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Perkins®

# Service Manual

## 1104D Industrial Engine

Model NH and NJ

Comprising:

| | |
|---|---|
| Operation and Maintenance Manual (OMM) | **SEBU8172-00** |
| Systems Operation Testing and Adjusting (SO&A) | **SENR7967-00** |
| Specifications (Specs) | **SENR8913-00** |
| Disassembly and Assembly (D&A) | **SENR9525-00** |
| Trouble Shooting Guide (TSG) | **SENR9982-00** |
| Electrical Schematic (ES) | **RENR9959-00** |

REFERENCE ONLY

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Perkins®

SEBU8172-01
March 2008

# Operation and Maintenance Manual

## 1104D Industrial Engine

NH (Engine)
NJ (Engine)

REFERENCE ONLY

# Important Safety Information

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

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

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

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

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

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

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

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

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

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

**⚠ WARNING**

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

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

REFERENCE ONLY

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REFERENCE ONLY

# 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 engine 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**.

REFERENCE ONLY

# Safety Section

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## Safety Messages

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

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

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

### (1) Universal Warning

**⚠ WARNING**

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

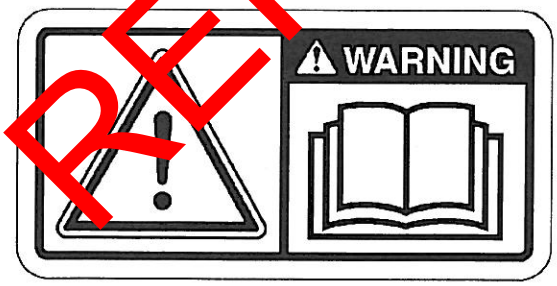
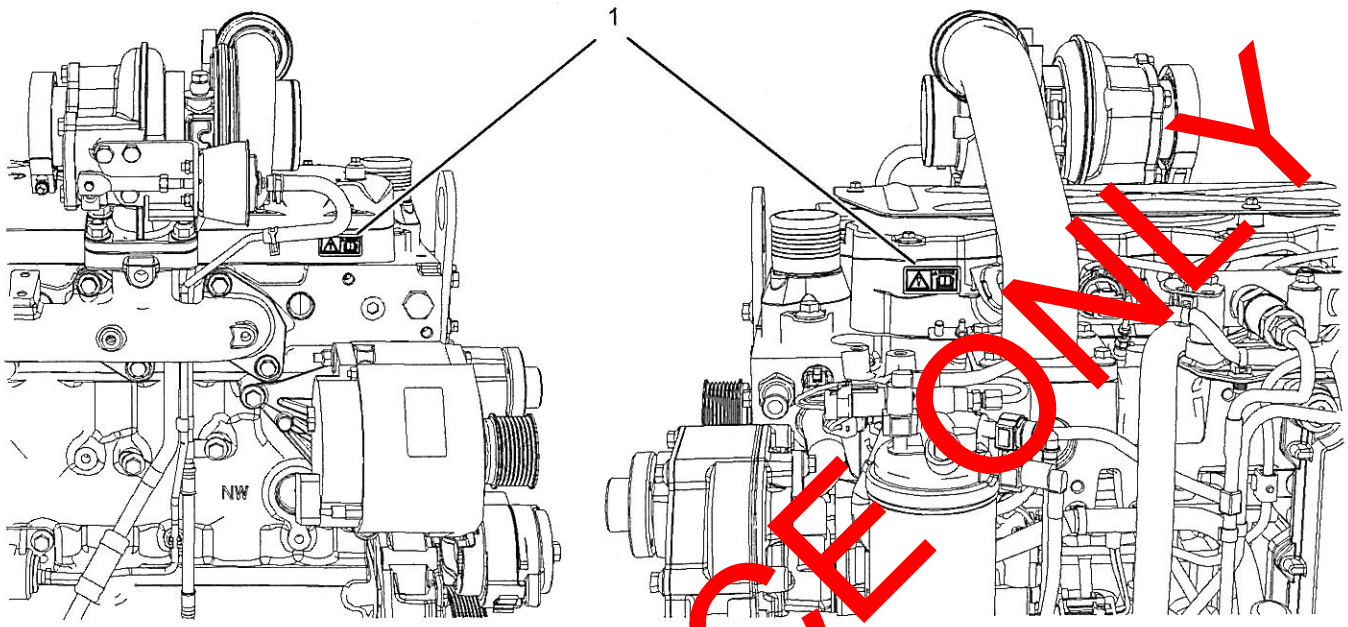



Illustration 1 g01154807
Typical example

The Universal Warning label (1) is located on both sides of the valve mechanism cover base. Refer to illustration 1.

REFERENCE ONLY




g01268960

Illustration 2

(1) Universal warning

## (2) Hand (High Pressure)

**⚠ WARNING**

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

REFERENCE ONLY

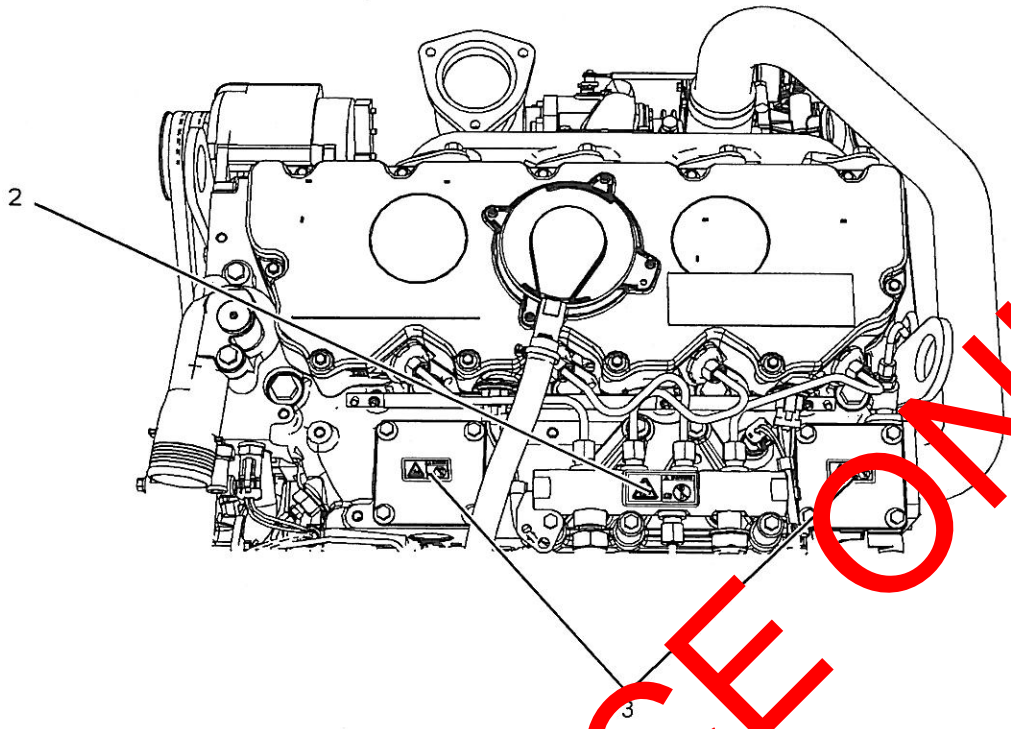



Illustration 3 g01426636

(2) Hand (High Pressure) (3) Ether




Illustration 4 g01154858

Typical example




Illustration 5 g01154809

Typical example

The warning label for the Hand (High Pressure) (2) is located on the top of the fuel manifold. Refer to illustration 4.

## (3) Ether

**WARNING**

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

The ether warning label (3) is located on the cover of the inlet manifold. Refer to illustration 4.

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

REFERENCE ONLY

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# General Hazard Information

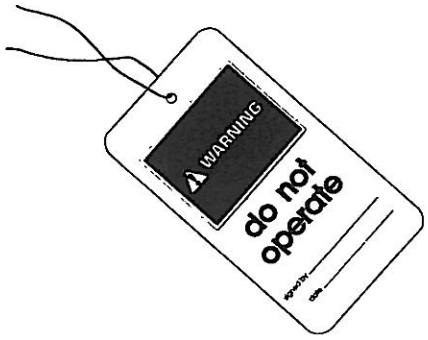



Illustration 6 g00104545

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



Illustration 7 g00702020

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

Do not wear loose clothing or jewelry that can snag on controls or 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 blow 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.

REFERENCE ONLY

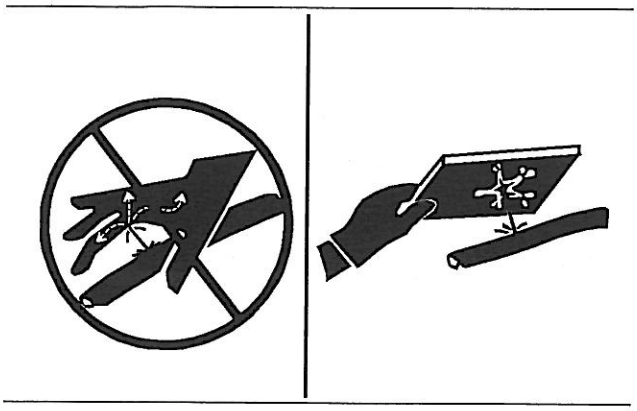


Illustration 8 g00687600

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

## Containing Fluid Spillage

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

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

Obey all local regulations for the disposal of liquids.

i02334785

# Burn Prevention

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine.

**⚠ WARNING**

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

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines.

Allow the pressure to be purged in the fuel system, in the hydraulic system, in the lubrication system, or in the cooling system before any lines, fittings or related items are disconnected.

## Coolant

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

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

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

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

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

## Oils

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

## Batteries

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

REFERENCE ONLY

i02320721

# Fire Prevention and Explosion Prevention

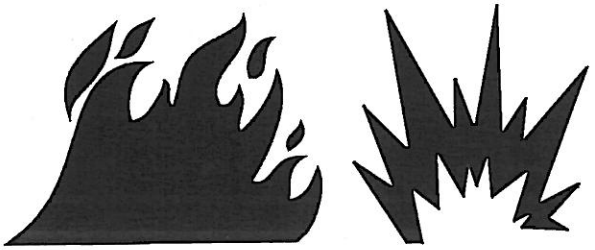


Illustration 9 g00704000

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

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

After the emergency stop button is operated, ensure that you allow 15 minutes, before the engine covers are removed.

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

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

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

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

Do not expose the engine to any flame.

Exhaust shields (if equipped) protect hot exhaust components from oil or fuel spray in 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.

**⚠ WARNING**

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

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines.

Ensure that the engine is stopped. 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.

Oil filters and fuel filters must be correctly installed. The filter housings must be tightened to the correct torque. Refer to the Disassembly and Assembly manual for more information.

REFERENCE ONLY



Illustration 10 g00704059

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



Illustration 11 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. Keep the recommended cables, connections, and battery box covers when the engine is operated.

## Fire Extinguisher

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

## Lines, Tubes and Hoses

Do not bend high pressure lines. Do not strike high pressure lines. Do not install any lines that are damaged.

Leaks can cause fires. Consult your Perkins dealer or your Perkins distributor for replacement parts.

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

- High pressure fuel line or lines are removed.
- End fittings are damaged or leaking.
- Outer coverings are chafed or cut.
- Wires are exposed.
- Outer coverings are ballooning.
- Flexible 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.

REFERENCE ONLY

i02143194

# Crushing Prevention and Cutting Prevention

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

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

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

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

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

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

i02235[illegible]2

# Mounting and Dismounting

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

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

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

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

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

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# High Pressure Fuel Lines

**⚠ WARNING**

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

REFERENCE ONLY

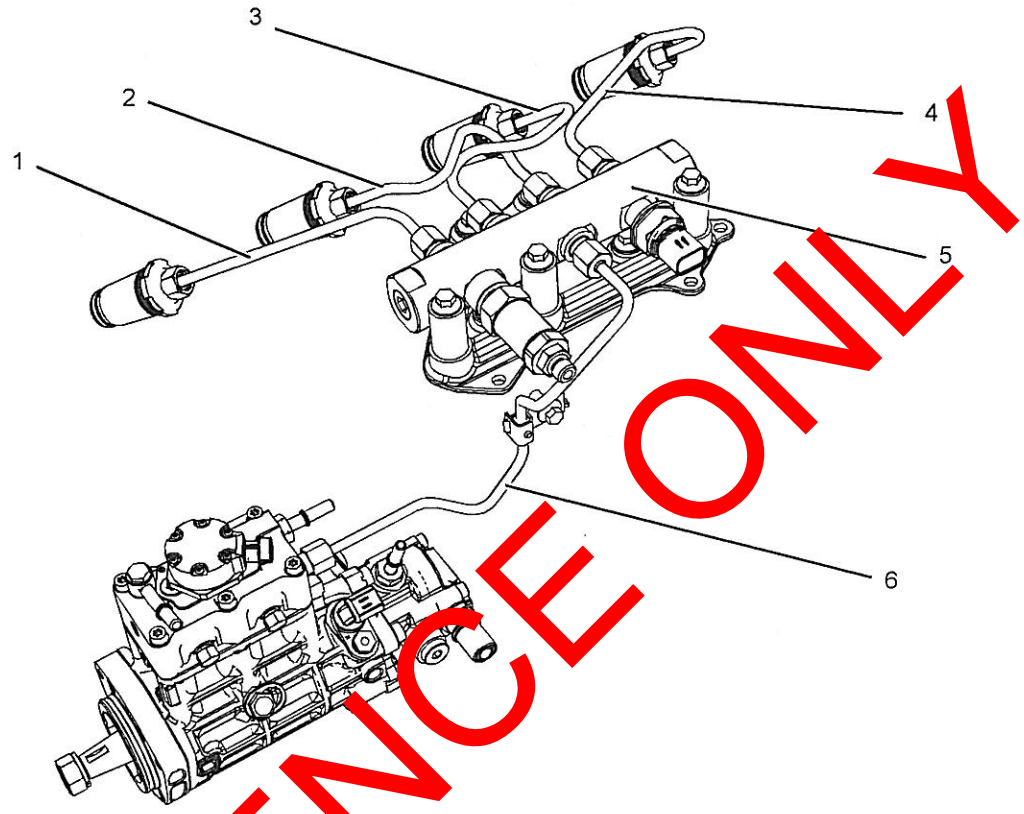



Illustration 12 g01425090

(1) High pressure line
(2) High pressure line
(3) High pressure line
(4) High pressure line
(5) High pressure fuel manifold (rail)
(6) High pressure line

The high pressure fuel lines are the fuel lines that are between the high pressure fuel pump and the high pressure fuel manifold and the fuel lines that are between the fuel manifold and cylinder head. These fuel lines are different from fuel lines on other fuel systems.

This is because of the following differences:

- The high pressure fuel lines are constantly charged with high pressure.
- The internal pressures of the high pressure fuel lines are higher than other types of fuel system.
- The high pressure fuel lines are formed to shape and then strengthened by a special process.

Do not step on the high pressure fuel lines. Do not deflect the high pressure fuel lines. Do not bend or strike the high pressure fuel lines. Deformation or damage of the high pressure fuel lines may cause a point of weakness and potential failure.

Do not check the high pressure fuel lines with the engine or the starting motor in operation. After the engine has stopped allow 60 seconds to pass in order to allow the pressure to be purged before any service or repair is performed on the engine fuel lines.

Do not loosen the high pressure fuel lines in order to remove air from the fuel system. This procedure is not required.

Visually inspect the high pressure fuel lines before the engine is started. This inspection should be each day.

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General Hazard Information”.

- Inspect the high pressure for the following: damage, deformation, a nick, a cut, a crease, or a dent

REFERENCE ONLY

- Do not operate the engine with a fuel leak. If there is a leak do not tighten the connection in order to stop the leak. The connection must only be tightened to the recommended torque. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Remove and Fuel Injection Lines - Install".
- If the high pressure fuel lines are torqued correctly and the high pressure fuel lines are leaking the high pressure fuel lines must be replaced.
- Ensure that all clips on the high pressure fuel lines are in place. Do not operate the engine with clips that are damaged, missing or clips that are loose.
- Do not attach any other item to the high pressure fuel lines.
- Loosened high pressure fuel lines must be replaced. Also removed high pressure fuel lines must be replaced. Refer to Disassembly and Assembly Manual, " Fuel Injection Lines - Install".

i02813489

## Before Starting Engine

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

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

Inspect the engine for potential hazards.

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

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

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

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

See the Service Manual for repairs and for adjustments.

i02251260

## Engine Starting

**WARNING**

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

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

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

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

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

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

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

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

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

REFERENCE ONLY

i02234873

## Engine Stopping

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

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

Stop the engine if an overspeed condition occurs during the initial start-up of a new engine or an engine that has been overhauled.

To stop an electronically controlled engine, cut the power to the engine and/or shutting off the air supply to the engine.

i02234878

## Electrical System

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

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

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

## Grounding Practices

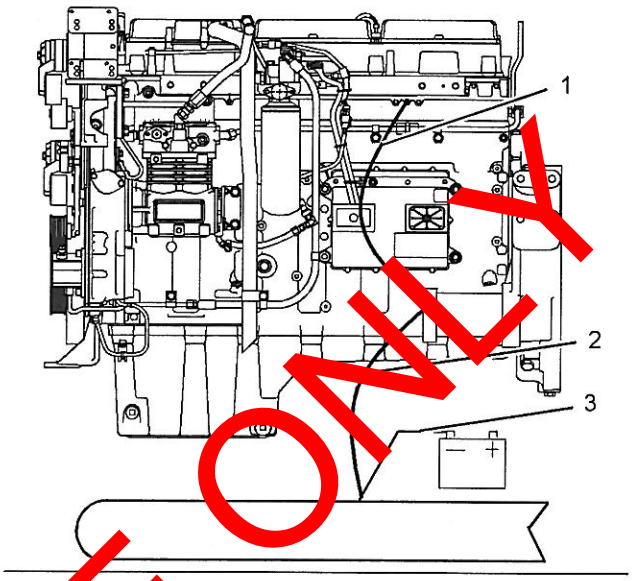



Illustration 13 g01162916

Typical example

(1) Starting motor to engine block
(2) Ground to starting motor
(3) Ground to battery

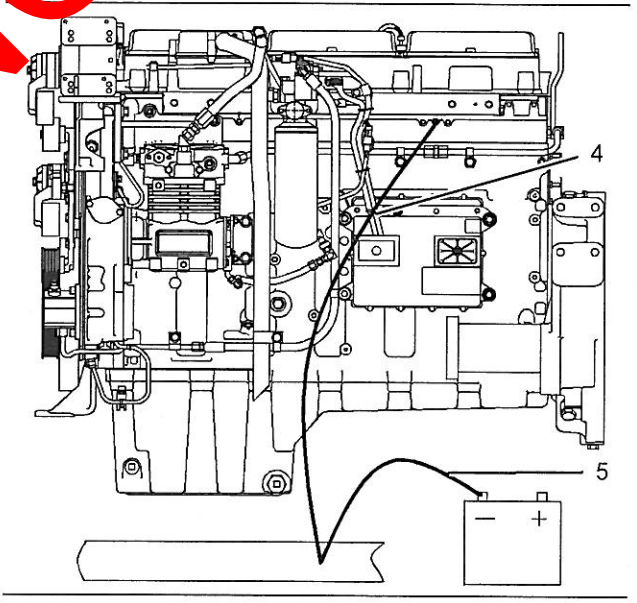



Illustration 14 g01162918

Typical example

(4) Ground to engine
(5) Ground to battery

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

REFERENCE ONLY

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

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

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

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

The power supply connections and the ground connections for the engine electronics should always be from the isolator to the battery.

i02650954

## Engine Electronics

**⚠ WARNING**

**Tampering with the electronic system installation or the OEM wiring installation can be dangerous and could result in personal injury or death and/or engine damage.**

**⚠ WARNING**

**Electrical Shock Hazard. The electronic unit injectors use DC voltage. The ECM sends this voltage to the electronic unit injectors. Do not come in contact with the harness connector for the electronic unit injectors while the engine is operating. Failure to follow this instruction could result in personal injury or death.**

This engine has a comprehensive, programmable Engine Monitoring System. The Electronic Control Module (ECM) has the ability to monitor the engine operating conditions. If any of the engine parameters extend outside an allowable range, the ECM will initiate an immediate action.

The following actions are available for engine monitoring control:

- Warning
- Derate
- Shutdown

The following monitored engine operating conditions have the ability to limit engine speed and/or the engine power:

- Engine Coolant Temperature
- Engine Oil Pressure
- Engine Speed/Timing
- Intake Manifold Air Temperature

The Engine Monitoring package can vary for different engine models and different engine applications. However, the monitoring system and the engine monitoring control will be similar for all engines.

**Note:** Many of the engine control systems and display modules that are available for Perkins Engines will work in unison with the Engine Monitoring System. Together the two controls will provide the engine monitoring function for the specific engine application. Refer to Troubleshooting for more information on the Engine Monitoring System.

REFERENCE ONLY

# Product Information Section

# General Information

i01889424

## Welding on Engines with Electronic Controls

NOTICE
Proper welding procedures are necessary in order to avoid damage to the engine's ECM, sensors, and associated components. When possible, remove the component from the unit and then weld the component. If removal of the component is not possible, the following procedure must be followed when you weld with a unit that is equipped with an Electronic Engine. The following procedure is considered to be the safest procedure to weld a component. This procedure should provide a minimum risk of damage to electronic components.

NOTICE
Do not ground the welder to electrical components such as the ECM or sensors. Improper grounding can cause damage to the drive train bearings, hydraulic components, electrical components, and other components.

Clamp the ground cable from the welder to the component that will be welded. Place the clamp as close as possible to the weld. This will help reduce the possibility of damage.

1. Stop the engine. Turn the switched power to the OFF position.
2. Disconnect the negative battery cable from the battery. If a battery disconnect switch is provided, open the switch.
3. Disconnect the J1/P1 connectors from the ECM. Move the harness to a position that will not allow the harness to accidentally move back and make contact with any of the ECM pins.

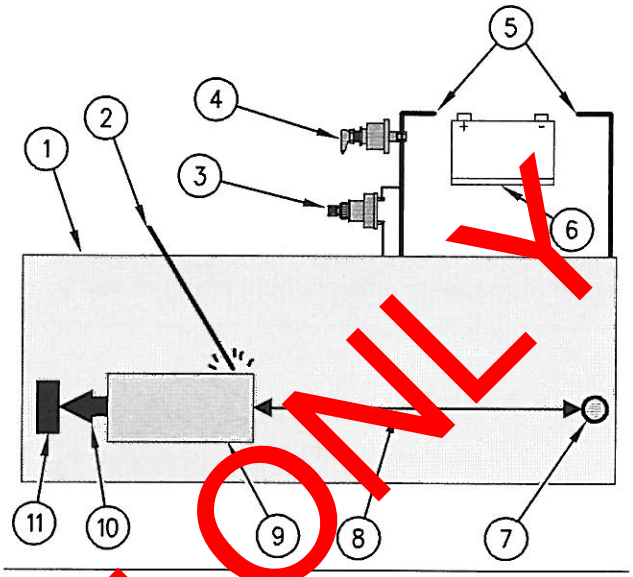



Illustration 15 g00765012

Use the example above. The current flow from the welder to the ground clamp of the welder will not cause damage to any associated components.

(1) Engine
(2) Welding rod
(3) Keyswitch in the OFF position
(4) Battery disconnect switch in the open position
(5) Disconnected battery cables
(6) Battery
(7) Electrical/Electronic component
(8) Maximum distance between the component that is being welded and any electrical/electronic component
(9) The component that is being welded
(10) Current path of the welder
(11) Ground clamp for the welder

4. Connect the welding ground cable directly to the part that will be welded. Place the ground cable as close as possible to the weld in order to reduce the possibility of welding current damage to bearings, hydraulic components, electrical components, and ground straps.

**Note:** If electrical/electronic components are used as a ground for the welder, or electrical/electronic components are located between the welder ground and the weld, current flow from the welder could severely damage the component.

