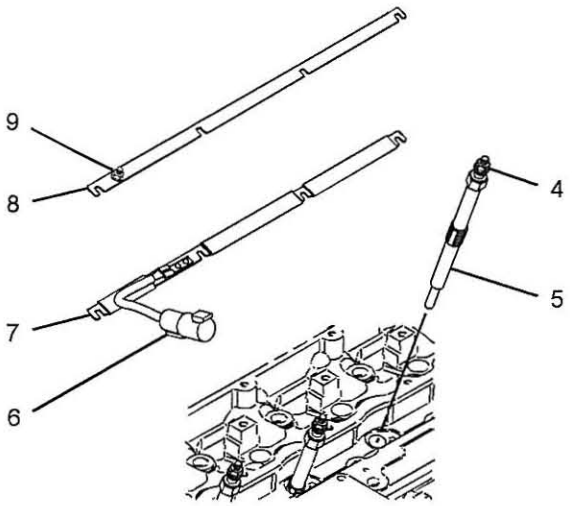

Illustration 286 g01119840
Typical example

1. Clean the threads of the glow plugs.
2. Install the glow plugs (5) into the cylinder head. Tighten the glow plugs to a torque of 15 N·m (11 lb ft).
3. Position the bus bar (7) or (8) onto the glow plugs. Tighten the nuts (4) on the glow plugs to a torque of 2 N·m (17 lb in).
4. Connect the harness assembly to the Deutsch connector (5) on the bus bar (7), if equipped.
5. Connect the harness assembly to the stud (9) on the bus bar (8), if equipped.

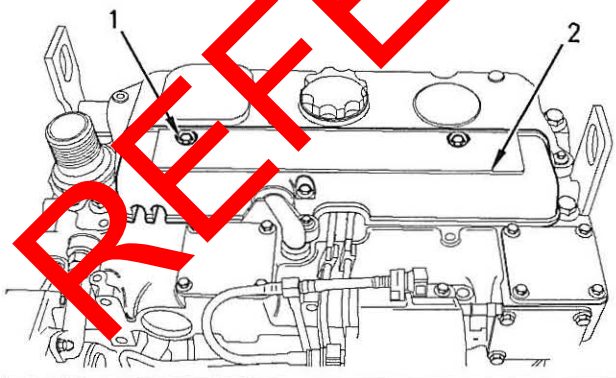

Illustration 287 g01001306
Typical example

6. Position the cover (2) onto the cylinder head. Install the setscrews (1). Tighten the setscrews to a torque of 9 N·m (80 lb in).
7. Turn the disconnect switch to the ON position.

i02011941

V-Belts - Remove and Install

Removal Procedure

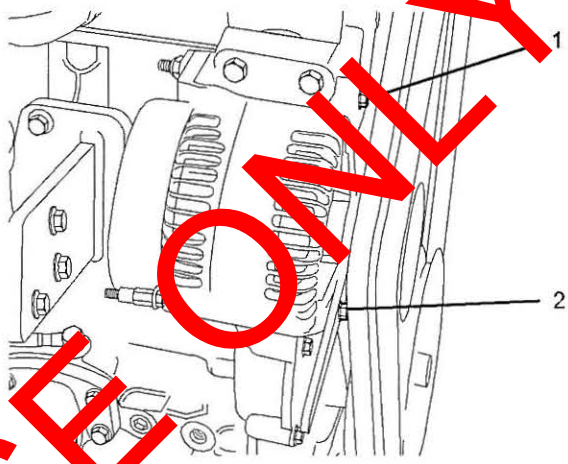

Illustration 288 g01015311

1. Loosen the setscrew (1), and the tension adjustment setscrew (2). Slide the alternator toward the engine.
2. Maneuver the V-belts around the fan and remove the V-belts.

Note: Never replace only one V-belt. Always replace the V-belts as a set.

Installation Procedure

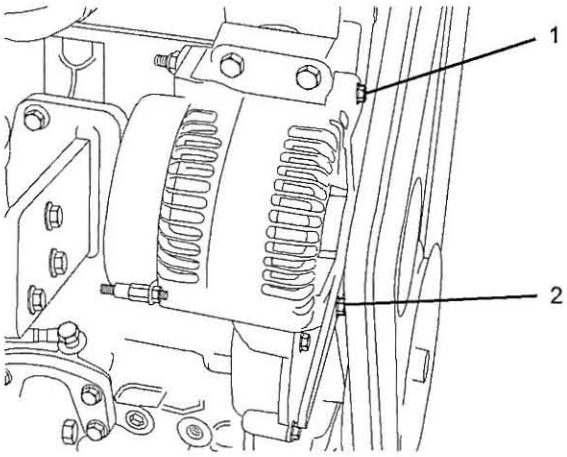

Illustration 289 g01015311

1. Install the V-belts behind the fan and onto the correct pulleys.
2. Adjust the tension on the V-belts by moving the alternator away from the engine. Tighten the tension adjustment setscrew (2) after the correct belt tension is made. Refer to Specifications, "Belt Tension Chart" for the correct tension of the V-belts. Tighten the tension adjustment setscrew (2) to a torque of 78 N·m (58 lb ft).
3. Tighten the setscrew (1) to a torque of 22 N·m (16 lb ft).
4. Tighten the nut (1) to a torque of 22 N·m (16 lb ft).