5. Protect the wiring harness from welding debris and spatter.
6. Use standard welding practices to weld the materials.

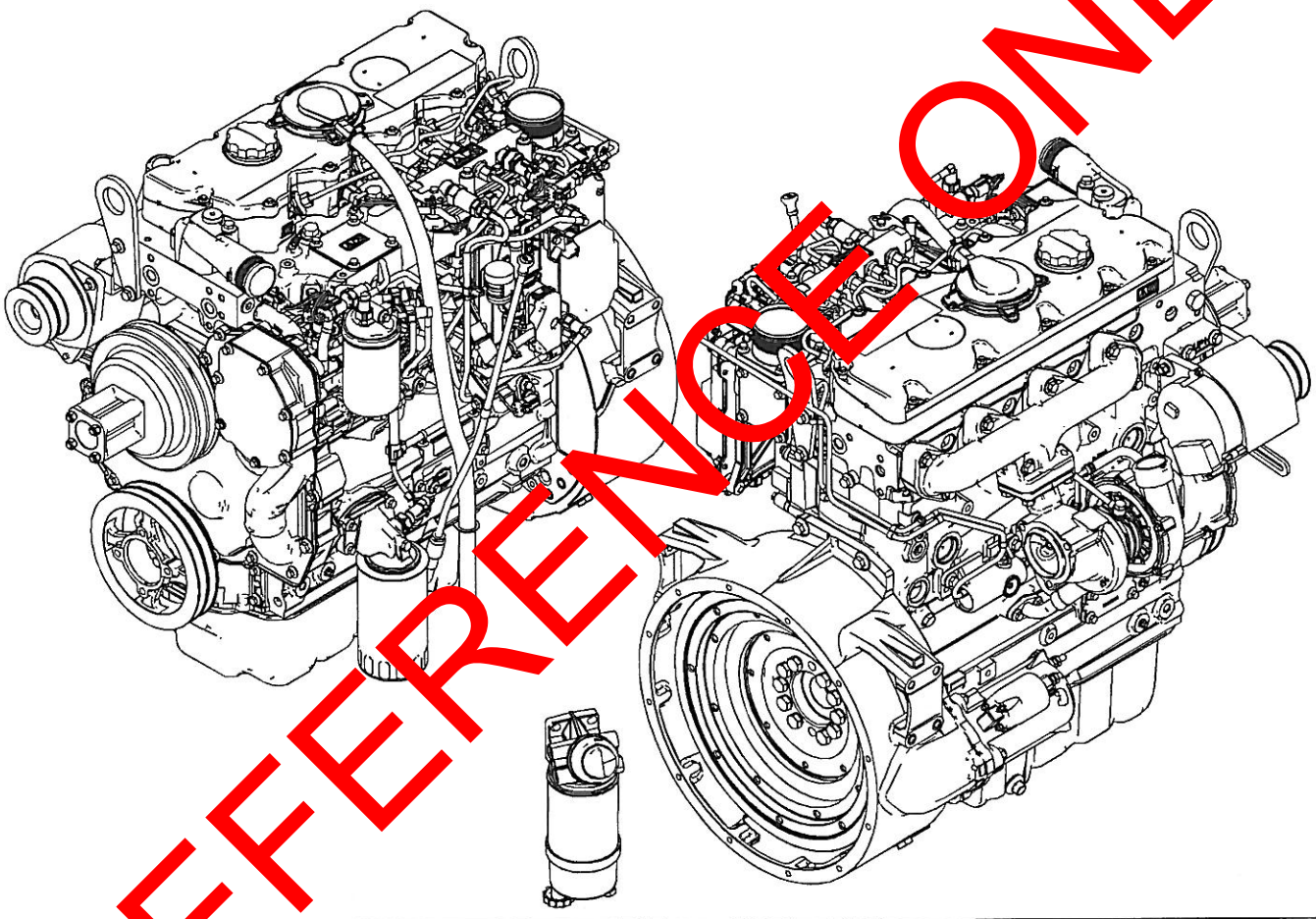
REFERENCE ONLY

# Model Views

i02861104

## Model View Illustrations

The following model views show typical features of the engine. Due to individual applications, your engine may appear different from the illustrations.



g01425089

Illustration 6

The 3104D PJU engine is turbocharged and aftercooled.

REFERENCE ONLY

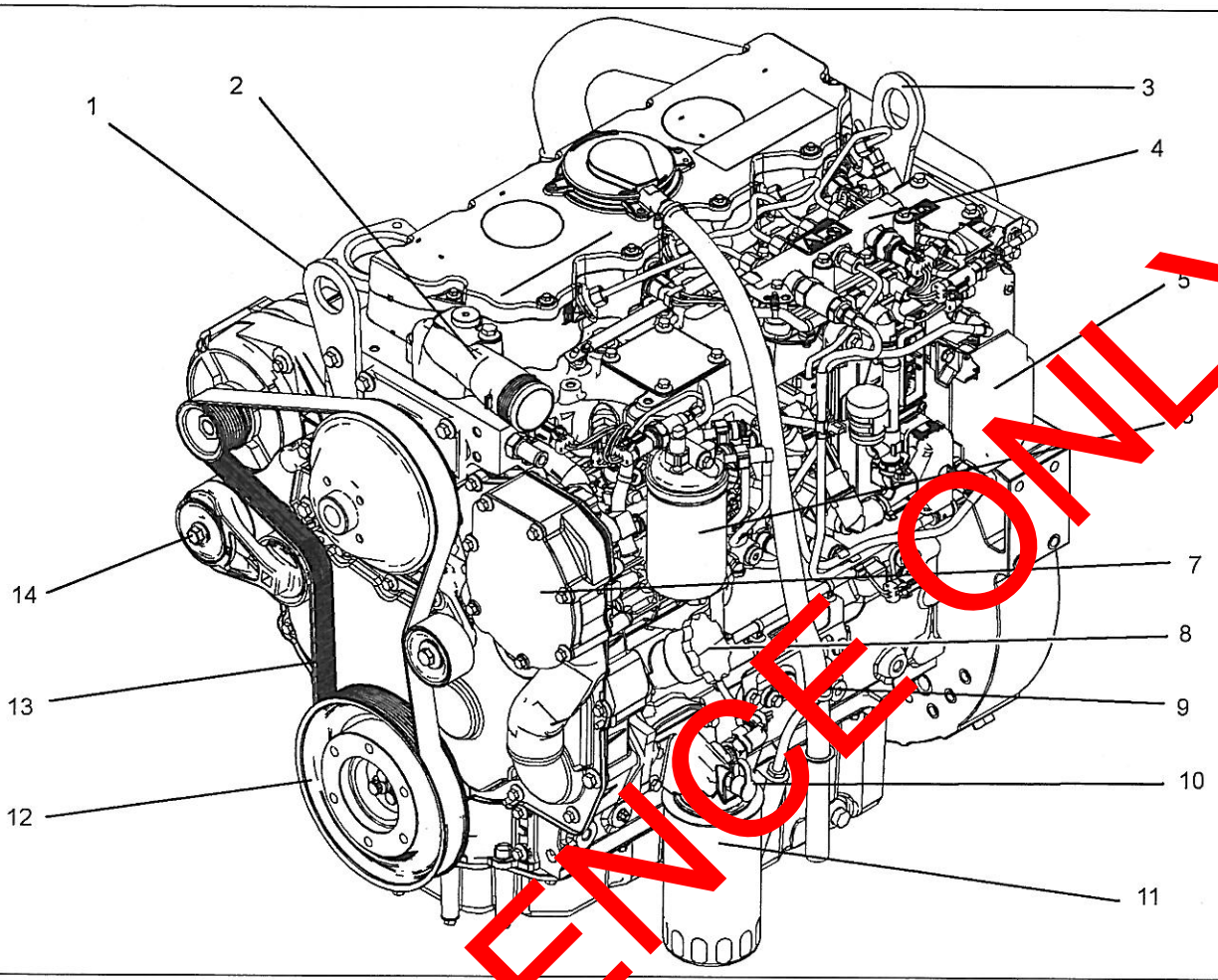


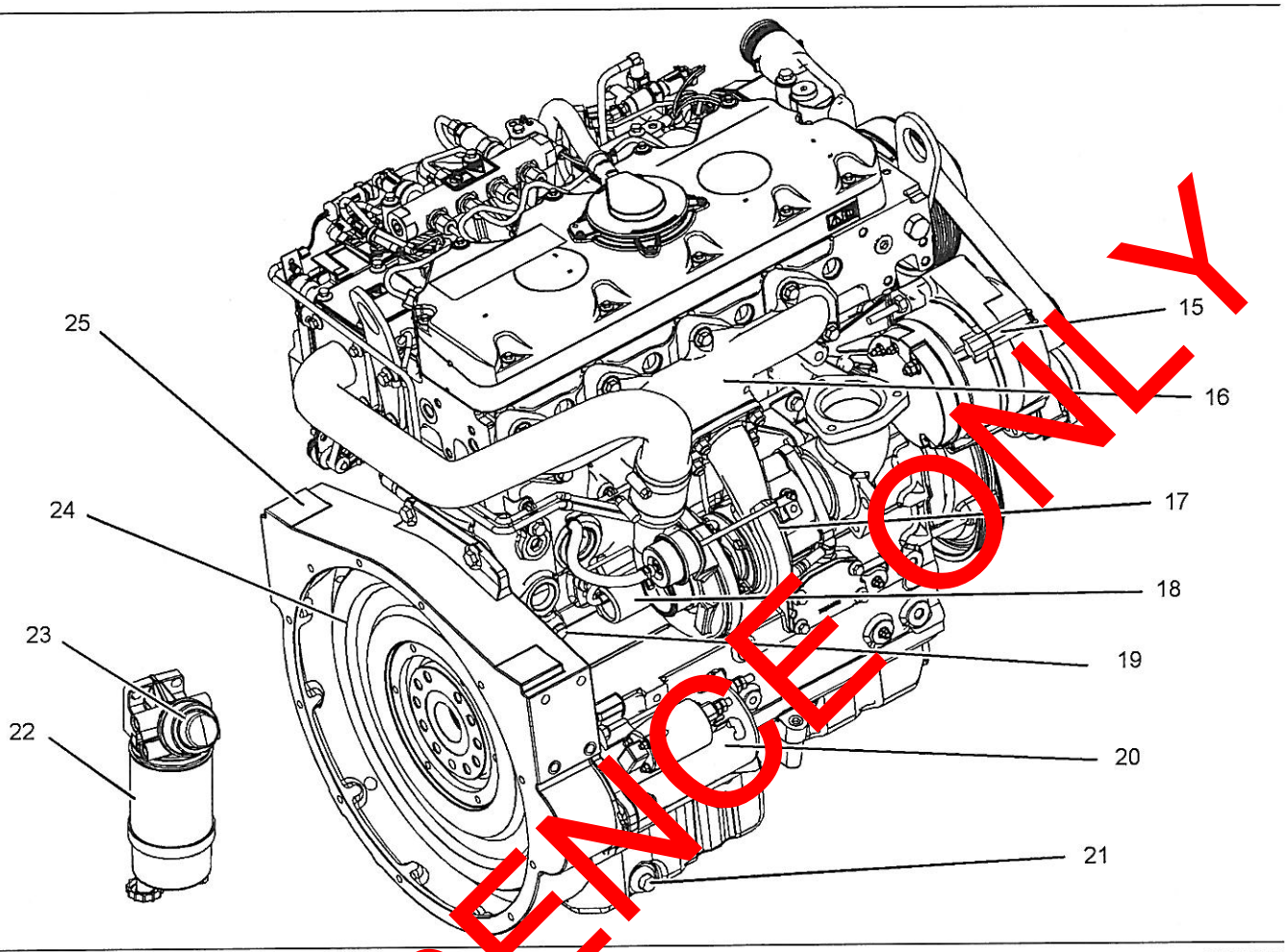

Illustration 17 g01428165

The 1104D NH engine is turbocharged.

Front left engine view

(1) Front lifting eye
(2) Water outlet
(3) Rear lifting eye
(4) Fuel manifold (rail)
(5) Electronic control module
(6) Secondary fuel filter
(7) Water pump
(8) Oil Filler
(9) Oil gauge
(10) Oil sampling valve
(11) Oil filter
(12) Crankshaft pulley
(13) Drive Belt
(14) Belt tensioner

REFERENCE ONLY




g01428176

Illustration 18

Rear right engine view

(15) Alternator
(16) Exhaust manifold
(17) Turbocharger
(18) Wastegate solenoid
(19) Drain plug or coolant sampling valve
(20) Starting Motor
(21) Oil drain plug
(22) Primary fuel filter
(23) Hand fuel priming pump
(24) Flywheel
(25) Flywheel housing

**Note:** The primary fuel filter may be mounted off the engine.

i02861107

## Engine Description

The 1104 Electronic Engine models NH and NJ are designed for the following applications: machine and industrial mobile equipment. The engine is available in the following type of aspiration:

- Turbocharged
- Turbocharged aftercooled
- In-line 4 cylinder

## Engine Specifications

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

REFERENCE ONLY

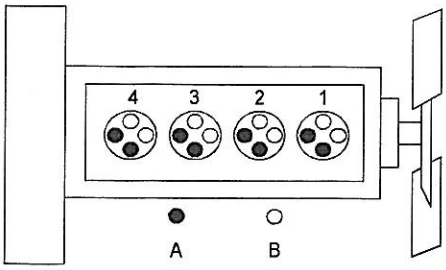



Illustration 19 g01187485

(A) Exhaust valves
(B) Inlet valves

Table 1

| 1104 Electronic Engine Specifications | |
|---|---|
| Operating Range (rpm) | 750 to 2640[1] |
| Number of Cylinders | 4 In-Line |
| Bore | 105 mm (4.13 inch) |
| Stroke | 127 mm (5 inch) |
| Aspiration | NH Turbocharged Engine<br>NJ Turbocharged engine that is aftercooled |
| Compression Ratio | 16.2:1 |
| Displacement | 4.4 L (269 in³) |
| Firing Order | 1,3,4,2 |
| Rotation (flywheel end) | Counterclockwise |
| Valve Lash Setting (Inlet) | 0.35 mm (0.013 inch) |
| Valve Lash Setting (Exhaust) | 0.35 mm (0.013 inch) |

(1) The operating rpm is dependent on the engine rating, the application, and the configuration of the throttle.

## Electronic Engine Features

The engine operating conditions are monitored. The Electronic Control Module (ECM) controls the response of the engine to these conditions and to the demands of the operator. These conditions and operator demands determine the precise control of fuel injection by the ECM. The electronic engine control system provides the following features:

- Engine monitoring
- Engine speed governing
- Control of the injection pressure
- Cold start strategy
- Automatic air/fuel ratio control
- Torque rise shaping
- Injection timing control
- System diagnostics

For more information on electronic engine features, refer to the Operation and Maintenance Manual, "Features and Controls" topic (Operation Section).

## Engine Diagnostics

The engine has built-in diagnostics in order to ensure that the engine systems are functioning correctly. The operator will be alerted to the condition by a "Stop or Warning" lamp. Under certain conditions, the engine horsepower and the vehicle speed may be limited. The electronic service tool may be used to display the diagnostic codes.

There are three types of diagnostic codes: active, logged, and event.

Most of the diagnostic codes are logged and stored in the ECM. For additional information, refer to the Operation and Maintenance Manual, "Engine Diagnostics" topic (Operation Section).

The ECM provides an electronic governor that controls the injector output in order to maintain the desired engine rpm.

## Engine Cooling and Lubrication

The cooling system consists of the following components:

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

The engine lubricating oil is supplied by a rotor type oil pump. The engine lubricating oil is cooled and the engine lubricating oil is filtered. The bypass valves can provide unrestricted flow of lubrication oil to the engine if the oil filter element should become plugged.

REFERENCE ONLY

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

REFERENCE ONLY

# Product Identification Information

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## Plate Locations and Film Locations

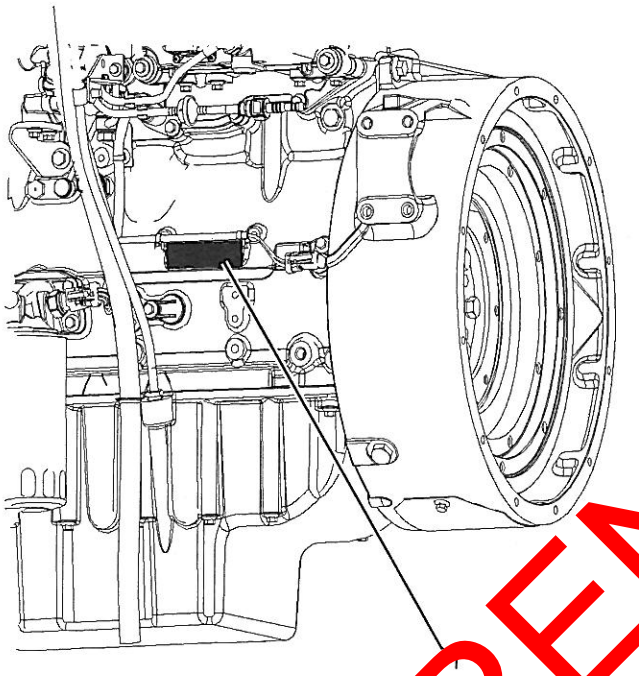


Illustration 20 g01248563
Location of the serial number plate

Perkins engines are identified by an engine serial number.

An example of an engine number is NH*****U000001J.

*** _____ The list number for the engine

NH _____ Type of engine

U _____ Built in the United Kingdom

000001 _____ Engine Serial Number

J _____ Year of Manufacture

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

The numbers for fuel setting information for electronic engines are stored within the personality module. These numbers can be read by using the Electronic Service Tool.

### Serial Number Plate (1)

The engine serial number plate is located on the left side of the cylinder block to the rear of the engine.

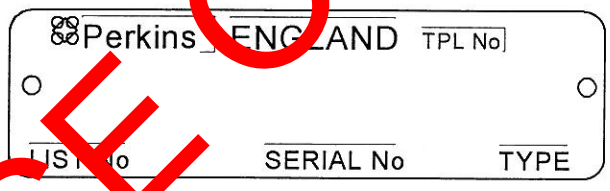



Illustration 21 g01094203
Serial number plate

i02164876

## Reference Numbers

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

### Record for Reference

Engine Model _____

Engine Serial number _____

Engine Low Idle rpm _____

Engine Full Load rpm _____

Primary Fuel Filter _____

Water Separator Element _____

Secondary Fuel Filter Element _____

REFERENCE ONLY

Lubrication Oil Filter Element _____

Auxiliary Oil Filter Element _____

Total Lubrication System Capacity _____

Total Cooling System Capacity _____

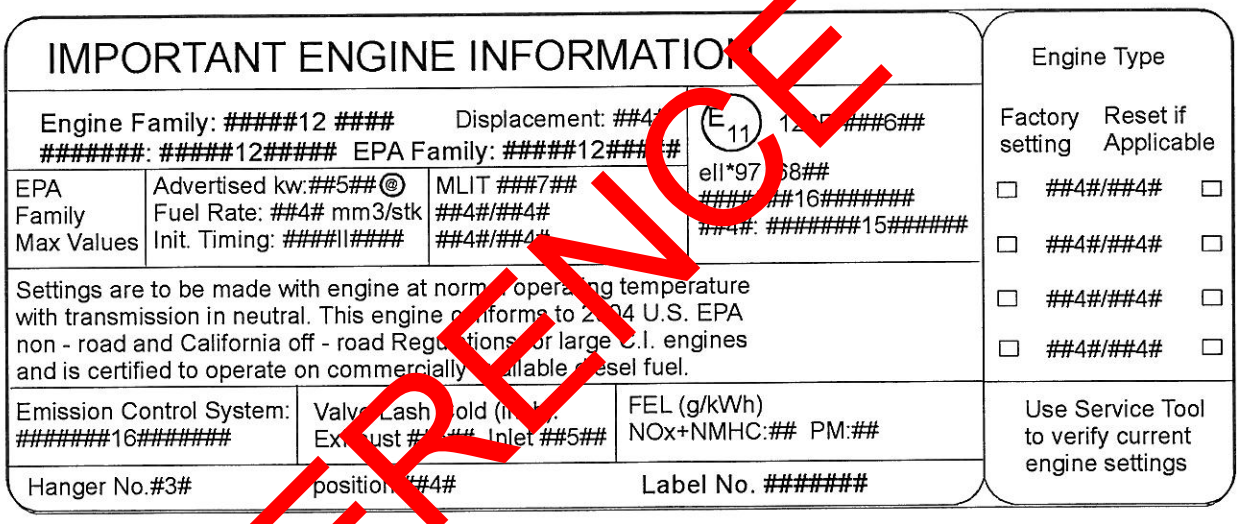
Air Cleaner Element _____

Fan Drive Belt _____

Alternator Belt _____

i02861254

## Emissions Certification Film




g01440937

Illustration 22
Typical example

REFERENCE ONLY

# Operation Section

# Lifting and Storage

i02164186

## Engine Lifting

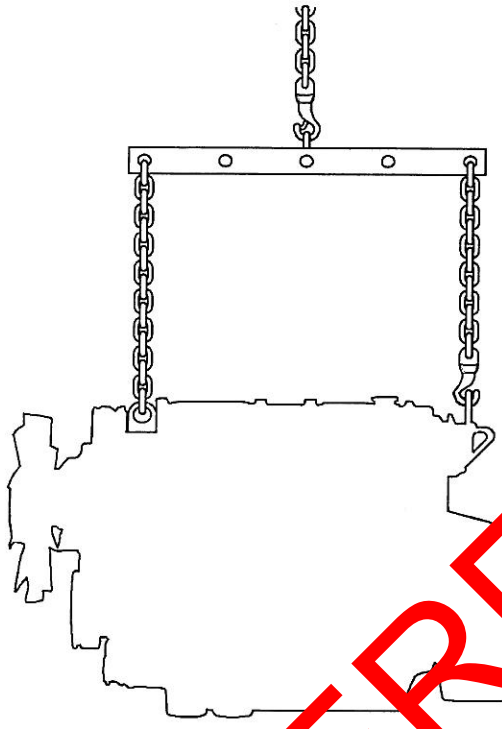


Illustration 23 g01097527

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.

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## Engine Storage

If the engine is not started for a month or longer the lubricating oil will drain from the cylinder walls and from the piston rings. Rust can form on the cylinder walls. Rust on the cylinder walls will cause increased engine wear and a reduction in engine service life.

Perkins are not responsible for damage which may occur when an engine is in storage after a period in service.

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

If an engine is out of operation and if use of the engine is not planned for more than one month, a complete protection procedure is recommended.

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

1. Completely clean the outside of the engine.
2. Ensure that the vehicle is on level ground.
3. Drain the fuel system completely and refill the system with preservative fuel. 1772204 POWERPART Lay-Up 1 can be mixed with the normal fuel in order to change the fuel into preservative fuel.

   If preservative fuel is not available, the fuel system can be filled with normal fuel. This fuel must be discarded at the end of the storage period together with the fuel filter elements.

REFERENCE ONLY

**⚠ WARNING**

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

4. Drain and refill the cooling system. Refer to this Operation and Maintenance Manual, "Cooling System coolant (Commercial Heavy Duty - Change or Cooling System coolant (ELC) - Change" for information on draining, flushing and refilling the cooling system.

**⚠ WARNING**

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

5. Operate the engine until the engine reaches normal operating temperature. Stop the engine. After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

6. Drain the lubricating oil from the oil pan.

   Renew the canister(s) of the lubricating oil filter.

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

7. Operate the engine in order to circulate engine oil.

8. Disconnect the battery. Ensure that the battery is in a fully charged condition. Protect the terminals against corrosion. 1734115 POWERPART Lay-Up 3 can be used on the terminals. Put the battery into safe storage.

9. If equipped, replace the crankcase breather element. Seal the end of the breather pipe.

10. Remove the valve mechanism cover. Spray 1762811 POWERPART Lay-Up 2 around the rocker shaft assembly.

11. Remove the glow plugs. Slowly rotate the crankshaft. By checking the valves, position the piston at BDC. Spray 1762811 POWERPART Lay-Up 2 for two seconds into the cylinder bore. This procedure must be carried out on each cylinder.

12. Install the glow plugs. Install the valve mechanism cover.

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

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

15. Seal the vent of the fuel tank or the fuel filler cap with waterproof tape.

16. Remove the alternator drive belt and put the drive belt into storage.

17. In order to prevent corrosion to the outside of the engine, spray the engine with 1734115 POWERPART Lay-Up 3. Do not spray the area inside the alternator.

REFERENCE ONLY

# Gauges and Indicators

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## Gauges and Indicators

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

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

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

Some engine applications are equipped with Indicator Lamps. Indicator lamps can be used as a diagnostic aid. There are two lamps. One lamp has an orange lens and the other lamp has a red lens.

These indicator lamps can be used in two ways:

- The indicator lamps can be used to identify the current operational status of the engine. The indicator lamps can also indicate that the engine has a fault. This system is automatically operated via the ignition switch.
- The indicator lamps can be used to identify active diagnostic codes. This system is activated by pressing the Flash Code button.

Refer to the Troubleshooting Guide, "Indicator Lamps" for further information.

NOTICE

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

**Engine Oil Pressure** – The oil pressure should be greatest after a cold engine is started. The typical engine oil pressure with SAE10W40 is 350 to 450 kPa ( 50 to 65 psi) at rated rpm.

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

1. Remove the load.
2. Stop the engine.
3. Check and maintain the oil level.

**Jacket Water Coolant Temperature** – Typical temperature range is 83° to 95°C (181.4° to 171°F). The maximum allowable temperature at sea level with the pressurized cooling system at 48 kPa (7 psi) is 103 °C (217.4 °F). Higher temperatures may occur under certain conditions. The water temperature reading may vary according to load. The temperature reading should never exceed 7 °C (44.6 °F) below the boiling point for the pressurized system that is being used.

A 100 kPa (14.5 psi) radiator cap may be installed on the cooling system. The temperature of this cooling system must not exceed 112 °C (233.6 °F).

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

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

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

NOTICE

To help prevent engine damage, never exceed the high idle rpm. Overspeeding can result in serious damage to the engine. Operation at speeds exceeding high idle rpm should be kept to a minimum.

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

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

REFERENCE ONLY



**Service Hour Meter** – The gauge indicates total operating hours of the engine.

REFERENCE ONLY

# Features and Controls

i02651062

## Monitoring System

**WARNING**

**If the Shutdown mode has been selected and the warning indicator activates, engine shutdown may take as little as 20 seconds from the time the warning indicator is activated. Depending on the application, special precautions should be taken to avoid personal injury. The engine can be restarted following shutdown for emergency maneuvers, if necessary.**

NOTICE

The Engine Monitoring System is not a guarantee against catastrophic failures. Programmed delays and derate schedules are designed to minimize false alarms and provide time for the operator to stop the engine.

The following parameters are monitored:

- Coolant temperature
- Intake air temperature
- Engine intake manifold pressure
- Engine Oil pressure
- Pressure in the fuel rail
- Engine speed/timing

## Programmable Options and System Operation

**WARNING**

**If the Warning/Derate/Shutdown mode has been selected and the warning indicator activates, bring the engine to a stop whenever possible. Depending on the application, special precautions should be taken to avoid personal injury.**

The engine can be programmed to the following modes:

### "Warning"

The "Warning" lamp and the warning signal (orange lamp) turn "ON" and the warning signal is activated continuously in order to alert the operator that one or more of the engine parameters is not within normal operating range.

### "Warning/Derate"

The "Diagnostic" lamp turns "ON" and the warning signal (red lamp) is activated. After the warning, the engine power will be derated. The warning lamp will begin to flash when the derating occurs.

The engine will be derated if the engine exceeds preset operational limits. The engine derate is achieved by restricting the amount of fuel that is available for each injection. The amount of this reduction of fuel is dependent on the severity of the fault that has caused the engine derate, typically up to a limit of 50%. This reduction in fuel results in a predetermined reduction in engine power.

### "Warning/Derate/Shutdown"

The "Diagnostic" lamp turns "ON" and the warning signal (red lamp) is activated. After the warning, the engine power will be derated. The engine will continue at the rpm of the set derate until a shutdown of the engine occurs. The engine can be restarted after a shutdown for use in an emergency.

A shutdown of the engine may occur in as little as 20 seconds. The engine can be restarted after a shutdown for use in an emergency. However, the cause of the initial shutdown may still exist. The engine may shut down again in as little as 20 seconds.

If there is a signal for low oil pressure or for coolant temperature, there will be a two second delay in order to verify the condition.

For each of the programmed modes, refer to Troubleshooting , "Indicator Lamps" for more information on Indicator Lamps.

For more information or assistance for repairs, consult your Perkins dealer or your Perkins distributor.

REFERENCE ONLY

i02296746

# Monitoring System

Table 2

| Warning Lamp | Shutdown Lamp | Lamp Status | Description of lamp status | Engine Status |
|---|---|---|---|---|
| ON | ON | Lamp check | When the engine start switch is turned to the "ON" position both lamps will illuminate for 2 seconds only. | The engine has not been started. |
| OFF | OFF | No faults | There are no active diagnostic faults. | The engine is running normally. |
| ON | OFF | Active diagnostic fault | An active diagnostic fault has been detected. | The engine is running normally. |
| ON | FLASHING | Active diagnostic fault | A serious active diagnostic fault has been detected and an engine derate has been invoked. | The engine is running but the engine has been derated. |
| FLASHING | OFF | Warning | One or more of the engine protection values has been exceeded. | The engine is running normally. |
| FLASHING | FLASHING | Derate and warning | One or more of the engine protection values has been exceeded. | The engine is running but the engine has been derated. |
| ON | ON | Engine shutdown | One or more of the engine protection values has been exceeded or a serious active diagnostic fault has been detected. | The engine is shutdown or shutdown is imminent. |

i02251773

# Sensors and Electrical Components

## Sensor Locations

Illustration 24 shows the typical locations of the sensors and the ECM on the engine. Specific engines may appear different from the illustration due to differences in applications.

REFERENCE ONLY

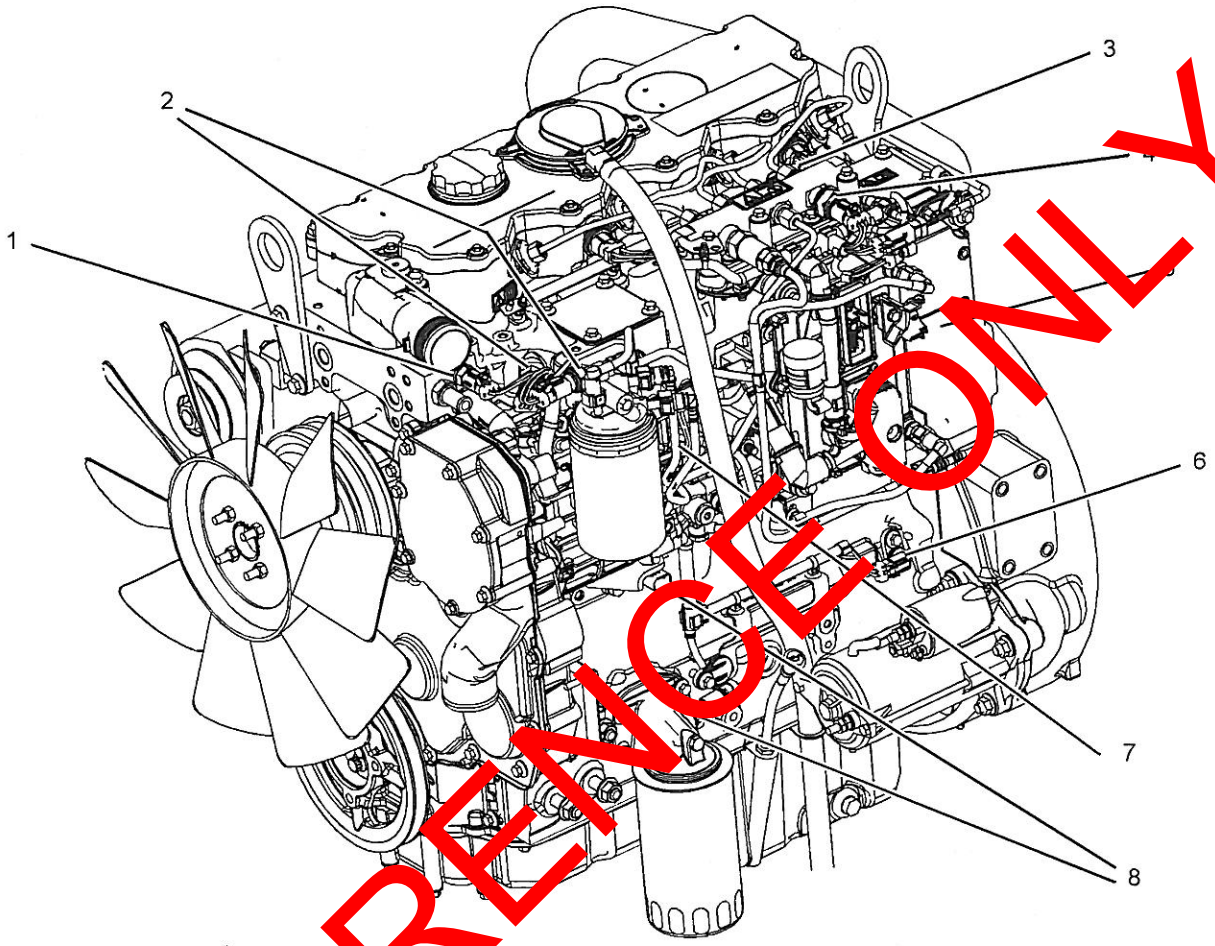



Illustration 24 g01425443

(1) Coolant temperature sensor
(2) Intake manifold pressure sensor
(3) Inlet air temperature sensor
(4) Fuel pressure sensor
(5) Electronic control module
(6) Primary position sensor
(7) Secondary position sensor
(8) Engine oil pressure sensor

Illustration 25 shows the sensors and the ECM in position on the engine.

REFERENCE ONLY

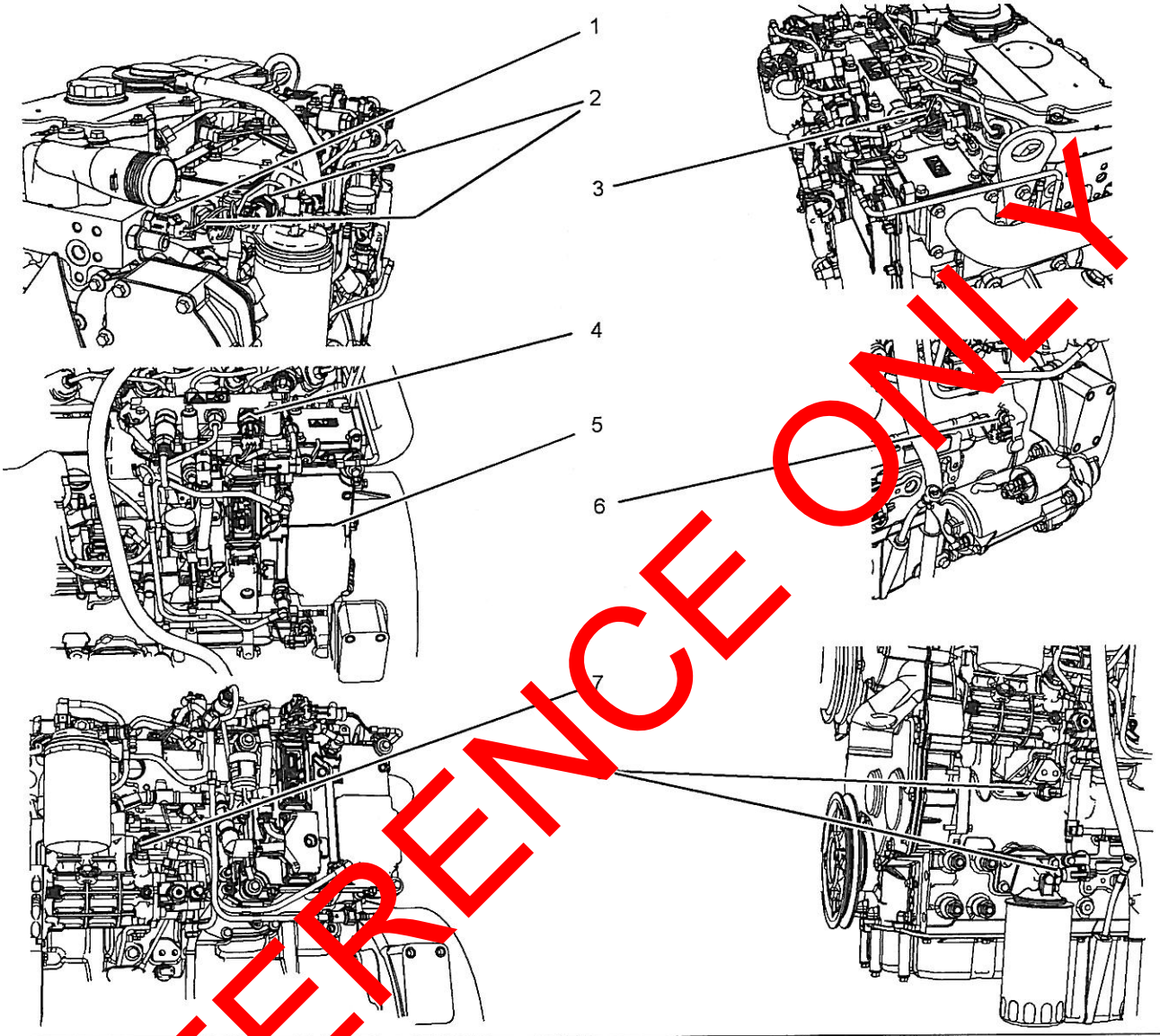



Illustration 25

g01425468

REFERENCE ONLY

## Failure of Sensors

### All Sensors

A failure of any of the sensors may be caused by one of the following malfunctions:

- Sensor output is open.
- Sensor output is shorted to "- battery" or "+ battery".
- Measured reading of the sensor is out of the specification.

## Programmable Monitoring System (PMS)

The Programmable Monitoring System determines the level of action that is taken by the Electronic Control Module (ECM) in response to a condition that can damage the engine. These conditions are identified by the ECM from the signals that are produced from the following sensors.

- Coolant Temperature Sensor
- Intake manifold Air Temperature Sensor
- Intake manifold Pressure Sensor
- Fuel Pressure Sensor

- Engine Oil Pressure Sensor
- Primary Speed/Timing Sensor
- Secondary Speed/Timing Sensor

## Coolant Temperature Sensor 1

The coolant temperature sensor monitors engine coolant temperature. The output of the ECM (5) can indicate a high coolant temperature through a relay or a lamp. The coolant temperature sensor is used by the ECM to determine initiation of the Cold Start Condition.

### Failure of the Coolant Temperature Sensor

The ECM (5) will detect a failure of the coolant temperature sensor. The diagnostic lamp will warn the operator about the status of the coolant temperature sensor. A failure of the coolant temperature sensor will not cause a shutdown of the engine or any horsepower change. In order to check the correct operation of the sensor, refer to Troubleshooting, "Engine Temperature Sensor Circuit - Test".

## Intake Manifold Air Temperature Sensor 2

**Note:** This sensor can have two different locations. The location will depend on the type of engine.

The intake manifold air temperature sensor measures the intake air temperature. A signal is sent to the ECM (5). The intake manifold air temperature sensor is also used by the ECM to determine initiation of the Cold Start Strategy.

In order to check the correct operation of the sensor, refer to Troubleshooting, "Engine Temperature Sensor Circuit - Test".

## Intake Manifold Pressure Sensor 3

The intake manifold pressure sensor measures pressure in the manifold. A signal is sent to the ECM (5).

## Fuel Pressure Sensor 4

The fuel pressure sensor measures the fuel pressure in the fuel manifold. A signal is sent to the ECM (5).

## Electronic Control Module 5

The ECM is the control computer of the engine. The ECM provides power to the electronics. The ECM monitors data that is input from the sensors of the engine. The ECM acts as a governor in order to control the speed and the power of the engine.

The ECM adjusts injection timing and fuel pressure for the best engine performance, the best fuel economy and the best control of exhaust emissions.

## Primary Speed/Timing Sensor 6

If the ECM (5) does not receive a signal from the primary speed/timing sensor, the "DIAGNOSTIC" lamp will indicate a diagnostic fault code which will be logged in the ECM memory.

If the ECM does not receive a signal from the primary speed/timing sensor (6), the ECM will read the signal from the secondary speed/timing sensor (8). The ECM continually checks in order to determine if there is a signal from both sensors.

Intermittent failure of the sensors will cause erratic engine control.

### Failure of the Primary Speed/Timing Sensor

Correct operation of the primary speed/timing sensor is essential. Software in the ECM protects against reverse running of the engine. If the primary speed/timing sensor fails there is no automatic protection against reverse running. In some applications, it is possible for the transmission to run the engine in reverse. In this event, Stop the engine immediately. Turn the keyswitch to the "OFF" position.

In order to check the correct operation of the sensor, refer to Troubleshooting, "Engine speed/Timing sensor - Test".

## Secondary Speed/Timing Sensor 7

The signal from the secondary speed/timing sensor is used by the ECM (5) on engine start-up in order to check the stroke of the pistons. The secondary speed/timing sensor may be used by the ECM in order to operate the engine if the primary speed/timing sensor is faulty.

In order to check the correct operation of the sensor, refer to Troubleshooting, "Engine speed/Timing sensor-Test".

REFERENCE ONLY

## Engine Oil Pressure Sensor 8

**Note:** This sensor can have two different locations. The location will depend on the type of engine.

The engine oil pressure sensor is an absolute pressure sensor that measures the engine oil pressure in the main oil gallery. The engine oil pressure sensor detects engine oil pressure for diagnostic purposes. The engine oil pressure sensor sends a signal to the ECM (5).

### Low Oil Pressure Warning

The setpoint for the low pressure warning is dependent upon the engine speed. The fault will be active and logged only if the engine has been running for more than 8 seconds.

### Very Low Oil Pressure Warning

The very low oil pressure setpoint is dependent upon the engine speed. If the DERATE mode of the engine monitoring system is selected, the ECM (5) will derate the engine power. The engine horsepower will be limited.

### Failure of the Engine Oil Pressure Sensor

The ECM (5) will detect failure of the engine oil pressure sensor. The diagnostic lamp warns the user about the status of the engine oil pressure sensor. The engine oil pressure related strategies will be disabled in the event of a failure of the engine oil pressure sensor. A failure of the engine oil pressure sensor will not cause a shutdown of the engine or any horsepower change. In order to check the correct operation of the sensor, refer to Troubleshooting, "5 Volt Sensor Supply Circuit - Test".

i02858345

## Engine Shutoffs and Engine Alarms

### Shutoffs

The shutoffs are electrically operated or mechanically operated. The electrically operated shutoffs are controlled by the ECM.

Shutoffs are set at critical levels for the following items:

- Operating temperature
- Operating pressure
- Operating level
- Operating rpm

The particular shutoff may need to be reset before the engine will start.

NOTICE
Always determine the cause of the engine shutdown. Make necessary repairs before attempting to restart the engine.

Be familiar with the following items:

- Types and locations of shutoff
- Conditions which cause each shutoff to function
- The resetting procedure that is required to restart the engine

### Alarms

The alarms are electrically operated. The operation of the alarms are controlled by the ECM.

The alarm is operated by a sensor or by a switch. When the sensor or the switch is activated a signal is sent to the ECM. An event code is created by the ECM. The ECM will send a signal in order to illuminate the lamp.

Your engine may be equipped with the following sensors or switches:

**Coolant level** – The low coolant level switch indicates when the coolant level is low.

**Coolant temperature** – The coolant temperature sensor indicates high jacket water coolant temperature.

**Intake manifold air temperature** – The intake manifold air temperature sensor indicates high intake air temperature.

**Intake manifold pressure** – The intake manifold pressure sensor checks the rated pressure in the engine manifold.

**Fuel rail pressure** – The fuel rail pressure sensor checks for high pressure or low pressure in the fuel rail.

**Engine oil pressure** – The engine oil pressure sensor indicates when oil pressure drops below rated system pressure, at a set engine speed.

REFERENCE ONLY

**Engine overspeed** – The primary speed/timing sensor checks the engine speed. The alarm is activated at 3000 RPM.

**Air filter restriction** – The switch checks the air filter when the engine is operating.

**User defined switch** – This switch can shut down the engine remotely.

**Water in fuel switch** – This switch checks for water in the primary fuel filter when the engine is operating.

**Note:** The sensing element of the coolant temperature switch must be submerged in coolant in order to operate.

Engines may be equipped with alarms in order to alert the operator when undesirable operating conditions occur.

NOTICE
When an alarm is activated, corrective measures must be taken before the situation becomes an emergency in order to avoid possible engine damage.

If corrective measures are not taken within a reasonable time, engine damage could result. The alarm will continue until the condition is corrected. The alarm may need to be reset.

## Testing

Turning the keyswitch to the ON position will check the indicator lights on the control panel. All the indicator lights will be illuminated for two seconds after the keyswitch is operated. Replace suspect bulbs immediately.

Refer to Troubleshooting for more information.

i02237393

## Overspeed

An overspeed condition is detected by the Electronic Control Module (ECM). The event code will be logged if the engine speed exceeds 3000 rpm. The "DIAGNOSTIC" lamp will indicate a diagnostic active code. The diagnostic active code will remain active until the engine speed drops to 2800 rpm.

REFERENCE ONLY

# Engine Diagnostics

i02651093

## Self-Diagnostics

Perkins electronic engines have the capability to perform a self-diagnostics test. When the system detects an active problem, a diagnostic lamp is activated. Diagnostic codes will be stored in permanent memory in the Electronic Control Module (ECM). The diagnostic codes can be retrieved by using the electronic service tool. Refer to Troubleshooting , “Electronic Service Tools” for further information.

Some installations have electronic displays that provide direct readouts of the engine diagnostic codes. Refer to the manual that is provided by the OEM for more information on retrieving engine diagnostic codes. Alternatively refer to Troubleshooting , “Indicator Lamps” for further information.

Active codes represent problems that currently exist. These problems should be investigated first.

Logged codes represent the following items:

- Intermittent problems
- Recorded events
- Performance history

The problems may have been repaired since the logging of the code. These codes do not indicate that a repair is needed. The codes are guides or signals when a situation exists. Codes may be helpful to troubleshoot problems.

When the problems have been corrected, the corresponding logged fault codes should be cleared.

i02651107

## Diagnostic Lamp

A diagnostic lamp is used to indicate the existence of an active fault. Refer to Troubleshooting , “Indicator Lamps” for more information. A fault diagnostic code will remain active until the problem is repaired. The diagnostic code may be retrieved by using the electronic service tool. Refer to Troubleshooting , “Electronic Service Tools” for more information.

i02855276

## Diagnostic Flash Code Retrieval

### “Diagnostic” Lamp

Use the “DIAGNOSTIC” Lamp or an electronic service tool to determine the diagnostic flash code.

Use the following procedure to retrieve the flash codes if the engine is equipped with a “DIAGNOSTIC” lamp:

1. Turn the keyswitch “ON/OFF” two times within 3 seconds.

A flashing“YELLOW” lamp indicates a 3 digit code for the engine. The sequence of flashes represents the system diagnostic message. Count the first sequence of flashes in order to determine the first digit of the flash code. After a two second pause, the second sequence of flashes will identify the second digit of the flash code. After the second pause, the third sequence of flashes will identify the flash code.

Any additional flash codes will follow after a pause. These codes will be displayed in the same manner. Flash Code 551 indicates that No Detected Faults have occurred since the ignition keyswitch has been turned to the ON position.

For further information, assistance for repairs, or troubleshooting, refer to the Service Manual or consult an authorized Perkins dealer.

Table 3 lists the flash codes and the table also gives a brief description of the flash codes.

**Note:** Table 3indicates the potential effect on engine performance with “ACTIVE” flash codes.

Some codes record events. Also, some codes may also indicate that a mechanical system needs attention. Troubleshooting is not required for code “551”. Code 001 will not display a flash code. Some codes will limit the operation or the performance of the engine.

Table 3 indicates the potential effect on the engine performance with active flash codes. Table 3 also forms a list of Electronic diagnostic codes and descriptions.

REFERENCE ONLY

Table 3

| Flash Codes for the Industrial Engine | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Diagnostic Flash Code | | Effect On Engine Performance (1) | | | | Suggested Operator Action | | |
| | | Engine Misfire | Low Power | Reduced Engine Speed | Engine Shutdown | Shut Down the Engine (2) | Service (3) | Schedule a Service. (4) |
| 111 | Cylinder 1 Fault | X | X | | | | X | |
| 112 | Cylinder 2 Fault | X | X | | | | X | |
| 113 | Cylinder 3 Fault | X | X | | | | X | |
| 114 | Cylinder 4 Fault | X | X | | | | X | |
| 133 | Intake Manifold Temperature sensor fault (5) | X | | | | | X | |
| 141 | Primary Speed/ Timing Sensor Fault | | | X | | | X | |
| 142 | Secondary Speed/Timing Sensor Fault | | | | | | X | |
| 143 | Timing Calibration Fault | X | | | | | | X |
| 144 | Engine Operation Mode Selector Switch Fault | | X | | | | X | |
| 151 | High Air Filter Restriction | | X | | | | X | |
| 154 | Throttle Position sensor Fault | | | X | | | X | |
| 155 | Secondary Throttle Position sensor Fault | | | X | | | X | |
| 157 | Oil Pressure Sensor Fault(5) | | X | X | X | X | X | |
| 159 | Fuel Rail Pressure Sensor Fault | | X | | | | X | |
| 162 | High Pressu Fuel Pump Fau | | X | X | | | X | |
| 168 | Temp ratu Sensor ult | | | X | X | | X | |
| 169 | Low Engine olant | | | | X | | | X |
| 177 | astegate Solenoid ault | | | X | | | | |
| 185 | High Exhaust Temperature | | X | | | | X | |
| 197 | Intake Manifold Pressure Sensor Fault | | X | | | | X | |
| 199 | Glow Plug Start Relay Fault | | | | | | X | |

(continued)

REFERENCE ONLY

(Table 3, contd)

| Flash Codes for the Industrial Engine | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Diagnostic Flash Code | | Effect On Engine Performance (1) | | | | Suggested Operator Action | | |
| | | Engine Misfire | Low Power | Reduced Engine Speed | Engine Shutdown | Shut Down the Engine (2) | Service (3) | Schedule a Service. (4) |
| 415 | Incorrect Engine Software | | | X | X | | X | |
| 426 | Machine Security System Module Fault (6) | | | | | | X | |
| 429 | Keyswitch Fault | | | | | | | X |
| 511 | Intermittent Battery Power to ECM | X | X | | X | | X | |
| 514 | SAE J1939 Data Link Fault | | | X | | | X | |
| 516 | 5 Volt Sensor DC Power Supply Fault(5) | | X | | | | | X |
| 517 | 8 Volt Sensor DC Power Supply Fault | | X | | | | | X |
| 527 | Check Customer Parameters or System Parameters (5) | | X | X | | | | X |

(1) An "X" indicates that the effect on engine performance may occur if the code is active.
(2) Shut Down the Engine: Operate the engine cautiously. Get immediate service. Severe engine damage may result.
(3) The operator should go to the nearest location that has a qualified service program.
(4) Schedule Service: The problem should be investigated when the operator has access to a qualified service program.
(5) These Flash Codes may affect the system under specific environmental conditions such as engine start-up at cold temperature and cold weather operation at high altitudes.
(6) The engine will not start.