i01987612

Fan - Remove and Install

Removal Procedure

Start By:

a. Remove the V-Belts. Refer to this Disassembly and Assembly Manual, "V-Belts - Remove and Install".

Note: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustration shows the four cylinder engine.

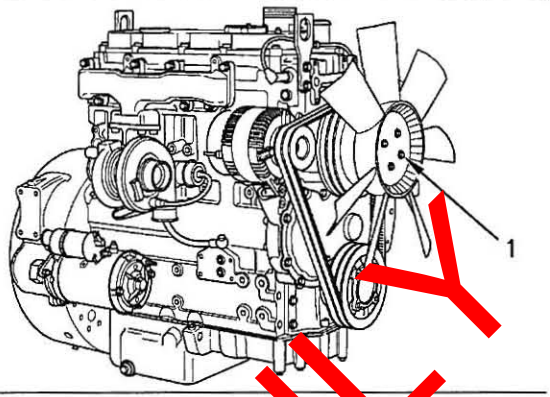

Illustration 290 g00926178
Typical example

1. Remove the setscrew (1).
2. Remove the fan.
3. If equipped, remove the extension for the fan.
4. Remove the fan pulley.

Installation Procedure

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. The illustration shows the four cylinder engine.

1. Inspect the condition of the fan pulley. Replace the fan pulley, if necessary.
2. Install the fan pulley.
3. If the engine is equipped with an extension for the fan, install the extension.
4. Inspect the condition of the fan and replace the fan, if necessary.
5. Install the fan.

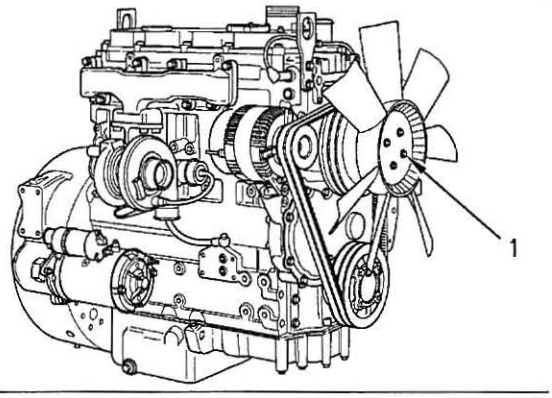

Illustration 291 g00926178
Typical example

6. Install the setscrews (1). Tighten the setscrews (1) to a torque of 12 N·m (9 lb ft).

End By:

a. Install the V-Belts. Refer to this Disassembly and Assembly Manual, "V-Belts - Remove and Install".

i02011983

Fan Drive - Remove and Install

Removal Procedure

Start By:

a. Remove the fan. Refer to this Disassembly and Assembly Manual, "Fan - Remove and Install".

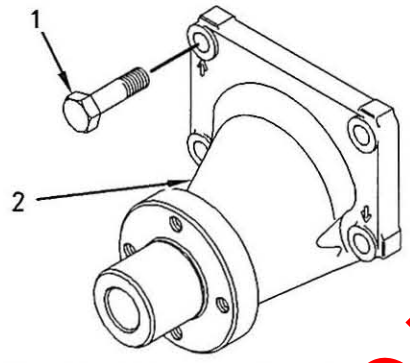

Illustration 292 g00[illegible]500

1. Remove the setscrews (1) from the fan drive (2).
2. Remove the fan drive (2).

Installation Procedure

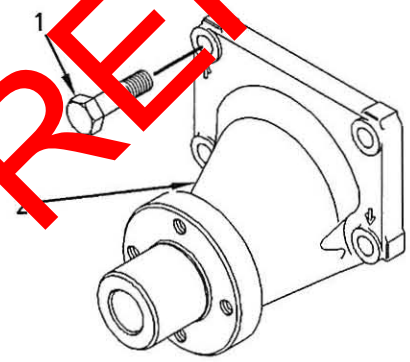

Illustration 293 g00944500

1. Install the fan drive (2).
2. Install the setscrews (1). Tighten the setscrews to a torque of 44 N·m (32 lb ft).

End By:

a. Install the fan. Refer to this Disassembly and Assembly Manual, "Fan - Remove and Install".

i02012014

Alternator - Remove

Removal Procedure

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

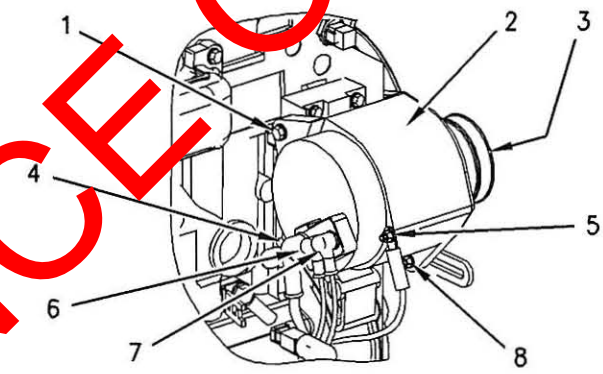

Illustration 294 g00999883
Typical Example

2. Place an index mark on all of the harness assemblies that are connected to the alternator.
3. Disconnect the harness assemblies (4), (6), and (7) from the alternator.
4. Disconnect the ground harness assembly (5) from the alternator.
5. Loosen the nut and the setscrew (1).
6. Remove the tension adjustment setscrew (8) and slide the alternator (2) toward the engine. Remove the V-belts from the alternator pulley.
7. Remove the setscrew (1) from the alternator bracket. Remove the alternator (2) from the engine.
8. If necessary, remove the nut (3) and the alternator pulley from the alternator.

i02245824

Alternator - Install

Installation Procedure

Note: If the alternator pulley was removed, install the alternator pulley and the nut (3). Tighten the nut to a torque of 80 N·m (59 lb ft).

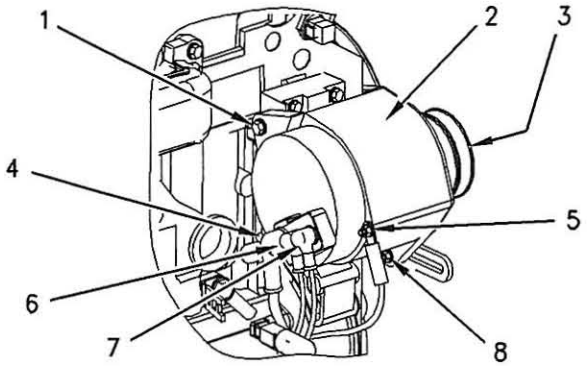

Illustration 295 g00999883
Typical Example

1. Put the alternator (2) in position onto the engine.
2. Install the nut and the setscrew (1). Tighten the nut finger tight.
3. Install the tension adjustment setscrew (8) through the adjustment bracket and into the alternator. Do not tighten the tension adjustment setscrew (8) at this time.
4. Install the V-belts onto the alternator pulley. Adjust the tension on the V-belts by moving the alternator (2) away from the engine. Tighten the tension adjustment setscrew (8) after the correct belt tension is made. Refer to the Specifications Manual, "Belt Tension Chart" for the correct tension of the V-belts.
5. Tighten the nut and the setscrew (1).
6. Connect the harness assemblies (4), (6), and (7) to the alternator.
7. Connect the ground harness assembly (5) to the alternator.
8. Refer to the Specifications Manual, "Alternator " for the correct torque for the terminal nuts.
9. Turn the battery disconnect switch to the ON position.

i01987613

Electric Starting Motor - Remove and Install

Removal Procedure

Note: The removal procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

1. Ensure that the battery is disconnected or isolated.
2. Place an identification mark on all of the harness assemblies that are connected to the starting motor (4).

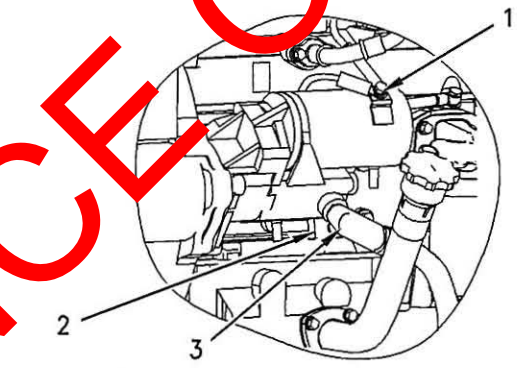

Illustration 296 g00999973
Typical Example

3. Disconnect the ground harness assembly (1) from the starting motor (4).
4. Disconnect the harness assembly (2) and disconnect the harness assembly (3) from the starting motor (4).