REFERENCE ONLY

i01902949

## Fault Logging

The system provides the capability of Fault Logging. When the Electronic Control Module (ECM) generates an active diagnostic code, the code will be logged in the memory of the ECM. The codes that have been logged by the ECM can be identified by the electronic service tool. The active codes that have been logged will be cleared when the fault has been rectified or the fault is no longer active. The following logged faults can not be cleared from the memory of the ECM without using a factory password: Overspeed, low engine oil pressure, and high engine coolant temperature.

i02651197

## Engine Operation with Active Diagnostic Codes

If a diagnostic lamp illuminates during normal engine operation, the system has identified a situation that is not within the specification. Use the electronic service tool to check the active diagnostic codes.

The active diagnostic code should be investigated. The cause of the problem should be corrected as soon as possible. If the cause of the active diagnostic code is repaired and there is only one active diagnostic code, the diagnostic lamp will turn off.

Operation of the engine and performance of the engine can be limited as a result of the active diagnostic code that is generated. Acceleration rates may be significantly slower and power outputs may be automatically reduced. Refer to Troubleshooting , "Troubleshooting with a Diagnostic Code" for more information on the relationship between each active diagnostic code and the possible effect on engine performance.

i01902985

## Engine Operation with Intermittent Diagnostic Codes

If a diagnostic lamp illuminates during normal engine operation and the diagnostic lamp shuts off, an intermittent fault may have occurred. If a fault has occurred, the fault will be logged into the memory of the Electronic Control Module (ECM).

In most cases, it is not necessary to stop the engine because of an intermittent code. However, the operator should retrieve the logged fault codes and the operator should reference the appropriate information in order to identify the nature of the event. The operator should log any observation that could have caused the lamp to light.

- Low power
- Limits of the engine speed
- Excessive smoke, etc

This information can be useful to help troubleshoot the situation. The information can also be used for future reference. For more information on diagnostic codes, refer to the Troubleshooting Guide for this engine.

REFERENCE ONLY

# Engine Starting

i02322201

## Before Starting Engine

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

- Open the fuel supply valve (if equipped).

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

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

**⚠ WARNING**

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

- Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.
- Reset all of the shutoffs or alarm components (if equipped).
- Ensure that any equipment that is driven by the engine has been disengaged from the engine. Minimize electrical loads or remove any electrical loads.

i02322203

## Starting the Engine

**Note:** Do not adjust the engine speed control during start-up. The electronic control module (ECM) will control the engine speed during start-up.

### Starting the Engine

1. Disengage any equipment that is driven by the engine.
2. Turn the keyswitch to the RUN position. Leave the keyswitch in the RUN position until the warning light for the glow plugs is extinguished.
3. When the warning light for the glow plugs is extinguished turn the keyswitch to the START position in order to engage the electric starting motor and crank the engine.

**Note:** The operating period of the warning light for the glow plugs will change due to the temperature of the engine.

NOTICE
Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before attempting to start the engine again.

4. Allow the keyswitch to return to the RUN position after the engine starts.
5. Repeat step 2 through step 4 if the engine fails to start.

i02325155

## 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.

REFERENCE ONLY

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

Use the procedure that follows for cold weather starting.

**Note:** Do not adjust the engine speed control during start-up. The electronic control module (ECM) will control the engine speed during start-up.

1. Disengage any driven equipment.

2. Turn the keyswitch to the RUN position. Leave the keyswitch in the RUN position until the warning light for the glow plugs is extinguished.

NOTICE
Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before attempting to start the engine again.

3. When the warning light for the glow plugs is extinguished turn the keyswitch to the START position in order to engage the electric starting motor and crank the engine.

**Note:** The operating period of the warning light for the glow plugs will change due to the temperature of the engine.

4. Allow the keyswitch to return to the RUN position after the engine starts.

5. Repeat step 2 through step 4 if the engine fails to start.

**Note:** The engine should not be "raced" in order to speed up the warm up process.

6. Allow the engine to idle for three to five minutes, or allow the engine to idle until the water temperature indicator begins to rise. When idling after the engine has started in cold weather, increase the engine rpm from 1000 to 1200 rpm. This will warm up the engine more quickly. Maintaining an elevated low idle speed for extended periods will be easier with the installation of a hand throttle. Allow the white smoke to disperse before proceeding with normal operation.

7. Operate the engine at low load until all systems reach operating temperature. Check the gauges during the warm-up period.

i02322204

# Starting with Jump Start Cables

**⚠ WARNING**

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

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

**Note:** If it is possible, first diagnose the reason for the starting failure. Refer to Troubleshooting, "Engine Will Not Crank and Engine Cranks But Will Not Start" for further information. Make any necessary repairs. If the engine will not start only due to the condition of the battery, either charge the battery, or start the engine by using another battery with jump start cables. The condition of the battery can be rechecked after the engine has been switched OFF.

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

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

Turn all electrical accessories OFF before attaching the jump start cables.

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

1. Turn the start switch on the stalled engine to the OFF position. Turn off all the engine's accessories.

2. Connect one positive end of the jump start cable to the positive cable terminal of the discharged battery. Connect the other positive end of the jump start cable to the positive cable terminal of the electrical source.

REFERENCE ONLY

3. Connect one negative end of the jump start cable to the negative cable terminal of the electrical source. Connect the other negative end of the jump start cable to the engine block or to the chassis ground. This procedure helps to prevent potential sparks from igniting the combustible gases that are produced by some batteries.

4. Start the engine.

5. Immediately after the engine is started, disconnect the jump start cables in reverse order.

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

i02330138

## After Starting Engine

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

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

Do not check the high pressure fuel lines with the engine or the starting motor in operation. If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General Hazard Information".

- Check for any fluid or for any air leaks at idle rpm and at one-half full rpm (no load on the engine) before operating the engine under load. This is not possible in some applications.
- Allow the engine to idle for three to five minutes, or allow the engine to idle until the water temperature indicator begins to rise. Check all gauges during the warm-up period.

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

REFERENCE ONLY

# Engine Operation

i02330143

## Engine Operation

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

The engine can be operated at the rated rpm after the engine reaches operating temperature. The engine will reach normal operating temperature if the engine is operated at low idle speed and operated with a light load. This procedure is more effective than idling the engine at no load. The engine should reach operating temperature in a few minutes.

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

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.

REFERENCE ONLY

# Engine Stopping

i02334873

## Stopping the Engine

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

Avoid accelerating the engine prior to shutting it down.

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

**Note:** Individual applications will have different control systems. Ensure that the shutoff procedures are understood. Use the following general guidelines in order to stop the engine.

1. Remove the load from the engine. Reduce the engine speed (rpm) to low idle. Allow the engine to idle for five minutes in order to cool the engine.
2. Stop the engine after the cool down period according to the shutoff system on the engine and turn the ignition key switch to the OFF position. If necessary, refer to the instructions that are provided by the OEM.

i01903586

## 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.

i02330274

## After Stopping Engine

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

**⚠ WARNING**

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

- After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

  Check the crankcase oil level. Maintain the oil level between the "MIN" mark and the "MAX" mark on the engine oil level gauge.

- If the engine is equipped with a service hour meter, note the reading. Perform the maintenance that is in the Operation and Maintenance Manual, "Maintenance Interval Schedule".

- Fill the fuel tank in order to help prevent accumulation of moisture in the fuel. Do not overfill the fuel tank.

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

**⚠ WARNING**

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

- Allow the engine to cool. Check the coolant level.

REFERENCE ONLY

- Check the coolant for correct antifreeze protection and the correct corrosion protection. Add the correct coolant/water mixture, if necessary.
- Perform all required periodic maintenance on all driven equipment. This maintenance is outlined in the instructions from the OEM.

REFERENCE ONLY

# Cold Weather Operation

i02717265

## Cold Weather Operation

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

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

This section will cover the following information:

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

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

- Weather conditions
- Engine applications

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

### Hints for Cold Weather Operation

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

**⚠ WARNING**

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

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

**⚠ WARNING**

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

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

### Viscosity of the Engine Lubrication Oil

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

### Recommendations for the Coolant

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

REFERENCE ONLY

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

### Engine Block Heaters

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

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

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

## Idling the Engine

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

While the engine is idling, the application of a light load (parasitic load) will assist in achieving the minimum operating temperature. The minimum operating temperature is 82 °C (179.6 °F).

## Recommendations for Coolant Warm Up

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

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

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

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

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

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

### The Water Temperature Regulator and Insulated Heater Lines

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

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

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

REFERENCE ONLY

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

### Insulating the Air Inlet and Engine Compartment

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

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

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## Fuel and the Effect from Cold Weather

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

The following components provide a means of minimizing problems in cold weather:

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

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

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

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

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

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

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

REFERENCE ONLY

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# Fuel Related Components in Cold Weather

## Fuel Tanks

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

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

Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe.

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

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

## Fuel Filters

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

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

## Fuel Heaters

**Note:** The OEM may equip the application with fuel heaters. If this is the case, the temperature of the fuel must not exceed 73 °C (163 °F) at the fuel transfer pump.

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

REFERENCE ONLY

# Maintenance Section

# Refill Capacities

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## Refill Capacities

### Lubrication System

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

Table 4

| Engine Refill Capacities | | |
|---|---|---|
| **Compartment or System** | **Minimum** | **Maximum** |
| Crankcase Oil Sump(1) | 5 L (1.1658 Imp gal) | 7 L (1.5398 Imp gal) |

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

### Cooling System

Refer to the OEM specifications for the External System capacity. This capacity information will be needed in order to determine the amount of coolant/antifreeze that is required for the Total Cooling System.

Table 5

| Engine Refill Capacities | |
|---|---|
| **Compartment or System** | **Liters** |
| Engine Only | 7 L (1.5398 Imp gal) |
| External System Per OEM(1) | |

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

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# Fluid Recommendations

## General Lubricant Information

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

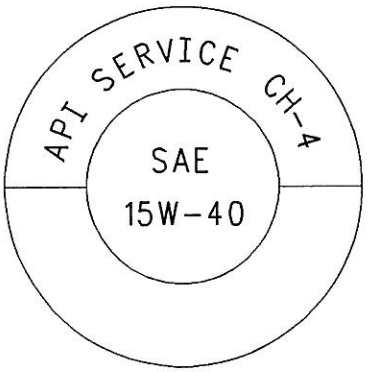
- EMA_____Engine Manufacturers Association
- API_____American Petroleum Institute
- SAE_____Society Of Automotive Engineers Inc.

### EMA Guidelines

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

### API Licensing

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




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Illustration 26

Typical API symbol

REFERENCE ONLY

### Terminology

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

## Engine Oil

### Commercial Oils

NOTICE
For applications above 168 kW CI-4 oil must be used.

Table 6

| API Classifications for the 1104D Industrial Engine | |
|---|---|
| **Oil Specification** | **Maintenance Interval** |
| CH-4/CI-4 | 500 Hours |
| CI-4 | 500 Hours |
| CG-4 | 250 Hours |

**Maintenance intervals for engines that use biodiesel** – The oil change interval can be adversely affected by the use of biodiesel. Use oil analysis in order to monitor the condition of the engine oil. Use oil analysis also in order to determine the oil change interval that is optimum.

**Note: These engine oils are not approved by perkins and these engine oils must not be used:CC, CD, CD-2, and CF-4.**

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

Only use commercial oils that meet the following classifications:

- API_____ CH-4 CI-4

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

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

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

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

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

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

REFERENCE ONLY

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

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

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

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

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

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

The Total Base Number (TBN) for an oil depends on the fuel sulfur level. For direct injection engines that use distillate fuel, the minimum TBN of the new oil must be 10 times the fuel sulfur level. The TBN is defined by "ASTM D2896". The minimum TBN of the oil is 5 regardless of fuel sulfur level. Illustration 27 demonstrates the TBN.

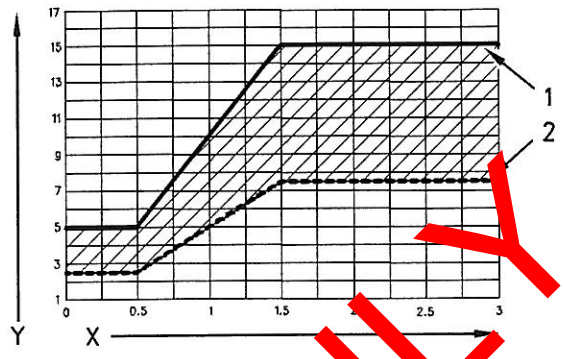



Illustration 27 g00799818

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

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

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

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

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

Table 7

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

## Lubricant Viscosity Recommendations for Direct Injection (DI) Diesel Engines

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

REFERENCE ONLY

Refer to Table 8 (minimum temperature) in order to determine the required oil viscosity for starting a cold engine.

Refer to Table 8 (maximum temperature) in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

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

Table 8

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

## Synthetic Base Stock Oils

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

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

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

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

## Re-refined Base Stock Oils

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

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

## Lubricants for Cold Weather

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

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

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

Perkins recommends the following lubricants for use in cold weather conditions:

Use a commercial oil that is API:CI-4, CI-4 PLUS, CH-4, and CG-4. The oil must have one of the following lubricant viscosity grades: SAE 0W-20, SAE 0W-30, SAE 0W-40, SAE 5W-30, and SAE 5W-40

## Aftermarket Oil Additives

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

REFERENCE ONLY

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

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

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

### Oil analysis

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

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

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

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# Fluid Recommendations (Fuel Specification)

- **Glossary**
- ISO International Standards Organization
- ASTM American Society for Testing and Materials
- HFRR High Frequency Reciprocating Rig for Lubricity testing of diesel fuels
- FAME Fatty Acid Methyl Esters
- CFR Co-ordinating Fuel Research
- LSD Low Sulfur Diesel
- ULSD Ultra Low Sulfur Diesel
- RME Rape Methyl Ester
- SME Soy Methyl Ester
- EPA Environmental Protection Agency of the United States

## General Information

NOTICE
Every attempt is made to provide accurate, up to date information. By use of this document you agree that Perkins Engines Company Limited is not responsible for errors or omissions.

NOTICE
These recommendations are subject to change without notice. Contact your local Perkins distributor for the most up to date recommendations.

## Diesel Fuel Requirements

Satisfactory engine performance is dependent on the use of a good quality fuel. The use of a good quality fuel will give the following results: long engine life and acceptable exhaust emissions levels. The fuel must meet the minimum requirements that are stated in table 9.

NOTICE
The footnotes are a key part of the Perkins Specification for Distillate Diesel Fuel Table. Read ALL of the footnotes.

REFERENCE ONLY

Table 9

| Perkins Specification for Distillate Diesel Fuel (1) | | | | |
|---|---|---|---|---|
| **Property** | **UNITS** | **Requirements** | **"ASTM"Test** | **"ISO"Test** |
| Aromatics | %Volume | 35% maximum | D1319 | "ISO"3837 |
| Ash | %Weight | 0.01% maximum | D482 | "ISO"6245 |
| Carbon Residue on 10% Bottoms | %Weight | 0.35% maximum | D524 | "ISO"4262 |
| Cetane Number (2) | - | 40 minimum | D613/D6890 | "ISO"5165 |
| Cloud Point | °C | The cloud point must not exceed the lowest expected ambient temperature. | D2500 | "ISO"3015 |
| Copper Strip Corrosion | - | No. 3 maximum | D130 | "ISO"2160 |
| Density at 15 °C (59 °F) (3) | Kg / M $^3$ | 801 minimum and 876 maximum | No equivalent test | "ISO 3675 ""ISO 12185" |
| Distillation | °C | 10% at 282 °C (539.6 °F) maximum 90% at 360 °C (680 °F) maximum | D86 | "ISO"3405 |
| Flash Point | °C | legal limit | D93 | "ISO"2719 |
| Thermal Stability | - | Minimum of 80% reflectance after aging for 180 minutes at 150 °C (302 °F) | D6468 | No equivalent test |
| Pour Point | °C | 6 °C (42.8 °F) minimum below ambient temperature | D97 | "ISO"3016 |
| Sulfur (1)(4) | %mass | 15 ppm maximum | D5453/D26222 | "ISO 20846 ""ISO 20884" |
| Kinematic Viscosity (5) | "MM"$^2$"/S (cSt)" | The viscosity of the fuel that is delivered to the fuel injection pump. "1.4 minimum/4.5 maximum" | D445 | "ISO"3405 |
| Water and sediment | % weight | 0.1% maximum | D1796 | "ISO"3734 |
| Water | % weight | 0.1% maximum | D1744 | No equivalent test |
| Sediment | % weight | 0.05% maximum | D473 | "ISO"3735 |

(continued)

REFERENCE ONLY

(Table 9, contd)

| | | | | |
|---|---|---|---|---|
| Gums and Resins (6) | mg/100mL | 10 mg per 100 mL maximum | D381 | "ISO"6246 |
| Lubricity corrected wear scar diameter at 60 °C (140 °F). (7) | mm | 0.52 maximum | D6079 | "ISO"12156-1 |

(1) This specification includes the requirements for Ultra Low Sulfur Diesel (ULSD). ULSD fuel will have ≤ 15 ppm (0.0015%) sulfur. Refer to "ASTM D5453", "ASTM D2622", or "ISO 20846, ISO 20884" test methods. This specification includes the requirements for Low Sulfur Diesel (LSD). LSD fuel will have ≤500 ppm (0.05%) sulfur. Refer to following:"ASTM 5453, ASTM D2622", "ISO 20846", and "ISO 20884 test methods".

(2) A fuel with a higher cetane number is recommended in order to operate at a higher altitude or in cold weather.

(3) "Via standards tables, the equivalent API gravity for the minimum density of 801 kg / m³ (kilograms per cubic meter) is 45 and for the maximum density of 876 kg / m³ is 30".

(4) Regional regulations, national regulations or international regulations can require a fuel with a specific sulfur limit. Consult all applicable regulations before selecting a fuel for a given engine application. Perkins fuel systems and engine components can operate on high sulfur fuels. Fuel sulfur levels affect exhaust emissions. High sulfur fuels also increase the potential for corrosion of internal components. Fuel sulfur levels above 0.5% may significantly shorten the oil change interval. For additional information, refer to this manual, "Fluid recommendations (General lubricant Information)".

(5) The values of the fuel viscosity are the values as the fuel is delivered to the fuel injection pumps. Fuel should also meet the minimum viscosity requirement and the fuel should meet the maximum viscosity requirements at 40 °C (104 °F) of either the "ASTM D445" test method or the "ISO 3104" test method. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to 4.5 cSt at the fuel injection pump.

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

(7) The lubricity of a fuel is a concern with low sulfur and ultra low sulfur fuel. To determine the lubricity of the fuel, use the "ISO 12156-1 or ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

NOTICE

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

## Diesel Fuel Characteristics

Perkins Recommendation

### Cetane Number

Fuel that has a high cetane number will give a shorter ignition delay. This will produce a better ignition quality. Cetane numbers are derived for fuels against proportions of cetane and heptamethylnonane in the standard CFR engine. Refer to "ISO 5165" for the test method.

Cetane numbers in excess of 45 are normally expected from current diesel fuel. However, a cetane number of 40 may be experienced in some territories. The United States of America is one of the territories that can have a low cetane value. A minimum cetane value of 40 is required during average starting conditions. A higher cetane value may be required for operations at high altitudes or in cold weather operations.

Fuel with a low cetane number can be the root cause of problems during cold start.

### Viscosity

Viscosity is the property of a liquid of offering resistance to shear or flow. Viscosity decreases with increasing temperature. This decrease in viscosity follows a logarithmic relationship for normal fossil fuel. The common reference is to kinematic viscosity. This is the quotient of the dynamic viscosity that is divided by the density. The determination of kinematic viscosity is normally by readings from gravity flow viscometers at standard temperatures. Refer to "ISO 3104" for the test method.

The viscosity of the fuel is significant because fuel serves as a lubricant for the fuel system components. Fuel must have sufficient viscosity in order to lubricate the fuel system in both extremely cold temperatures and extremely hot temperatures. If the kinematic viscosity of the fuel is lower than 1.4 cSt at the fuel injection pump damage to the fuel injection pump can occur. This damage can be excessive scuffing and seizure. Low viscosity may lead to difficult hot restarting, stalling and loss of performance. High viscosity may result in seizure of the pump.

Perkins recommends kinematic viscosities of 1.4 and 4.5 mm2/sec that is delivered to the fuel injection pump.

REFERENCE ONLY

## Density

Density is the mass of the fuel per unit volume at a specific temperature. This parameter has a direct influence on engine performance and a direct influence on emissions. This determines the heat output from a given injected volume of fuel. This is generally quoted in the following kg/m at 15 °C (59 °F).

Perkins recommends a value of density of 841 kg/m in order to obtain the correct power output. Lighter fuels are acceptable but these fuels will not produce the rated power.

## Sulfur

The level of sulfur is governed by emissions legislations. Regional regulation, national regulations or international regulations can require a fuel with a specific sulfur limit. The sulfur content of the fuel and the fuel quality must comply with all existing local regulations for emissions.

By using the test methods "ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884", the content of sulfur in low sulfur diesel (LSD) fuel must be below 500 PPM 0.05%. By using the test methods "ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884", the content of sulfur in ultra low sulfur (ULSD) fuel must be below 15 PPM 0.0015%. The use of LSD fuel and the use of ULSD fuel are acceptable provided that the fuels meet the minimum requirements that are stated in table 9. The lubricity of these fuels must not exceed wear scar diameter of 0.52 mm (0.020 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ".

In some parts of the world and for some applications, high sulfur fuels above 0.5% by mass might only be available. Fuel with very high sulfur content can cause engine wear. High sulfur fuel will have a negative impact on emissions of particulates. High sulfur fuel can be used provided that the local emissions legislation will allow the use. High sulfur fuel can be used in countries that do not regulate emissions.

When only high sulfur fuels are available, it will be necessary that high alkaline lubricating oil is used in the engine or that the lubricating oil change interval is reduced. Refer to this Operation and Maintenance Manual, "Fliud Recommendations (Genernal Lubrication Information)" for information on sulfur in fuel.

## Lubricity

This is the capability of the fuel to prevent pump wear. The fluid's lubricity describes the ability of the fluid to reduce the friction between surfaces that are under load. This ability reduces the damage that is caused by friction. Fuel injection systems rely on the lubricating properties of the fuel. Until fuel sulfur limits were mandated, the fuel's lubricity was generally believed to be a function of fuel viscosity.

The lubricity has particular significance to the current low viscosity fuel, low sulfur fuel and low aromatic fossil fuel. These fuels are made in order to meet stringent exhaust emissions. A test method for measuring the lubricity of diesel fuels has been developed and the test is based on the HFRR method that is operated at 60 °C (140 °F). Refer to "ISO 12156 part 1 and CEC document F06-A-96" for the test method.

Lubricity wear scar diameter of 0.52 mm (0.0205 inch) MUST NOT be exceeded. The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ".

Fuel additives can enhance the lubricity of a fuel. Contact your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can make recommendations for additives to use and for the proper level of treatment.

## Distillation

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

## Classification of the Fuels

Diesel engines have the ability to burn a wide variety of fuels. These fuels are divided into four general groups: Ref to table 10

Table 10

| Fuel Groups | Classification | |
|---|---|---|
| Group 1 | Preferred fuels | Full life of the Product |
| Group 2 | Permissible fuels with an appropriate fuel additive | These fuels MAY cause reduced engine life and performance |
| Group 3 | Permissible fuels with an appropriate fuel additive | These fuels WILL cause reduced engine life and performance |
| Group 4 | Biodiesel | |

REFERENCE ONLY

## Group 1 Specifications (Preferred Fuels)

This group of fuel specifications is considered acceptable:

- EN590 DERV Grade A, B, C, E, F, Class, 0, 1, 2, 3, and 4
- "BS2869 Class A2" Off-Highway Gas Oil Red Diesel
- "ASTM D975", Class 1D , and Class 2D
- "JIS K2204 Grades 1,2,3 and Special Grade 3" This grade of fuel must meet the minimum lubricity requirements that are stated in table 9.
- 5% FAME to "EN14214" can be mixed with the fuel that meets the requirements that are stated in table 9. This blend is commonly known as B5.

**Note:** The use of LSD fuel and the use of ULSD fuel is acceptable provided that the fuels meet the minimum requirements that are stated in table 9. The lubricity of these fuels must not exceed wear scar diameter of 0.52 mm (0.0205 inch). The lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ". By using the test methods "ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884", the content of sulfur in LSD fuel must be below 500 PPM 0.05%. By using the test methods "ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884", the content of sulfur in ULSD fuel must be below 15 PPM 0.0015%.

## Group 2 Specifications (Permissible Fuels)

This group of fuel specifications is considered acceptable, but only with an appropriate fuel additive, but these fuels MAY reduce the engine life and performance.

- "JP7 (MIL-T-38219)"
- "NATO F6 "
- JP8
- JP5
- "Jet A1 (ASTM D1655)"
- "Jet A (ASTM D1655)"
- "NATO F34 "

**Note:** These fuels are only acceptable provided that these fuels are used with an appropriate fuel additive. These fuels must meet the requirements that are stated in table 9. Fuel samples should be analyzed for the compliance. These fuels MUST NOT exceed lubricity wear scar diameter of 0.52 mm (0.0205 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ". Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

## Group 3 Specifications (Permissible Fuels)

This group of fuel specifications must be used only with the appropriate fuel additive. This fuel WILL reduce engine life and performance.

"JIS 2203#1 and #2 Toyu"

**Note:** These fuels are only acceptable provided that these fuels are used with an appropriate fuel additive. These fuels must meet the requirements that are stated in table 9. Fuel samples should be analyzed for the compliance. These fuels MUST NOT exceed lubricity wear scar diameter of 0.52 mm (0.0205 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to "ISO 12156-1 ". Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

## Group 4 Biodiesel

Biodiesel is a fuel that can be defined as mono-alkyl esters of fatty acids. Biodiesel is a fuel that can be made from a variety of feedstock. The most commonly available biodiesel in europe is Rape Methyl Ester (REM). This biodiesel is derived from rapeseed oil. Soy Methyl Ester (SME) is the most common biodiesel in the United States. This biodiesel is derived from soybean oil. Soybean oil or rapeseed oil are the primary feedstocks. These fuels are together known as Fatty Acid Methyl Esters (FAME).

REFERENCE ONLY

Raw pressed vegetable oils are NOT acceptable for use as a fuel in any concentration in compression engines. Without esterification, these oils gel in the crankcase and the fuel tank. These fuels may not be compatible with many of the elastomers that are used in engines that are manufactured today. In original forms, these oils are not suitable for use as a fuel in compression engines. Alternate base stocks for biodiesel may include animal tallow, waste cooking oils, or a variety of other feedstocks. In order to use any of the products that are listed as fuel, the oil must be esterified.

**Note:** Engines that are manufactured by Perkins are certified by use of the prescribed Environmental Protection Agency (EPA) and European Certification fuels. Perkins does not certify engines on any other fuel. The user of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer and allowed by the EPA and other appropriate regulatory agencies.

**Recommendation for the use of biodiesel**

Use of FAME fuels is permissible. However, the following conditions apply:

- The FAME fuel must comply with "EN14214".
- A maximum of 5% mixture of FAME can be used in mineral oil diesel fuel, provided that the fuel complies with the fuel specification that is listed in table 9. This blend is commonly known as B5. No mixture above 5% is acceptable. Concentrations above 5% will lead to reduced product service life and potential failure of the fuel injection equipment.

**Note:** When biodiesel, or any blend of biodiesel is used, the user has the responsibility for obtaining the proper local exemptions, regional exemptions, and/or national exemptions that are required for the use of biodiesel in any Perkins engine that is regulated by emissions standards. Biodiesel that meets EN 14214 is acceptable. The biodiesel must be blended with an acceptable distillate diesel fuel at the maximum stated percentages. However, the following operational recommendations must be followed:

- The oil change interval can be affected by the use of biodiesel. Use Services Oil Analysis in order to monitor the condition of the engine oil. Use Services Oil Analysis also in order to determine the oil change interval that is optimum.
- Confirm that biodiesel is acceptable for use with the manufacturer of the fuel filters.
- In a comparison of distillate fuels to biodiesel, biodiesel provides less energy per gallon by 5% to 7%. Do NOT change the engine rating in order to compensate for the power loss. This will help avoid engine problems when the engine is converted back to 100 percent distillate diesel fuel.
- The compatibility of the elastomers with biodiesel is being monitored. The condition of seals and hoses should be monitored regularly.
- Biodiesel may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attainment of the proper cloud point for the fuel.
- Biodiesel has poor oxidation stability, which can result in long term problems in the storage of biodiesel. The poor oxidation stability may accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because these engines operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.
- Biodiesel is a fuel that can be made from a variety of feedstock. The feedstock that is used can affect the performance of the product. Two of the characteristics of the fuel that are affected are cold flow and oxidation stability. Contact your fuel supplier for guidance.
- Biodiesel or biodiesel blends are not recommended for engines that will operate occasionally. This is due to poor oxidation stability. If the user is prepared to accept some risk, then limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles
- Biodiesel is an excellent medium for microbial contamination and growth. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. The use of conventionalanti-microbial additives and the effectiveness of conventional anti-microbial additives in biodiesel is not known. Consult your supplier of fuel and additive for assistance.
- Care must be taken in order to remove water from fuel tanks. Water accelerates microbial contamination and growth. When biodiesel is compared to distillate fuels, water is naturally more likely to exist in the biodiesel.

REFERENCE ONLY

## Fuel for Cold Weather Operation

The European standard “EN590” contains climate dependant requirements and a range of options. The options can be applied differently in each country. There are 5 classes that are given to arctic climates and severe winter climates. 0, 1, 2, 3, and 4.

Fuel that complies with “EN590 ” CLASS 4 can be used at temperatures as low as −44 °C (−47.2 °F). Refer to “EN590” for a detailed discretion of the physical properties of the fuel.

The diesel fuel “ASTM D975 1-D” that is used in the united states of america may be used in very cold temperatures that are below −18 °C (−0.4 °F).

In extreme cold ambient conditions, you may also use fuels that are listed in the table 11. These fuels are intended to be used in temperatures that can be as low as −54 °C (−65.2 °F).

Table 11

| Light Distillate Fuels (1) | |
|---|---|
| Specification | Grade |
| “MIL-T-5624R” | JP-5 |
| “MIL-T-83133D” | JP-8 |
| “ASTM D1655” | Jet-A-1 |

(1) The use of these fuels is acceptable with an appropriate fuel additive and the fuels must meet minimum requirements that are stated in Table 9. Fuel samples should be analyzed for the compliance. Fuels MUST NOT exceed 0.52 mm lubricity wear scar diameter that is tested on a HFRR. The test must be performed at 60 °C. Refer to “ISO 12156-1”. Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

**WARNING**

**Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or the fuel tank. Alcohol or gasoline must not be used in order to dilute diesel fuel. Failure to follow this instruction may result in death or personal injury.**

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in table 9. To ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are stated in the table 9.

## Fuel Additive

Supplemental diesel fuel additives are not generally recommended. This is due to potential damage to the fuel system or the engine. Your fuel supplier or the fuel manufacturer will add the appropriate supplemental diesel fuel additives.

Perkins recognizes the fact that additives may be required in some special circumstances. Fuel additives need to be used with caution. Contact your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can recommend the appropriate fuel additive and the correct level of treatment.

**Note:** For the best results, your fuel supplier should treat the fuel when additives are required. The treated fuel must meet the requirements that are stated in table 9.

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# Fluid Recommendations (Coolant Specifications)

## General Coolant Information

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

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

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

Clean the cooling system for the following reasons:

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

REFERENCE ONLY

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

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

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

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

## Water

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

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

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

If distilled water or deionized water is not available, use water with the properties that are listed in Table 12.

Table 12

| Acceptable Water | |
|---|---|
| Property | Maximum Limit |
| Chloride (Cl) | 40 mg/L |
| Sulfate (SO4) | 100 mg/L |
| Total Hardness | 170 mg/L |
| Total Solids | 340 mg/L |
| Acidity | pH of 5.5 to 9.0 |

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

- Local water utility company
- Agricultural agent
- Independent laboratory

## Additives

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

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

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

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

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

## Glycol

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

- Boiling
- Freezing
- Cavitation of the water pump

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

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

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

Most conventional antifreezes use ethylene glycol. Propylene glycol may also be used. In a 1:1 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling. See Tables 13 and 14.

REFERENCE ONLY

Table 13

| Ethylene Glycol | |
|---|---|
| **Concentration** | **Freeze Protection** |
| 50 Percent | −36 °C (−33 °F) |
| 60 Percent | −51 °C (−60 °F) |

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

Table 14

| Propylene Glycol | |
|---|---|
| **Concentration** | **Freeze Protection** |
| 50 Percent | −29 °C (−20 °F) |

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

## Coolant Recommendations

- ELC_____Extended Life Coolant
- SCA_____Supplement Coolant Additive
- ASTM_____American Society for Testing and Materials

The following two coolants are used in Perkins diesel engines:

**Preferred** – Perkins ELC

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

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

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

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

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

Table 15

| Coolant Service Life | |
|---|---|
| **Coolant Type** | **Service Life** |
| Perkins ELC | 6,000 Service Hours or Three Years |
| Commercial Heavy-Duty Antifreeze that meets "ASTM D4985" | 3000 Service Hours or Two Years |
| Perkins POWERPART SCA | 3000 Service Hours or Two Years |
| Commercial SCA and Water | 3000 Service Hours or Two Years |

### ELC

Perkins provides ELC for use in the following applications:

- Heavy-duty spark ignited gas engines
- Heavy-duty diesel engines
- Automotive applications

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

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

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

REFERENCE ONLY

# ELC Cooling System Maintenance

## Correct additions to the Extended Life Coolant

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

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

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

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

Do not use standard supplemental coolant additive (SCA).

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

## ELC Cooling System Cleaning

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

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

Before the cooling system is filled, the heater control (if equipped) must be set to the hot position. Refer to the OEM in order to set the heater control. After the cooling system is drained and the cooling system is refilled, operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture in order to fill the system to the specified level.

## Changing to Perkins ELC

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

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

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.

REFERENCE ONLY

## ELC Cooling System Contamination

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

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

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

## Commercial Heavy-Duty Antifreeze and SCA

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

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

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

Perkins engine cooling systems should be tested at 500 hour intervals for the concentration of SCA.

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

Refer to Table 16 for part numbers and for quantities of SCA.

Table 16

| Perkins Liquid SCA | |
|---|---|
| **Part Number** | **Quantity** |
| 21825735 | 10 |

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

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

Use the equation that is in Table 17 to determine the amount of Perkins SCA that is required when the cooling system is initially filled.

Table 17

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

Table 18 is an example for using the equation that is in Table 17.

Table 18

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

## Adding The SCA to The Heavy-Duty Coolant For Maintenance

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

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

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

REFERENCE ONLY

Use the equation that is in Table 19 to determine the amount of Perkins SCA that is required, if necessary:

Table 19

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

Table 20 is an example for using the equation that is in Table 19.

Table 20

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

## Cleaning the System of Heavy-Duty Antifreeze

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

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

REFERENCE ONLY

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# Maintenance Interval Schedule

## When Required

Battery - Replace ..... 68
Battery or Battery Cable - Disconnect ..... 69
Engine - Clean ..... 76
Engine Air Cleaner Element (Dual Element) - Clean/Replace ..... 77
Engine Oil Sample - Obtain ..... 81
Fuel System - Prime ..... 85
Severe Service Application - Check ..... 95

## Daily

Alternator Belt - Inspect/Adjust/Replace ..... 68
Cooling System Coolant Level - Check ..... 74
Driven Equipment - Check ..... 76
Engine Air Cleaner Service Indicator - Inspect ..... 79
Engine Air Precleaner - Check/Clean ..... 80
Engine Oil Level - Check ..... 80
Fuel System Primary Filter/Water Separator - Drain ..... 86
V-Belts - Inspect/Adjust/Replace ..... 97
Walk-Around Inspection ..... 98

## Every 50 Service Hours or Weekly

Fuel Tank Water and Sediment - Drain ..... 93

## Every 250 Service Hours

Engine Oil and Filter - Change ..... 83

## Initial 500 Service Hours

Engine Valve Lash - Inspect/Adjust ..... 83

## Every 500 Service Hours

Fan Clearance - Check ..... 84
V-Belts - Inspect/Adjust/Replace ..... 97

## Every 500 Service Hours or 1 Year

Battery Electrolyte Level - Check ..... 69
Cooling System Supplemental Coolant Additive (SCA) - Test/Add ..... 75
Crankcase Breather (Canister) - Replace ..... 75
Engine Air Cleaner Element (Dual Element) - Clean/Replace ..... 77
Engine Oil and Filter - Change ..... 81
Fuel System Primary Filter (Water Separator) Element - Replace ..... 87
Fuel System Secondary Filter - Replace ..... 90
Hoses and Clamps - Inspect/Replace ..... 93
Radiator - Clean ..... 94

## Every 1000 Service Hours

Engine Valve Lash - Inspect/Adjust ..... 83

## Every 2000 Service Hours

Aftercooler Core - Inspect ..... 67
Alternator - Inspect ..... 68
Belt Tensioner - Inspect ..... 70
Engine Mounts - Inspect ..... 80
Exhaust Manifold - Inspect ..... 84
Starting Motor - Inspect ..... 96
Turbocharger - Inspect ..... 96
Water Pump - Inspect ..... 99

## Every 3000 Service Hours

Alternator Belt - Inspect/Adjust/Replace ..... 68

## Every 3000 Service Hours or 2 Years

Cooling System Coolant (Commercial Heavy-Duty) - Change ..... 70

## Every 4000 Service Hours

Aftercooler Core - Clean/Test ..... 67

## Every 12 000 Service Hours or 6 Years

Cooling System Coolant (ELC) - Change ..... 72

## Commissioning

Fan Clearance - Check ..... 84

REFERENCE ONLY

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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 ensure cleanliness. Pressure test the core. If necessary, repair the core.

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

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

i02322295

# Aftercooler Core - Inspect

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

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

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

**⚠ WARNING**

**Personal injury can result from air pressure.**

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

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

REFERENCE ONLY

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

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

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

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

i02322311

# Alternator - Inspect

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

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

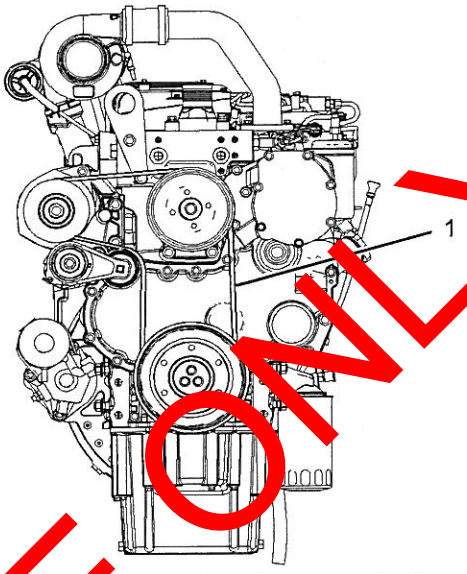
i02491869

# Alternator Belt - Inspect/Adjust/Replace (Poly V-Belt)

## Inspection

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

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




g01251375

Illustration 68
Typical example

## Adjustment

This type of belt has an automatic belt tensioner.

## Replace

Refer to Disassembly and Assembly manual, "Alternator Belt - Remove and Install".

i02322315

# Battery - Replace

**WARNING**

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

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

REFERENCE ONLY

**⚠ 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.

REFERENCE ONLY

3. Remove the positive connection.

4. Clean all disconnected connection and battery terminals.

5. Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright or shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit correctly. Coat the clamps and the terminals with a suitable silicone lubricant or petroleum jelly.

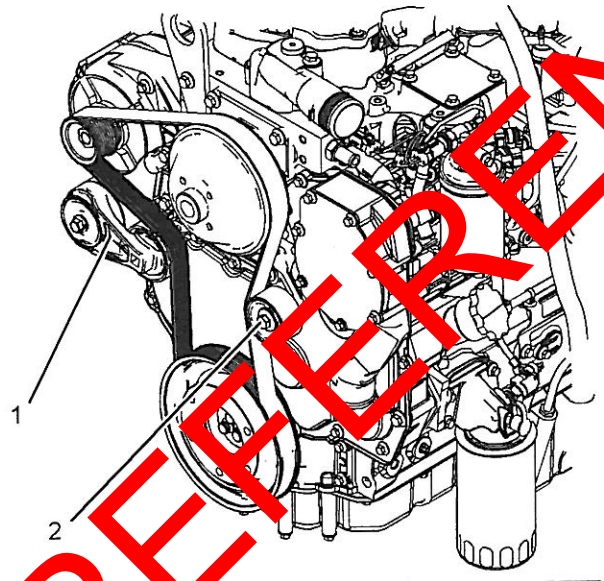
6. Tape the cable connections in order to help prevent accidental starting.

7. Proceed with necessary system repairs.

8. In order to connect the battery, connect the positive connection before the negative connector.

i02870187

## Belt Tensioner - Inspect




g01429637

Illustration 24
Typical example

Remove the belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

Ensure that the belt tensioner is securely installed. Visually inspect the belt tensioner (1) for damage. Check that the roller on the tensioner rotates freely. Some engines have a guide roller (2). Ensure that the guide roller is securely installed. Visually inspect the guide roller for damage. Ensure that the guide roller can rotate freely.

Install the belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

i02854855

## Cooling System Coolant (Commercial Heavy-Duty) - Change

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

Dispose of all fluids according to Local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

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

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

### Drain

**⚠ WARNING**

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

REFERENCE ONLY

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

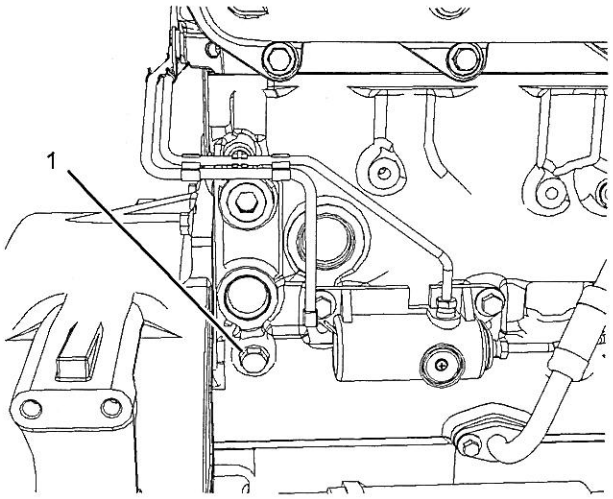



Illustration 30 g01244659
Typical example

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

   Allow the coolant to drain.

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

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

## Flush

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

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

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

Cooling system air locks may result in engine damage.

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

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

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

## Fill

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

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

Cooling system air locks may result in engine damage.

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

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

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

REFERENCE ONLY

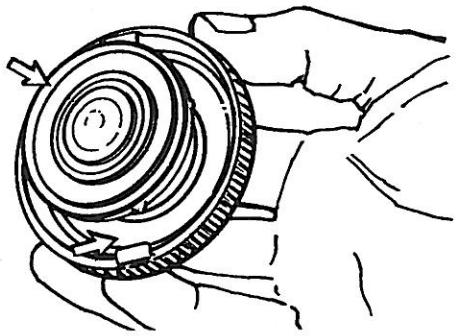


Illustration 31 g00103639
Filler cap

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

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

# Cooling System Coolant (ELC) - Change

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

Dispose of all fluids according to Local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

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

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

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

## Drain

**WARNING**

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

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

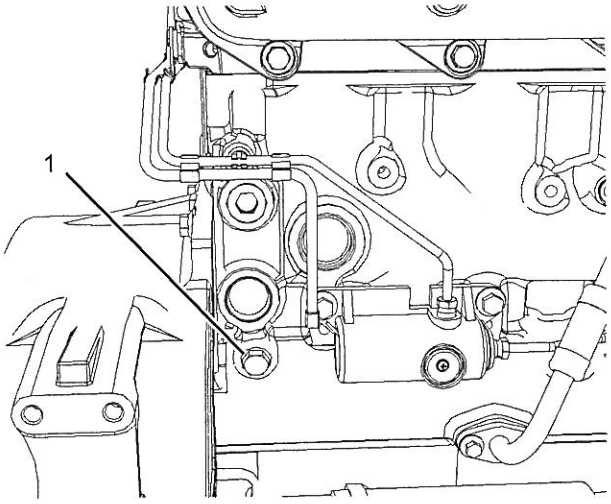



Illustration 32 g01244659
Typical example

REFERENCE ONLY

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

   Allow the coolant to drain.

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

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

## Flush

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

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

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

Cooling system air locks may result in engine damage.

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

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

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

## Fill

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

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

Cooling system air locks may result in engine damage.

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

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

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

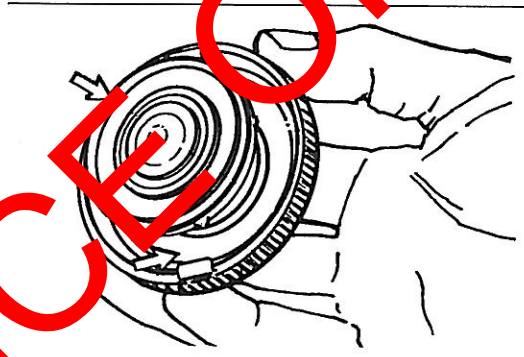


Illustration 33 g00103639
Filler cap

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

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

REFERENCE ONLY

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.

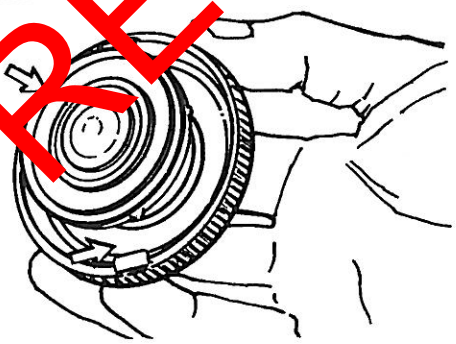


Illustration 34 g00103639

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.

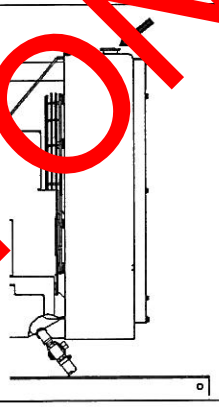


Illustration 35 g00285520

Cooling system filler cap

**⚠ WARNING**

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

1. Remove the cooling system filler cap slowly in order to relieve pressure.

2. Maintain the coolant level 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.

REFERENCE ONLY

i02335389

# Cooling System Supplemental Coolant Additive (SCA) - Test/Add

**⚠ WARNING**

**Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and the eyes. Do not drink cooling system coolant additive.**

## Test for SCA Concentration

### Heavy-Duty Coolant/Antifreeze and SCA

NOTICE
Do not exceed the recommended six percent supplemental coolant additive concentration.

Use a Coolant Conditioner Test Kit in order to check the concentration of the SCA.

## Add the SCA, If Necessary

NOTICE
Do not exceed the recommended amount of supplemental coolant additive concentration. Excessive supplemental coolant additive concentration can form deposits on the higher temperature surfaces of the cooling system, reducing the engine's heat transfer characteristics. Reduced heat transfer could cause cracking of the cylinder head and other high temperature components. Excessive supplemental coolant additive concentration could also result in radiator tube blockage, overheating, and/or accelerated water pump seal wear. Never use both liquid supplemental coolant additive and the spin-on element (if equipped) at the same time. The use of those additives together could result in supplemental coolant additive concentration exceeding the recommended maximum.

**⚠ WARNING**

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

1. Slowly loosen the cooling system filler cap in order to relieve the pressure. Remove the cooling system filler cap.

**Note:** Always discard drained fluids according to local regulations.

2. If necessary, drain some coolant from the cooling system into a suitable container in order to allow space for the extra SCA.

3. Add the correct amount of SCA. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" for more information on SCA requirements.

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

i02866782

# Crankcase Breather (Canister) - Replace

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

**Note:** The breather assembly is not installed on all engines.

1. Place a container under the canister (1).

2. Clean the outside of the canister. Use a suitable tool in order to remove the canister.

REFERENCE ONLY

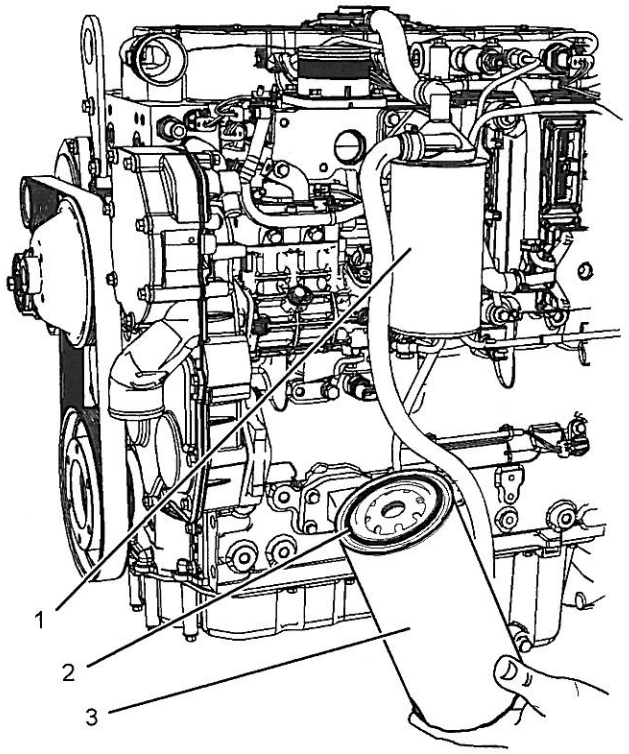



Illustration 36 g01428096

Typical example

3. Lubricate the O ring seal (2) on the new canister (3) with clean engine lubricating oil. Install the new canister. Tighten the canister to 12 N·m (8 lb ft). Do not overtighten the canister.

4. Remove the container. Dispose of the old canister and any split oil in a safe place.

i02151646

## Driven Equipment - Check

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

- Inspection
- Adjustment
- Lubrication
- Other maintenance recommendations

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

i01909392

## Engine - Clean

**⚠ WARNING**

**Personal injury or death can result from high voltage.**

**Moisture can create paths of electrical conductivity.**

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

NOTICE

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

NOTICE

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

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

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

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

REFERENCE ONLY

i02334355

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

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

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

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

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

### Dual Element Air Cleaners

The dual element air cleaner contains a primary air cleaner element and a secondary air cleaner element.

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

The secondary air cleaner element is not serviceable. Refer to the OEM information for instructions in order to replace the secondary air cleaner element.

When the engine is operating in environments that are dusty or dirty, air cleaner elements may require more frequent replacement.