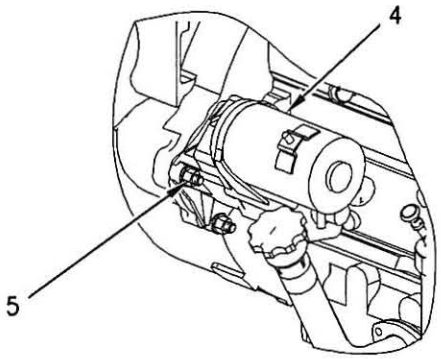

Illustration 297 g00999956
Typical Example

5. Remove the nuts (5) from the studs.

6. Remove the electric starting motor (4) from the flywheel housing.

Installation Procedure

Note: The installation procedure is identical for the three cylinder and the four cylinder engines. The illustrations show the four cylinder engine.

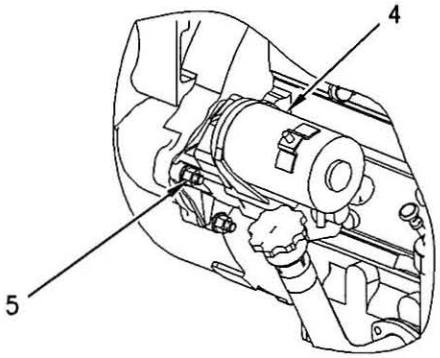

Illustration 298 g00999956
Typical Example

1. Install the electric starting motor (4) onto the flywheel housing.

2. Install the nuts (5) onto the studs. Tighten the nuts (5) to a torque of 44 N·m (32 lb ft).

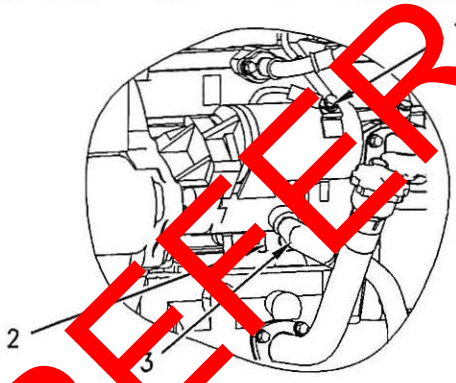

Illustration 299 g00999973
Typical Example

3. Connect the harness assembly (3), and the harness assembly (2) to the electric starting motor (4). Refer to the Specifications Manual, "Starter Motor" for the appropriate torques for the terminal nuts.

4. Connect the harness assembly (1) to the electric starting motor (4). Refer to the Specifications Manual, "Starter Motor" for the appropriate torques for the terminal nuts.

5. Turn the isolator for the battery to the ON position or reconnect the battery.

i02641613

Vacuum Pump - Remove and Install (Some 1104 engines only)

Removal Procedure

1. Disconnect the oil line from the vacuum pump and install a plastic cap onto the oil line. Install a plastic cap into the oil port in the vacuum pump.

2. Disconnect the vacuum line from the vacuum pump and install a plastic cap into the vacuum line. Install a plastic cap into the vacuum port in the vacuum pump.

3. Remove the setscrews and remove the vacuum pump from the front housing.

4. Remove the joint from the front housing and discard the joint.

Installation Procedure

1. Clean all dirt and oil from the surface area around the ports in the vacuum pump. Clean the mating faces on the vacuum pump and the front housing.

2. Install a new joint to the front housing and install the vacuum pump onto the housing with the setscrews. Tighten the setscrews to a torque of 22 N·m (16 lb ft).

3. Remove the plastic caps from the vacuum line and from the port in the vacuum pump. Install the vacuum line to the vacuum pump.

4. Remove the plastic caps from the oil line and from the port in the vacuum pump. Install the oil line to the vacuum pump.

i01981808

Hydraulic Pump (Steering) - Remove

Removal Procedure

1. Disconnect all of the hydraulic fluid lines from the hydraulic steering pump. Insert plastic caps into all of the open ports in the hydraulic steering pump and insert plastic caps onto the open ends of the hydraulic fluid lines.
2. Remove the setscrews that secure the hydraulic steering pump to the front housing and remove the hydraulic steering pump from the front housing.
3. Remove the O-ring from the front of the hydraulic steering pump. Discard the O-ring.

i02641617

Hydraulic Pump (Steering) - Install

Installation Procedure

1. Clean all dirt and oil from the surface area around the ports in the hydraulic steering pump. Clean the location of the O-ring at the front of the hydraulic steering pump. Clean the drive gear or the drive coupling for the hydraulic steering pump. Clean the mating surfaces of the hydraulic steering pump and the front housing.
2. Lubricate a new O-ring with clean engine oil. Install the O-ring onto the front of the hydraulic steering pump.
3. Install the hydraulic steering pump onto the front housing with the setscrews. Tighten the setscrews to a torque of 22 N·m (16 lb ft).
4. Remove the plastic caps from the hydraulic fluid lines and from the ports in the hydraulic steering pump. Install the hydraulic fluid lines to the hydraulic steering pump.

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