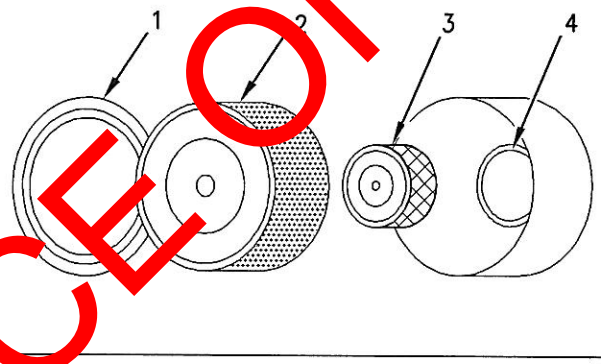



Illustration 37 g00736431

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

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

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

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

REFERENCE ONLY

## Cleaning the Primary Air Cleaner Elements

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

NOTICE
Do not tap or strike the air cleaner element.

Do not wash the primary air cleaner element.

Use low pressure (207 kPa; 30 psi maximum) pressurised air or vacuum cleaning to clean the primary air cleaner element.

Take extreme care in order to avoid damage to the air cleaner elements.

Do not use air cleaner elements that have damaged pleats, gaskets or seals.

Refer to the OEM information in order to determine the number of times that the primary air cleaner element can be cleaned. Do not clean the primary air filter element more than three times. The primary air cleaner element must be replaced at least one time per year.

Cleaning the air filter element will not extend the life of the air filter element.

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

Two methods may be used in order to clean the primary air cleaner element:

- pressurized air
- vacuum cleaning

### Pressurized Air

**WARNING**

**Personal injury can result from air pressure.**

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

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

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

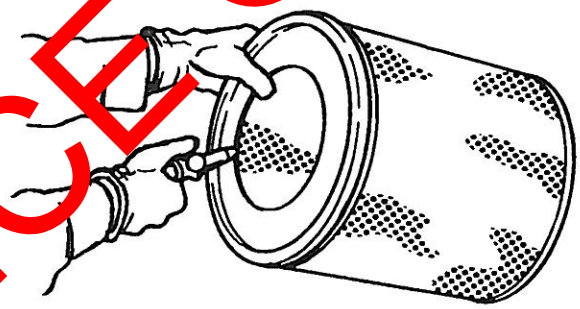


Illustration 38 g00281692

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

Aim the air hose so that air flows along the length of the filter. Follow the direction of the paper pleats in order to prevent damage to the pleats. Do not aim the air directly at the face of the paper pleats.

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

### Vacuum Cleaning

Vacuum cleaning is a good method for removing accumulated dirt from the dirty side (outside) of a primary air cleaner element. Vacuum cleaning is especially useful for cleaning primary air cleaner elements which require daily cleaning because of a dry, dusty environment.

Cleaning from the clean side (inside) with pressurized air is recommended prior to vacuum cleaning the dirty side (outside) of a primary air cleaner element.

REFERENCE ONLY

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

### Inspecting the Primary Air Cleaner Elements

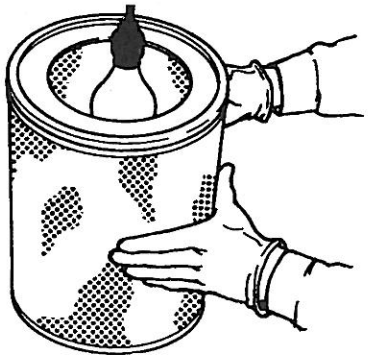


Illustration 39 g00281693

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

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

i02335405

## Engine Air Cleaner Service Indicator - Inspect

Some engines may be equipped with a different service indicator.

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

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

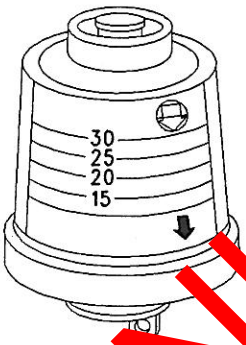



Illustration 40 g00103777
Typical service indicator

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

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

### Test the Service Indicator

Service indicators are important instruments.

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

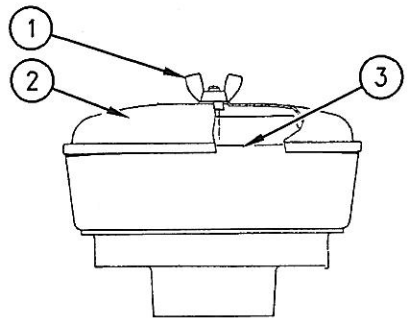
If the service indicator does not reset easily, or if the yellow core does not latch at the greatest vacuum, the service indicator should be replaced. If the new service indicator will not reset, the hole for the service indicator may be restricted.

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

REFERENCE ONLY

i02343354

# Engine Air Precleaner - Check/Clean




g00287039

Illustration 41

Typical example

(1) Wing nut
(2) Cover
(3) Body

Remove wing nut (1) and cover (2). Check for an accumulation of dirt and debris in body (3). Clean the body, if necessary.

After cleaning the precleaner, install cover (2) and wing nut (1).

**Note:** When the engine is operated in dusty applications, more frequent cleaning is required.

i02323089

# Engine Mounts - Inspect

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

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

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

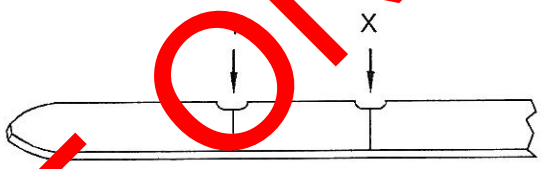
Any engine mount that shows deterioration should be replaced. Refer to the OEM information for the recommended torques.

i02335785

# Engine Oil Level - Check

**⚠ WARNING**

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




g01165836

Illustration 42

(X) "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.

REFERENCE ONLY

i01907674

# Engine Oil Sample - Obtain

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

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

## Obtain the Sample and the Analysis

**⚠ WARNING**

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

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

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

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

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

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

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

i02867741

# Engine Oil and Filter - Change

**⚠ WARNING**

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

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

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

## Drain the Engine Lubricating Oil

**Note:** Ensure that the vessel that will be used is large enough to collect the waste oil.

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

REFERENCE ONLY

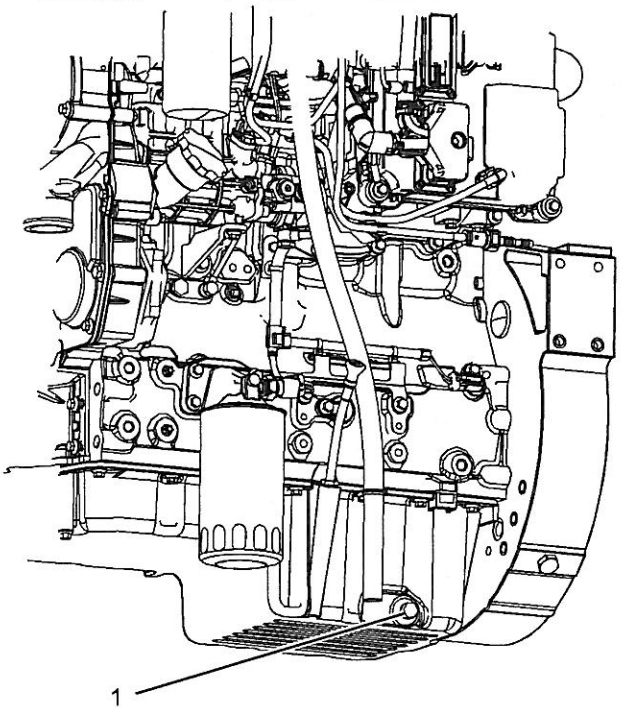



Illustration 43 g01428532

Typical example

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

After the oil has drained, the oil drain plugs should be cleaned and installed. If necessary, replace the O ring seal. Tighten the drain plug to 34 N·m (25 lb ft).

## Replace the Oil Filter

NOTICE

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

1. Remove the oil filter with a suitable tool. A horizontally installed oil filter can be drained before removal.

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

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

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

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

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

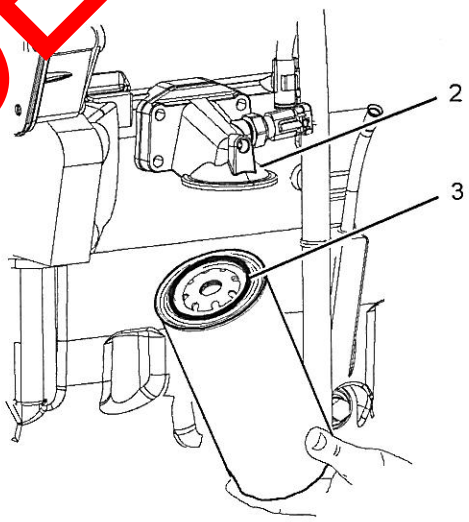



Illustration 44 g01187802

Typical example

3. Clean the sealing surface of the oil filter head (2). Ensure that the union is secure in the filter head.

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

NOTICE

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

REFERENCE ONLY

5. Install the oil filter. Tighten the oil filter to 12 N·m (8.8 lb ft). Do not overtighten the oil filter.

## Horizontal Oil Filter

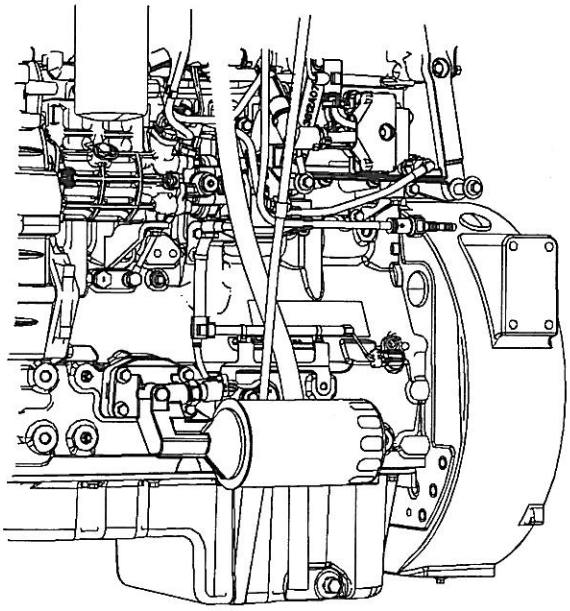


Illustration 45 g01425535
Typical example

**Note:** Some oil filters may be installed horizontally. Refer to illustration 45. This type of oil filter assembly can be drained before the filter is removed. Start at step 1 in order to remove the oil filter and install the oil filter.

## Fill the Oil Pan

1. Remove the oil filler cap. Refer to this Operation and Maintenance Manual, "Fluid Recommendations" for more information on suitable oils. Fill the oil pan with the correct amount of new engine lubricating oil. Refer to this Operation and Maintenance Manual, "Refill Capacities" for more information on refill capacities.

NOTICE
If equipped with an auxilliary oil filter system or a remote filter system, follow the OEM or the filter manufacture's remonmendations. Under filling or over filling the crankcase with oil can cause engine damage.

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

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

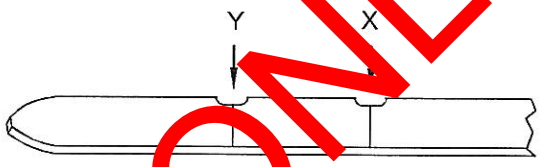



Illustration 46 g01165836
(Y) "Min" mark. (X) "Max" mark.

4. Remove the engine oil level gauge in order to check the oil level. Maintain the oil level between the "MIN" and "MAX" marks on the engine oil level gauge.

i02869394

# Engine Oil and Filter - Change (CG-4 Oil)

CG-4 engine oil may be used. If this grade of engine oil is used a 250 hour service interval is required for the engine oil and the engine oil filter.

i02503009

# Engine Valve Lash - Inspect/Adjust

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

REFERENCE ONLY

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

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

**⚠ WARNING**

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

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

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

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

i02862580

## Exhaust Manifold - Inspect

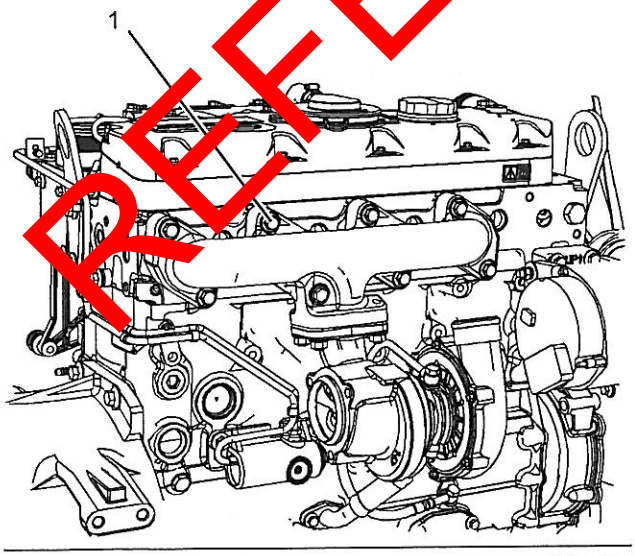



Illustration 47 g01425829

1. Inspect the exhaust manifold for damage. If necessary, replace the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install".

2. Check the torque on all the bolts (1). The bolts must be tightened in the sequence that is shown in illustration 48.

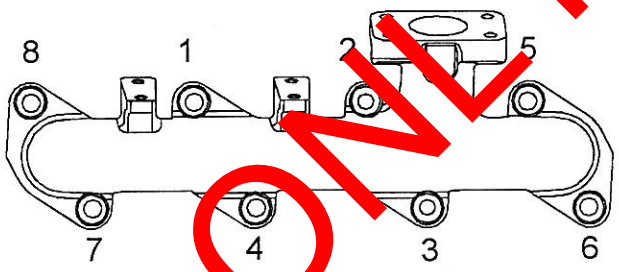



Illustration 48 g01363916

3. Tighten the bolts to the following torque 40 N·m (29.5 lb ft).

i02683336

## Fan Clearance - Check

There are different types of cooling systems. Refer to the OEM for information on clearance for the fan.

Ensure that the engine is stopped. Ensure that the cooling system is full. The clearance between the cover (1) and the fan (2) will require checking. The gap (A) between the edge of the cover and the tip of the fan blade must be checked in four equally spaced positions.

REFERENCE ONLY

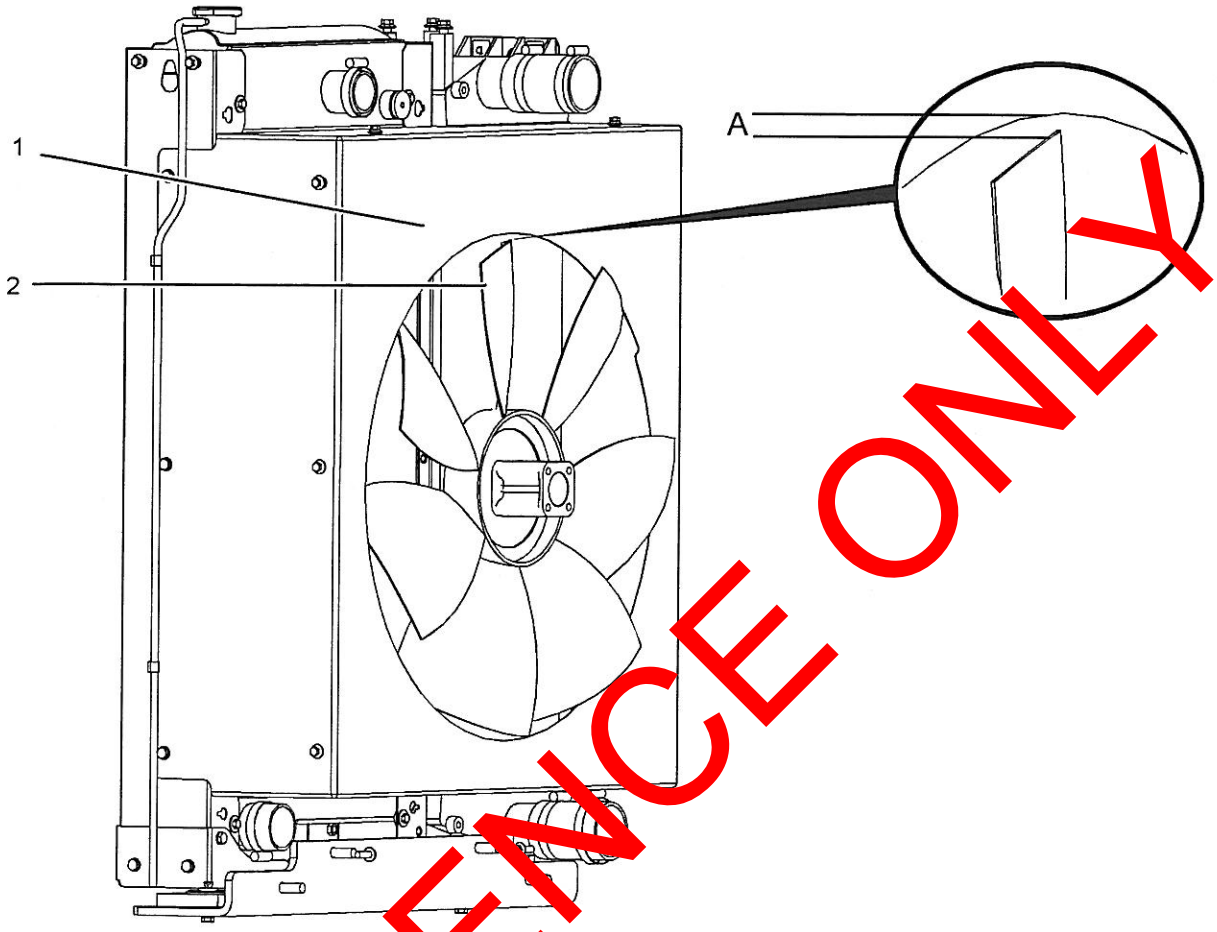



Illustration 49 g01348394

Adjustment of the cover will change the clearance (gap) between the edge of the cover and the tip of the fan blade. Ensure that the cover is centralized to the fan.

The maximum clearance is 12.3 mm (0.4921 inch). The minimum clearance is 6 mm (0.2362 inch).

i02871014

## Fuel System - Prime

**⚠ WARNING**

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

Refer to the Operation and Maintenance Manual , "General Hazard Information and High Pressure Fuel Lines" before adjustments and repairs are performed.

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

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

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

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

REFERENCE ONLY

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

## Hand Fuel Priming Pump

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

1. Ensure that the fuel system is in working order. Check that the fuel supply valve (if equipped) is in the "ON" position.

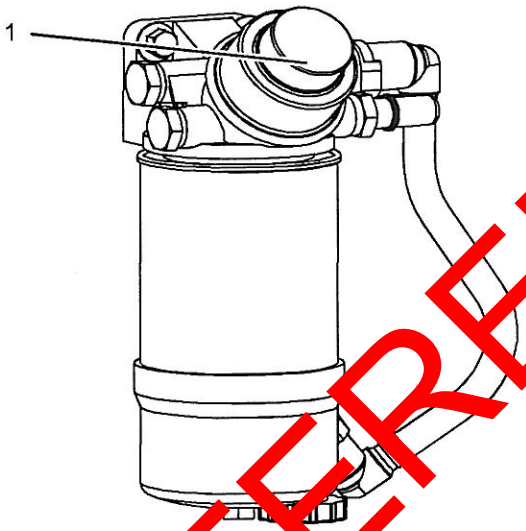



Illustration 50 g01476592
Typical example

2. Operate the fuel priming pump (1). Count the number of operations of the fuel priming pump. After 200 depressions of the fuel priming pump stop.
3. The engine fuel system should now be primed and the engine should now be able to start.
4. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of five minutes, immediately after air has been removed from the fuel system.

**Note:** Operating the engine for this period of time will help ensure that the fuel system is free of air.

**Note:** Do not loosen the high pressure fuel line in order to purge air from the fuel system. This procedure is not required.

**⚠ WARNING**

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

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General hazard Information".

i02869410

# Fuel System Primary Filter/Water Separator - Drain

**⚠ WARNING**

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

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

REFERENCE ONLY

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

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

1. Place a suitable container under the water separator in order to catch any fuel that might spill. Clean up any spilled fuel.

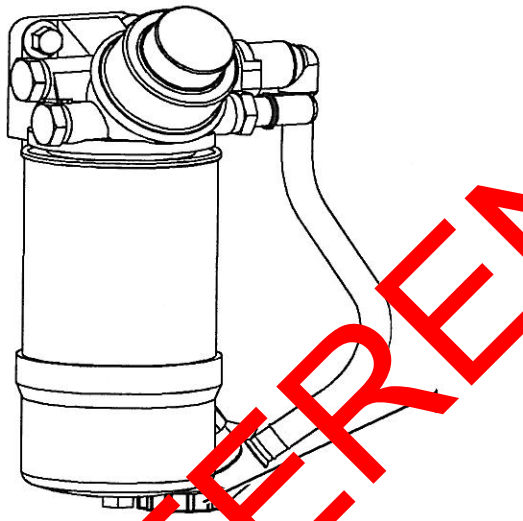


Illustration 51 g01476633
Typical example

2. Install a suitable tube onto the drain (1). Open the drain (1). Allow the fluid to drain into the container.

3. Tighten the drain (1) by hand pressure only. Remove the tube and dispose of the drained fluid in a safe place.

## Primary Filter with a Vent Screw

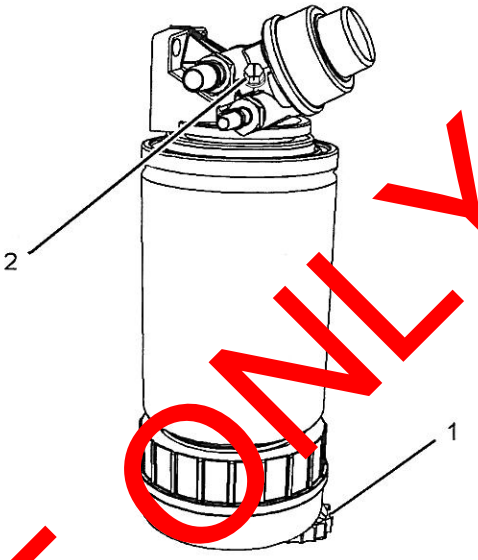



Illustration 52 g01371846
Typical example

**Note:** Not all primary filters require vent screw (2). This primary fuel filter that has a vent screw may be installed on a fuel system that has a low fuel tank.

1. Install a suitable tube onto drain (1). Loosen vent screw (2).

2. Open drain (1). Allow the fluid to drain into the container.

3. Tighten drain (1) by hand pressure only. Remove the tube and dispose of the drained fluid in a safe place.

4. Tighten vent screw to 6 N·m (53 lb in).

i02869425

# Fuel System Primary Filter (Water Separator) Element - Replace

## Type One Filter

**⚠ WARNING**

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

REFERENCE ONLY

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

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

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

1. Turn the fuel supply valve (if equipped) to the OFF position before performing this maintenance.

2. Place a suitable container under the water separator in order to catch any fuel that might spill. Clean up any spilled fuel. Clean the outside of the water separator.

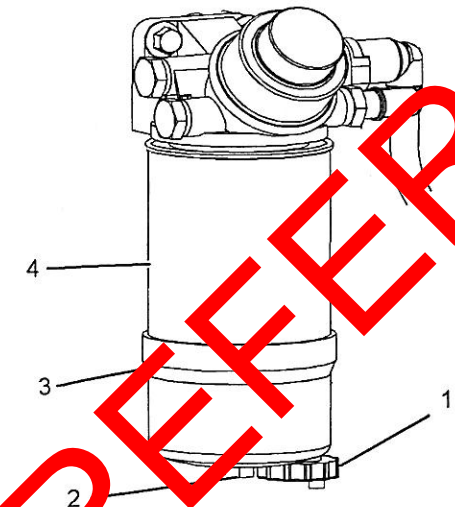



Illustration 53 g01259363
Typical example

3. Install a suitable tube onto drain (1). Open the drain (1). Allow the fluid to drain into the container. Remove the tube.

4. Tighten drain (1) by hand pressure only.

5. If equipped, remove the wiring harness from the sensor on the bottom of the glass bowl.

6. Hold glass bowl (3) and remove screw (2). Remove glass bowl (3) from canister (4).

7. Use a suitable tool in order to remove canister (4). Discard the old seals (5 and 6) and the canister in a safe place.

8. Clean glass bowl (3).

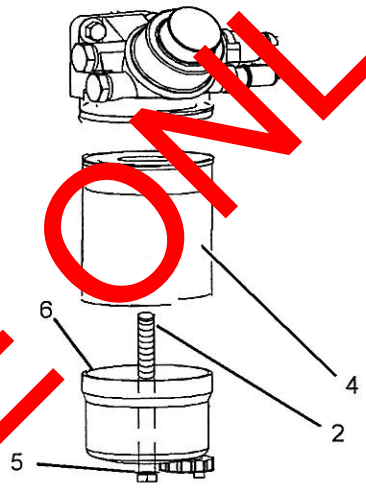



Illustration 54 g01259366
Typical example

9. Install the new canister. Do not use a tool in order to install the canister. Tighten the canister by hand.

10. Install new O ring seal (5) onto setscrew (2). Install new O ring seal (6) into the glass bowl.

11. Align the glass bowl to the canister. Ensure that the sensor (if equipped) is in the correct position. Install setscrew (2). Tighten the setscrew to a torque of 5 N·m (44 lb in).

12. If equipped, install the wiring harness to the sensor.

13. Remove the container and dispose of the fuel in a safe place.

14. The secondary filter must be replaced at the same time as the primary filter. Refer to the Operation and Maintenance Manual , "Fuel System Filter - Replace".

REFERENCE ONLY

## Type Two Filter

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

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

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

1. Turn the fuel supply valve (if equipped) to the OFF position before performing this maintenance.
2. Place a suitable container under the water separator in order to catch any fuel that might spill. Clean up any spilled fuel. Clean the outside of the water separator.

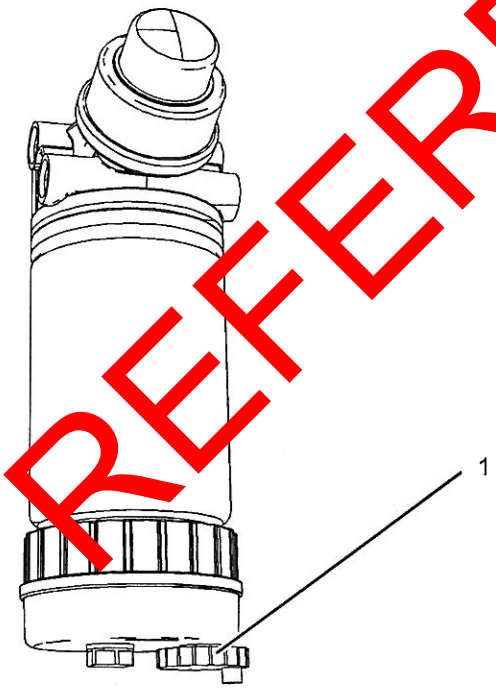



Illustration 55 g01429124

3. Install a suitable tube onto drain (1). Open drain (1). Allow the fluid to drain into the container. Remove the tube.
4. Tighten drain (1) by hand pressure only.
5. If equipped, remove the wiring harness from the sensor on the bottom of the bowl .

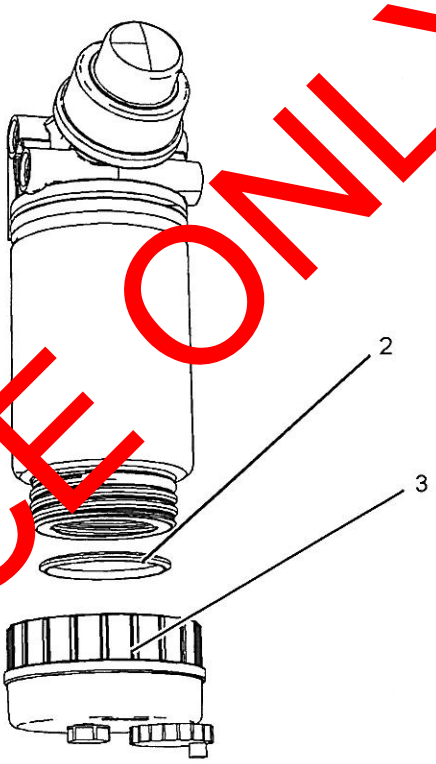



Illustration 56 g01429125

6. Rotate bowl (3) counterclockwise in order to remove the bowl. Remove O ring seal (2). Clean the bowl.

REFERENCE ONLY

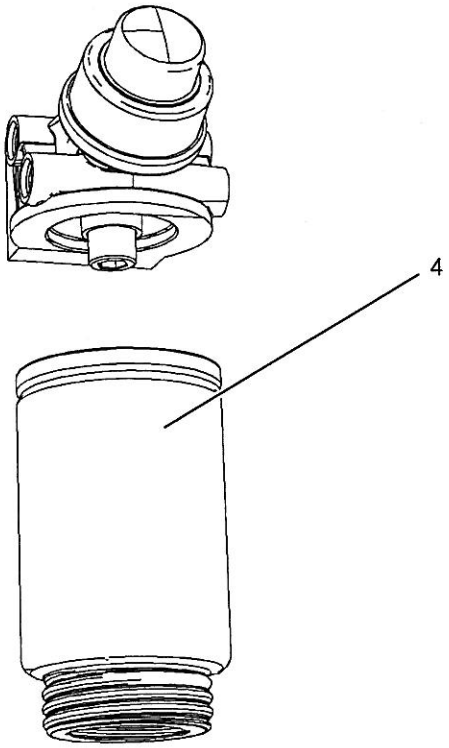



Illustration 57 g01429126

7. Use a suitable tool in order to remove old canister (4).

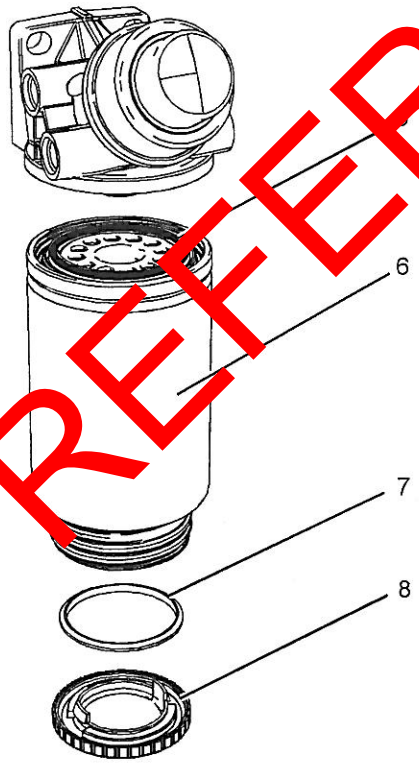



Illustration 58 g01429127

8. Lubricate O ring seal (5 ) with clean engine oil on the new canister. Install new canister (6). Spin on the canister until the O ring seal contacts the sealing surface. Then rotate the canister 360 degree in order to tighten the canister correctly.

9. Remove cap (8) from the threaded end of the new canister and remove new O ring seal (7). Install the new O ring seal into bowl (3).

10. Lubricate O ring seal (7) with clean engine oil. Install the bowl onto the new canister. Tighten the bowl to 15 N·m (11 lb ft).

11. If equipped, install the wiring harness to the sensor. Open the fuel supply valve.

12. Remove the container and dispose of the fluid in a safe place.

13. The secondary filter must be replaced at the same time as the primary filter. Refer to the Operation and Maintenance Manual , "Fuel System Filter - Replace".

i02869989

# Fuel System Secondary Filter - Replace

## Type One

**⚠ WARNING**

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

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

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

This fuel filter can be identified by the six drain holes in the filter. Refer to illustration 59.

REFERENCE ONLY

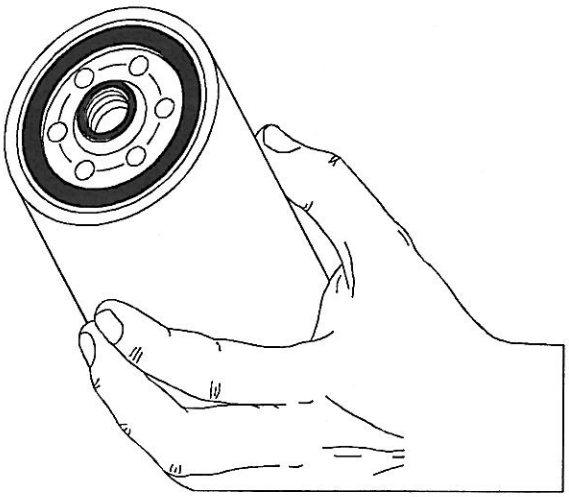


Illustration 59 g01429525

Typical example

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

1. Ensure that the fuel supply valve (if equipped) is in the OFF position. Place a suitable container under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel.

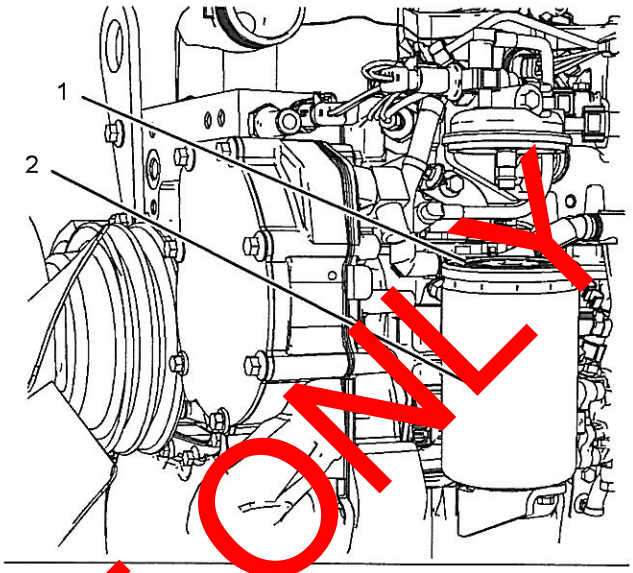



Illustration 60 g01429517

Typical example

2. Clean the outside of the fuel filter. Use a suitable tool in order to remove the canister (2) from the engine and dispose of the canister in a safe place.

3. Ensure that dirt can not enter the new canister. Do not fill the canister with fuel before the canister is installed. Lubricate the O ring seal (1) with clean engine oil on the new canister.

4. Install the new canister. Do not use a tool in order to install the canister. Tighten the canister by hand.

5. Spin on the canister until the O ring seal contacts the sealing surface. The canister will require a ¾ of a full turn in order to tighten the canister correctly.

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

## Type Two

**⚠ WARNING**

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

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

REFERENCE ONLY

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



Illustration 61 g01429532

This fuel filter can be identified by the 12 drain holes in the filter. Refer to illustration 61.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

1. Ensure that the fuel supply valve (if equipped) is in the OFF position. Place a suitable container under the fuel filter in order to catch any fuel that might spill. Clean up any spilled fuel.

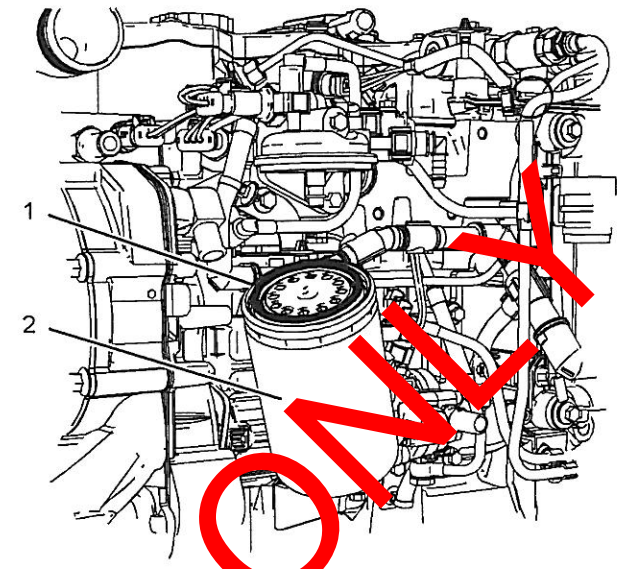



Illustration 62 g01429516
Typical example

2. Clean the outside of the fuel filter. Use a suitable tool in order to remove the canister (2) from the engine and dispose of the canister in a safe place.

3. Ensure that dirt can not enter the new canister. Do not fill the canister with fuel before the canister is installed. Lubricate the O ring seal (1) with clean engine oil on the new canister.

4. Install the new canister. Do not use a tool in order to install the canister. Tighten the canister by hand.

5. Spin on the canister until the O ring seal contacts the sealing surface. Then rotate the canister 360 degree in order to tighten the canister correctly.

6. Remove the container and dispose of the fuel in a safe place. If equipped, open the fuel supply valve.

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

REFERENCE ONLY

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

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

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

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

## Fuel Storage Tanks

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

- Weekly
- Service intervals
- Refill of the tank

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

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

i02349879

# Hoses and Clamps - Inspect/Replace

**WARNING**

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

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General hazard Information".

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

- Cracking
- Softness
- Loose clamps

REFERENCE ONLY

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

Check for the following conditions:

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

A constant torque hose clamp can be used in place of any standard hose clamp. Ensure that the constant torque hose clamp is the same size as the standard clamp.

Due to extreme temperature changes, the hose will harden. Hardening of the hoses will cause hose clamps to loosen. This can result in leaks. A constant torque hose clamp will help to prevent loose hose clamps.

Each installation application can be different. The differences depend on the following factors:

- Type of hose
- Type of fitting material
- Anticipated expansion and contraction of the hose
- Anticipated expansion and contraction of the fittings

## Replace the Hoses and the Clamps

Refer to the OEM information for further information on removing and replacing fuel hoses (if equipped).

The coolant system and the hoses for the coolant system are not usually supplied by Perkins. The following text describes a typical method of replacing coolant hoses. Refer to the OEM information for further information on the coolant system and the hoses for the coolant system.

**⚠ WARNING**

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

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

**Note:** Drain the coolant into a suitable, clean container. The coolant can be reused.

3. Drain the coolant from the cooling system to a level that is below the hose that is being replaced.
4. Remove the hose clamps.
5. Disconnect the old hose.
6. Replace the old hose with a new hose.
7. Install the hose clamps with a torque wrench.

**Note:** For the correct coolant, see this Operation and Maintenance Manual, "Fluid Recommendations".

8. Refill the cooling system. Refer to the OEM information for further information on refilling the cooling system.
9. Clean the cooling system filler cap. Inspect the cooling system filler cap's seals. Replace the cooling system filler cap if the seals are damaged. Install the cooling system filler cap.
10. Start the engine. Inspect the cooling system for leaks.

i02335774

# Radiator - Clean

The radiator is not usually supplied by Perkins. The following text describes a typical cleaning procedure for the radiator. Refer to the OEM information for further information on cleaning the radiator.

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

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

REFERENCE ONLY

**⚠ 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 two 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.

REFERENCE ONLY

**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.

i02718318

# Turbocharger - Inspect

A regular visual inspection of the turbocharger is recommended. If the turbocharger fails during engine operation, damage to the turbocharger compressor wheel and/or to the engine may occur. Damage to the turbocharger compressor wheel can cause additional damage to the pistons, the valves, and the cylinder head.

NOTICE

Turbocharger bearing failures can cause large quantities of oil to enter the air intake and exhaust systems. Loss of engine lubricant can result in serious engine damage.

Minor leakage of oil into a turbocharger under extended low idle operation should not cause problems as long as a turbocharger bearing failure has not occured.

When a turbocharger bearing failure is accompanied by a significant engine performance loss (exhaust smoke or engine rpm up at no load), do not continue engine operation until the turbocharger is renewed.

A visual inspection of the turbocharger can minimize unscheduled downtime. A visual inspection of the turbocharger can also reduce the chance for potential damage to other engine parts.

## Removal and Installation

**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 inspection or removed for the cleaning of the compressor.

1. Remove the pipe from the turbocharger exhaust outlet and remove the air intake pipe to the turbocharger. Visually inspect the piping for the presence of oil. Clean the interior of the pipes in order to prevent dirt from entering during reassembly.

2. Check for obvious heat discoloration of the turbocharger. Check for any loose bolts or any missing bolts. Check for damage to the oil supply line and the oil drain line. Check for cracks in the housing of the turbocharger. Ensure that the compressor wheel can rotate freely.

3. Check for the presence of oil. If oil is leaking from the back side of the compressor wheel, there is a possibility of a failed turbocharger oil seal.

REFERENCE ONLY

The presence of oil may be the result of extended engine operation at low idle. The presence of oil may also be the result of a restriction of the line for the intake air (clogged air filters), which causes the turbocharger to slobber.

4. Inspect the bore of the housing of the turbine outlet for corrosion.

5. Fasten the air intake pipe and the exhaust outlet pipe to the turbocharger housing. Ensure that all clamps are installed correctly and that all clamps are tightened securely.

i02866087

# V-Belts - Inspect/Adjust/Replace

## Inspection

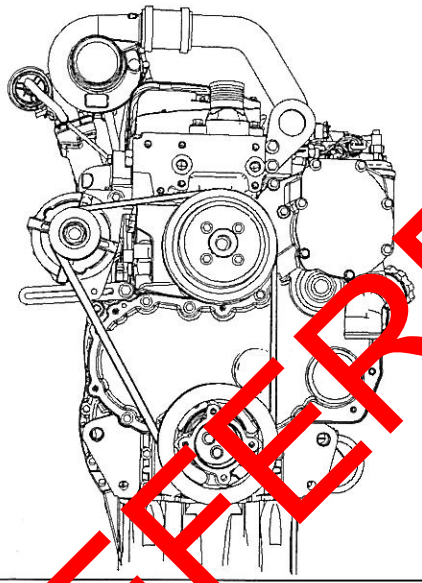


Illustration 63 g01249073

Arrangement for the V-belt

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

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

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

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

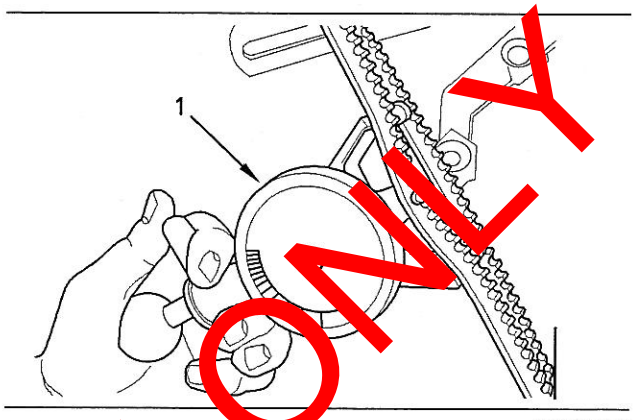



Illustration 64 g01003936

Typical example

(1) Belt tension gauge

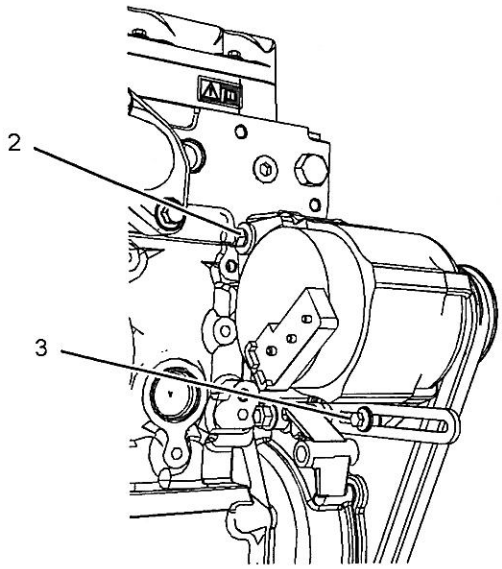
Fit the gauge (1) at the center of the longest free length and check the tension. The correct tension for a used belt is 355 N (79.8 lb). If the tension of the belt is below 250 N (56 lb) adjust the belt to 355 N (79.8 lb).

**Note:** The correct tension for a new belt or new belts is 535 N (120 lb). A higher tension is required in order to compensate for the stretch that is in a new belt. Only use the higher tension on a belt that has not been used. A used belt is a belt that has been in operation for 30 minutes or a longer period of time.

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

REFERENCE ONLY

## Adjustment




g01427780

Illustration 65

Typical example

1. Loosen nut (2) and the bolt (3).
2. Move the alternator in order to increase or decrease the belt tension. Tighten the nut (2) and the bolt (3) to 22 N·m (16 lb ft).(1).

## Replace

Refer to Disassembly and Assembly manual, "V-Belts - Remove and Install" for more information.

i02323090

# 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. Remove the water pump. Refer to Disassembly and Assembly , "Water Pump - Remove and Install". For more information, consult your Perkins dealer or your Perkins distributor.

- Inspect the lubrication system for leaks at the front crankshaft seal, the rear crankshaft seal, the oil pan, the oil filters and the rocker cover.
- Inspect the piping for the air intake system and the elbows for cracks and for loose clamps. Ensure that hoses and tubes are not contacting other hoses, tubes, wiring harnesses, etc.
- Ensure that the areas around the rotating parts are clear.
- Inspect the alternator belts and any accessory drive belts for cracks, breaks or other damage.
- Inspect the wiring harness for damage.

Belts for multiple groove pulleys must be replaced as matched sets. If only one belt is replaced, the belt will carry more load than the belts that are not replaced. The older belts are stretched. The additional load on the new belt could cause the belt to break.

REFERENCE ONLY

## High Pressure Fuel Lines

**WARNING**

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

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and assembly Manual, "Fuel Injection Lines - Install".

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General hazard Information".

Visually inspect the high pressure fuel lines for damage or signs of fuel leakage. Replace any damaged high pressure fuel lines or high pressure fuel lines that have leaked.

Ensure that all clips on the high pressure fuel lines are in place and that the clips are not loose.

- Inspect the rest of the fuel system for leaks. Look for loose fuel line clamps.
- Drain the water and the sediment from the fuel tank on a daily basis in order to ensure that only clean fuel enters the fuel system.
- Inspect the wiring and the wiring harnesses for loose connections and for worn wires or frayed wires. Check for any loose tie-wraps or missing tie-wraps.
- Inspect the ground strap for a good connection and for good condition.
- Disconnect any battery chargers that are not protected against the current drain of the starting motor. Check the condition and the electrolyte level of the batteries, unless the engine is equipped with a maintenance free battery.
- Check the condition of the gauges. Replace any gauges that are cracked. Replace any gauge that can not be calibrated.

i02499304

## Water Pump - Inspect

A failed water pump may cause severe engine overheating problems that could result in the following conditions:

- Cracks in the cylinder head
- A piston seizure
- Other potential damage to the engine

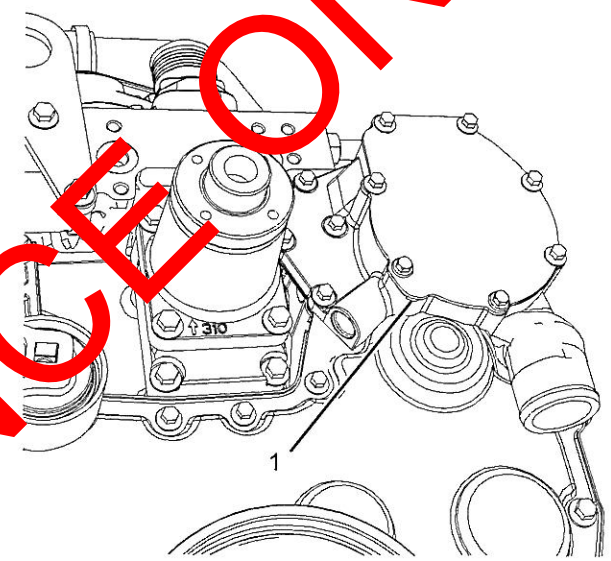



Illustration 66 g01249453

(1) Weep hole

**Note:** The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and parts contract.

Visually inspect the water pump for leaks. The water pump is not a serviceable item. In order to install a new water pump, refer to the Disassembly and Assembly Manual, "Water Pump - Remove and Install".

REFERENCE ONLY

# 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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REFERENCE ONLY

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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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RENR7967
September 2006

# Systems Operation Testing and Adjusting

## 1104D Industrial Engine

NH (Engine)
NJ (Engine)

REFERENCE ONLY

# Important Safety Information

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

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

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

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

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

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

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

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

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

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

**⚠ WARNING**

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

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

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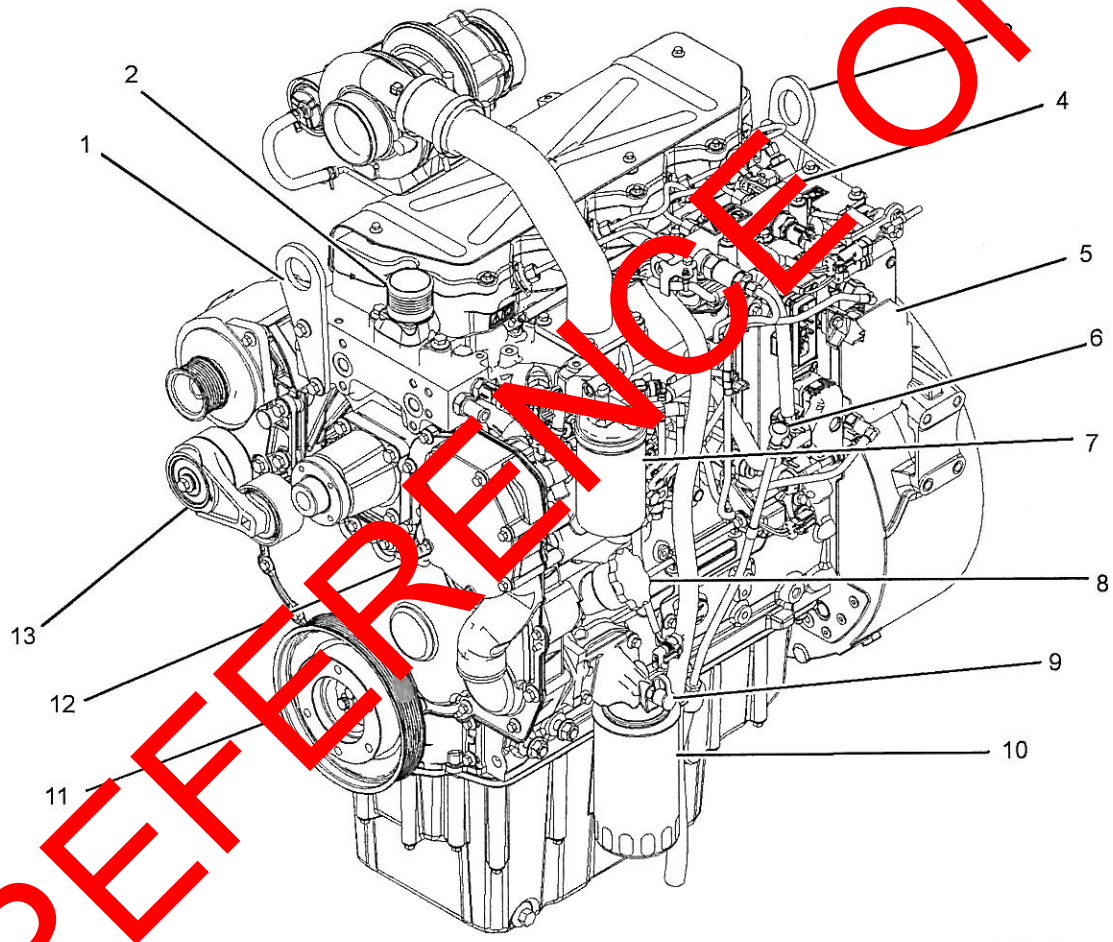
# Systems Operation Section

# General Information

i02517251

## Introduction

The following model views show a typical 1104D engine. Due to individual applications, your engine may appear different from the illustrations.




g01245941

Illustration 1

Front left engine view

(1) Front lifting eye
(2) Water outlet
(3) Rear lifting eye
(4) Fuel manifold (rail)
(5) Electronic control module
(6) Oil gauge
(7) Secondary fuel filter
(8) Oil filler
(9) Oil sampling valve
(10) Oil filter
(11) Crankshaft pulley
(12) Water pump
(13) Belt tensioner

REFERENCE ONLY

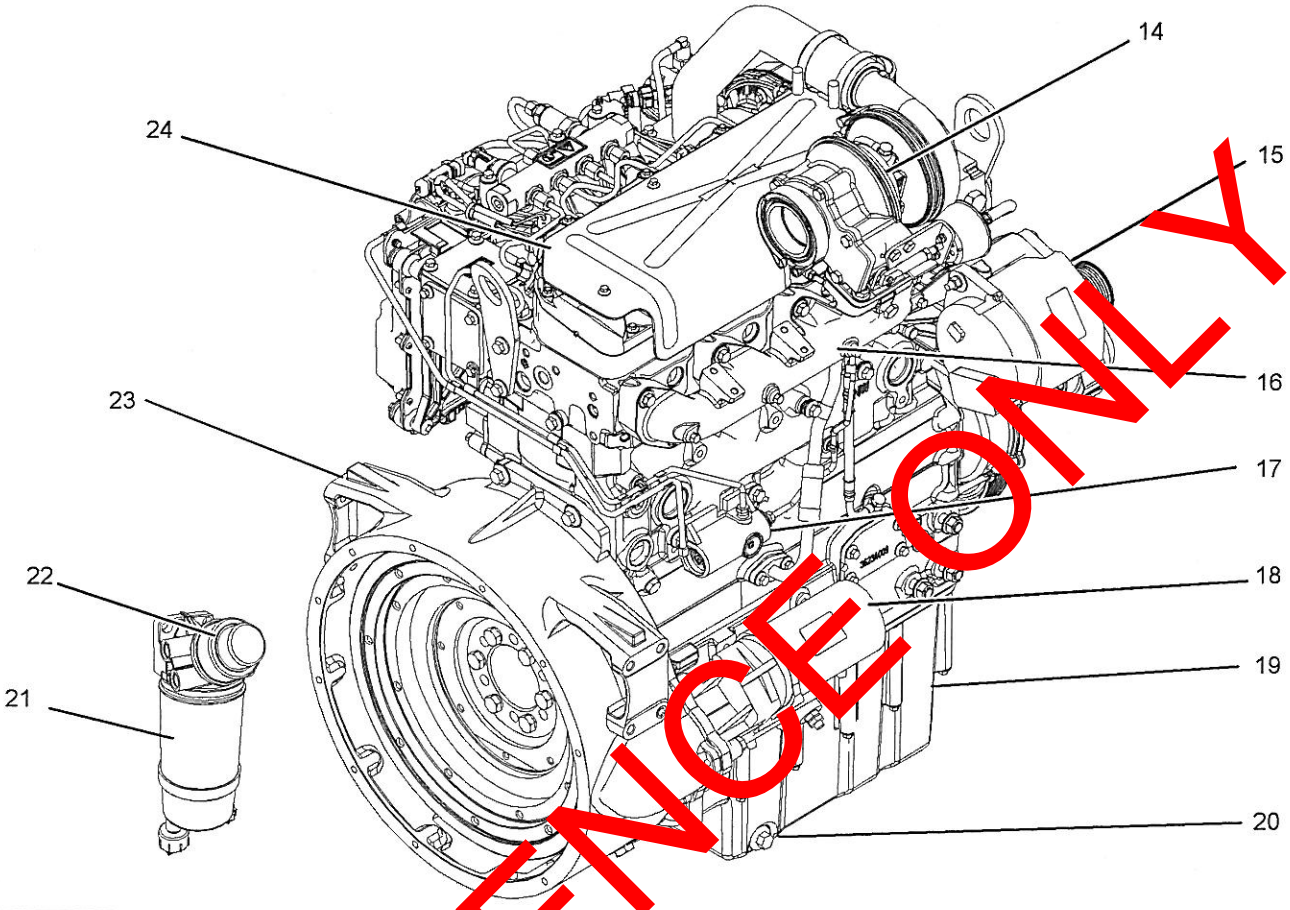



Illustration 2 g01245940

Rear right engine view

(14) Turbocharger
(15) Alternator
(16) Exhaust manifold
(17) Wastegate solenoid
(18) Starting motor
(19) Oil pan
(20) Drain plug
(21) Primary fuel filter
(22) Hand fuel priming pump
(23) Flywheel housing
(24) Heat shield

REFERENCE ONLY

**Note:** The primary fuel filter is mounted off the engine.

The 1104D models NH1 and NJ1 diesel engines are electronically controlled. The 1104D engine uses an Electronic Control Module (ECM) that receives signals from the fuel injection pump and other sensors in order to control the fuel injectors. The pump supplies fuel to the fuel injectors.

The four cylinders are arranged in-line. The cylinder head assembly has two inlet valves and two exhaust valves for each cylinder. The ports for the exhaust valves are on the right side of the cylinder head. The ports for the inlet valves are on the left side of the cylinder head. Each cylinder valve has a single valve spring.

Each cylinder has a piston cooling jet that is installed in the cylinder block. The piston cooling jet sprays engine oil onto the inner surface of the piston in order to cool the piston. The pistons have a Quiescent combustion chamber in the top of the piston in order to achieve clean exhaust emissions. 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 coating of graphite in order to reduce wear when the engine is new. 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.

A piston and a connecting rod are matched to each cylinder. The piston height is controlled by the distance between the center of the big end bearing and the center of the small end bearing of the connecting rod. Three different lengths of connecting rods are available in order to attain the correct piston height. The three different lengths of connecting rods are made by machining the blank small end bearing of each rod at three fixed distances vertically above the centerline of the big end bearing. .

The crankshaft has five main bearing journals. End play is controlled by thrust washers which are located on both sides of the number three main bearing.

The timing case is made of aluminum. The timing gears are stamped with timing marks in order to ensure the correct assembly of the gears. When the number 1 piston is at the top center position on the compression stroke, the marked teeth on the idler gear will match with the marks that are on the fuel injection pump, the camshaft, and the gear on the crankshaft. There is no timing mark on the rear face of the timing case.

The crankshaft gear turns the idler gear which then turns the following gears:

- the camshaft gear
- the fuel injection pump

The camshaft and the fuel injection pump r[illegible] at half the rpm of the crankshaft. The cylinder b[illegible]es a[illegible] machined into the cylinder block.

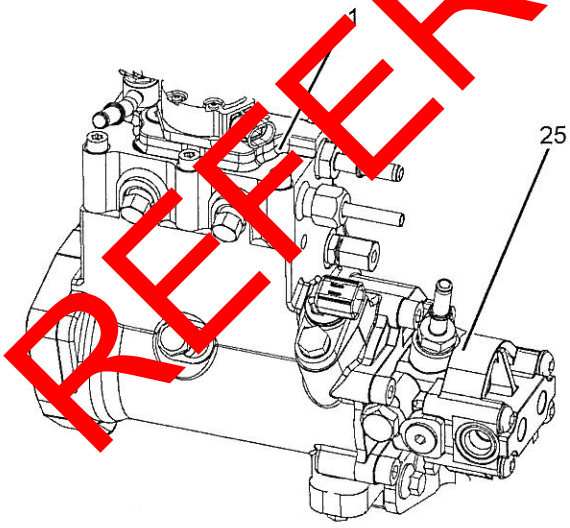



Illustration 3 g01259333

The fuel injection pump (1) that is installed on the left side of the engine is gear-driven from the timing case. The fuel transfer pump (25) is attached to the fuel injection pump (1). The fuel transfer pump draws low pressure fuel from the primary fuel filter. The fuel transfer pump delivers the fuel to the secondary filter at a pressure of 400 kPa (58 psi) to 500 kPa (72.5200 psi). The fuel injection pump draws fuel from the secondary filter. The fuel injection [illegible]ump increases the fuel to a maximum pressure of [illegible]30 MPa (18855 psi). The fuel injection pump d[illegible]e fuel to the fuel manifold. The fuel injection pump is [illegible]ot serviceable. Adjustments to the [illegible]ump timing should only be made by personnel that h[illegible]e had the correct training. The fuel injection pum[illegible] use[illegible] the [illegible]ngine ECM to control the engine RPM.

The specifications for the [illegible]04D refer to the Specifications, "E[illegible]gine D[illegible]sig[illegible]"

# Engine Operation

i02525716

## Basic Engine

### [illegible]oduction (Basic Engine)

The eight major mechanical components of the basic engine are the following parts:

- Cylinder block
- Cylinder head
- Pistons
- Connecting rods
- Crankshaft
- Timing gear case and gears
- Camshaft
- Rocker shaft assembly

REFERENCE ONLY

## Cylinder Block and Cylinder Head

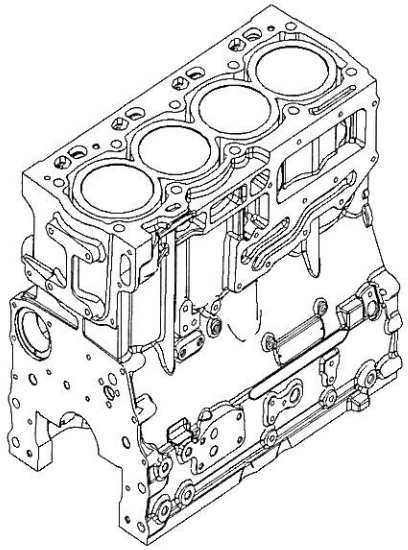


Illustration 4 g01263698

Typical Cylinder Block

The cast iron cylinder block for the 1104D engine has four cylinders which are arranged in-line. The cylinder block is made of cast iron in order to provide support for the full length of the cylinder bores. Worn cylinders may be rebored in order to accommodate oversize pistons and rings.

The cylinder block has five main bearings which support the crankshaft. Thrust washers are installed on both sides of number three main bearing in order to control the end play of the crankshaft.

Passages supply the lubrication for the crankshaft bearings. These passages are cast into the cylinder block.

The cylinders are honed to a specially controlled finish in order to ensure long life and low oil consumption.

The cylinder block has a bush that is installed for the front camshaft journal. The other camshaft journals run directly in the cylinder block.

The engine has a cooling jet that is installed in the cylinder block for each cylinder. The piston cooling jet sprays lubricating oil onto the inner surface of the piston in order to cool the piston.

A multi-layered steel (MLS) cylinder head gasket is used between the engine block and the cylinder head in order to seal combustion gases, water, and oil.

## Cylinder head

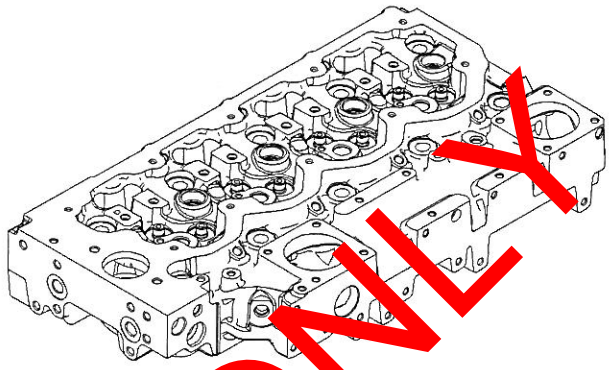


Illustration 5 g01263700

Typical cylinder head

The engine has a cast iron cylinder head. The inlet manifold is integral within the cylinder head. There are two inlet valves and two exhaust valve for each cylinder. Each pair of valves are connected by a valve bridge that is 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. The valve stems move in valve guides that are machined into the cylinder head. There is a renewable valve stem seal that fits over the top of the valve guide.

REFERENCE ONLY

## Pistons, Rings and Connecting Rods

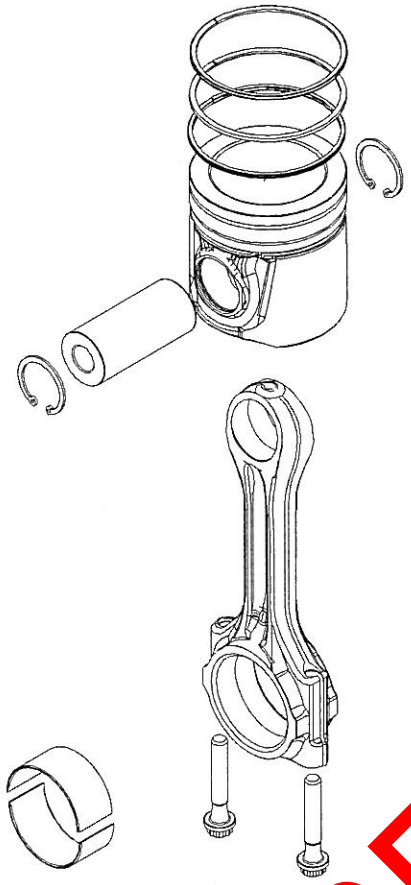


Illustration 6 g01263701
Typical example

The pistons have a Quiescent 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 piston skirt has a coating of graphite in order to reduce the risk of seizure when the engine is new.

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.

The connecting rods are machined from forged molybdenum steel. The connecting rods 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:

- The splitting produces an accurately matched surface on each side of the fracture for improved strength.

## Crankshaft

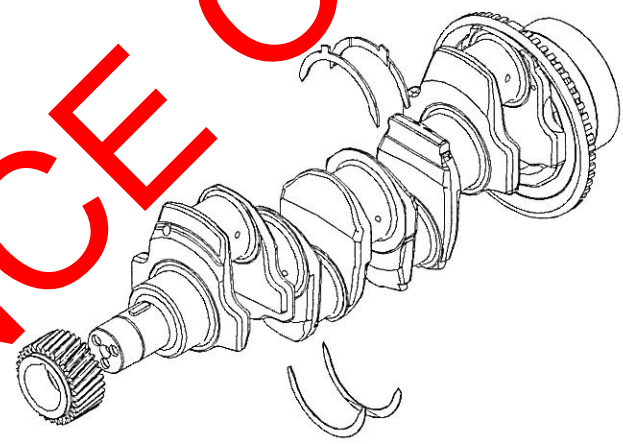


Illustration 7 g01263702

The crankshaft is a chromium molybdenum forging. The crankshaft has five main journals. Thrust washers are installed on both sides of number three main bearing in order to control the end play of the 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 and fuel transfer pump

REFERENCE ONLY

- 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.

A timing ring is installed to the crankshaft. The timing ring is used by the ECM in order to measure the engine speed and the engine position.

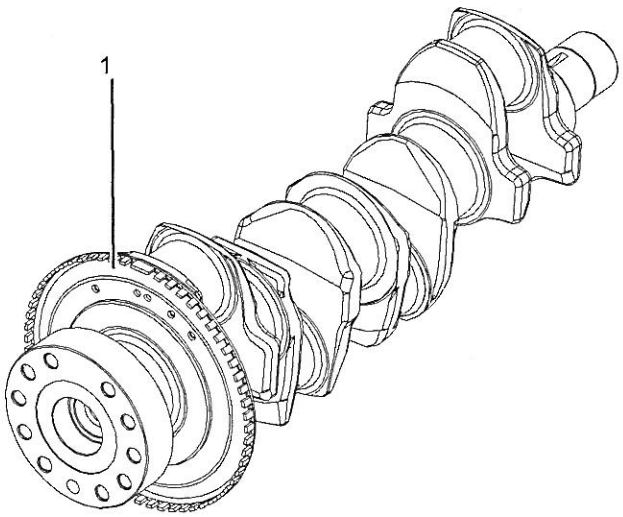



Illustration 8 g012

## Gears and Timing Gear Cas

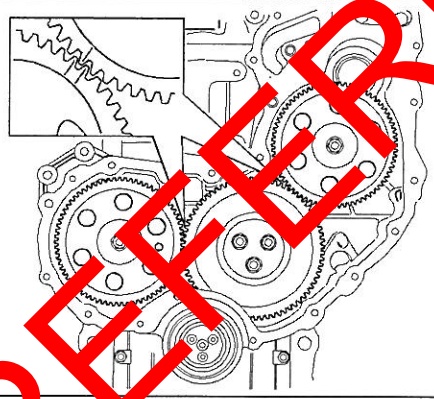


Illustration g01263705

The crankshaft oil seal is mounted in the aluminum timing case. The timing case cover is made from pressed steel.

The timing gears are made of steel.

The crankshaft gear drives an upper idler gear and a lower idler gear. The upper idler gear drives the camshaft and the fuel injection pump. The lower idler gear drives the oil pump. The water pump drive gear is driven by the fuel injection pump gear.

The camshaft and the fuel injection pump rotate at half the engine speed.

## Camshaft

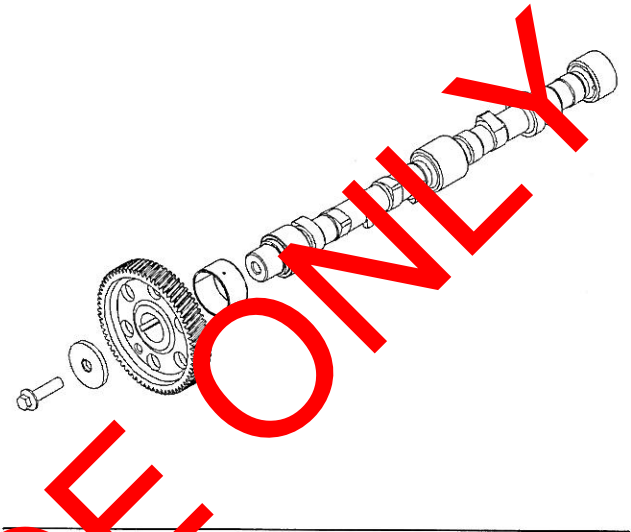


Illustration g01263706

The engine has a single camshaft. The camshaft is made of cast iron. The camshaft lobes are chill hardened.

The camshaft is driven at the front end. As the camshaft turns, the camshaft lobes move the valve system components. The valve system components move the cylinder valves.

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 open 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.

REFERENCE ONLY

## Rocker Shaft Assembly

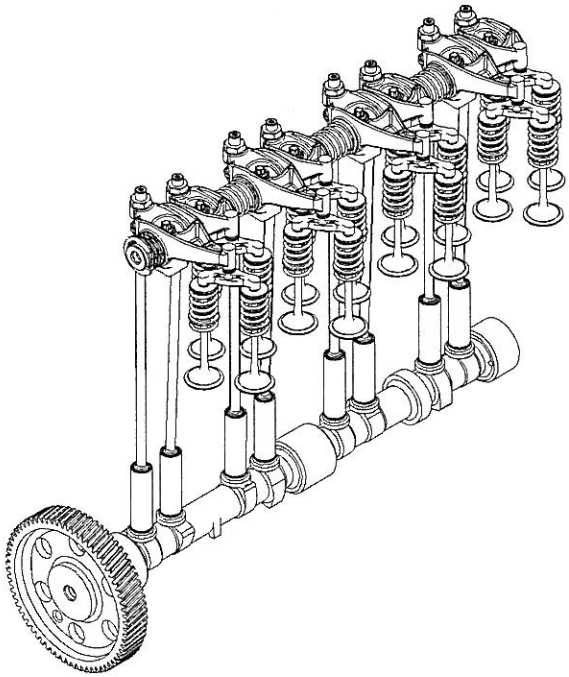


Illustration 11 g01263708

The camshaft has two camshaft lobes for each cylinder. The lobes operate either a pair of inlet valves or a pair of exhaust valves. As the camshaft turns, lobes on the camshaft cause the lifters to move the pushrod up and down. Upward movement of the pushrod against rocker arm results in a downward movement that acts on the valve bridges. This action opens a pair of valves which compresses the valve springs. When the camshaft has rotated to the peak of the lobe, the valves are fully open. When the camshaft rotates further, the two valve springs under compression start to expand. The valve stems are under tension of the springs. The stems are pushed upward in order to maintain contact with the valve bridges. The continued rotation of the camshaft causes the rocker arms, the pushrods and the lifters to move downward until the lifter reaches the bottom of the lobe. The valves are now closed. The cycle is repeated for all the valves on each cylinder.

REFERENCE ONLY

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# Air Inlet and Exhaust System

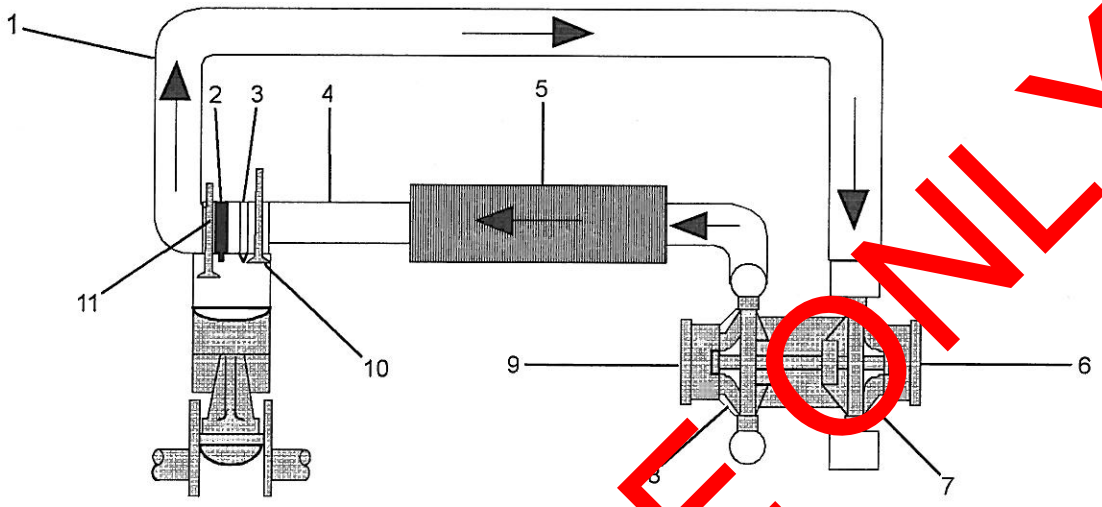



Illustration 12 g01205681

Air inlet and exhaust system

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

The components of the air inlet and exhaust system control the quality of air and the amount of air that is available for combustion. The air inlet and exhaust system consists of the following components:

- Air cleaner
- Turbocharger
- Aftercooler
- Inlet manifold
- Cylinder head, injectors and glow plugs
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold

Air is drawn in through the air cleaner into the air inlet of the turbocharger (9) by the turbocharger compressor wheel (8). The air is compressed and heated to about 150 °C (300 °F) before the air is forced to the aftercooler (5). As the air flows through the aftercooler the temperature of the compressed air lowers to about 50 °C (120 °F). Cooling of the inlet air increases combustion efficiency. Increased combustion efficiency helps achieve the following benefits:

- Lower fuel consumption
- Increased horsepower output
- Reduced particulate emission

From the aftercooler, air is forced into the inlet manifold (4). Air flow from the inlet manifold to the cylinders is controlled by inlet valves (10). There are two inlet valves and two exhaust valves for each cylinder. The inlet valves open when the piston moves down on the intake stroke. When the inlet valves open, cooled compressed air from the inlet port is forced into the cylinder. The complete cycle consists of four strokes:

- Inlet
- Compression

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- Power
- Exhaust

On the compression stroke, the piston moves back up the cylinder and the inlet valves (10) close. The cool compressed air is compressed further. This additional compression generates more heat.

**Note:** If the cold starting system is operating, the glow plugs (3) will also heat the air in the cylinder.

Just before the piston reaches the TC position, the ECM operates the electronic unit injector. Fuel is injected into the cylinder. The air/fuel mixture ignites. The ignition of the gases initiates the power stroke. Both the inlet and the exhaust valves are closed and the expanding gases force the piston downward toward the bottom center (BC) position .

From the BC position, the piston moves upward. This initiates the exhaust stroke. The exhaust valves open. The exhaust gases are forced through the open exhaust valves into the exhaust manifold.

Exhaust gases from exhaust manifold (1) enter the turbine side of the turbocharger in order to turn turbocharger turbine wheel (7). The turbine wheel is connected to the shaft that drives the compressor wheel. Exhaust gases from the turbocharger pass through exhaust outlet (6), a silencer and an exh[illegible] pipe.

## Turbocharger

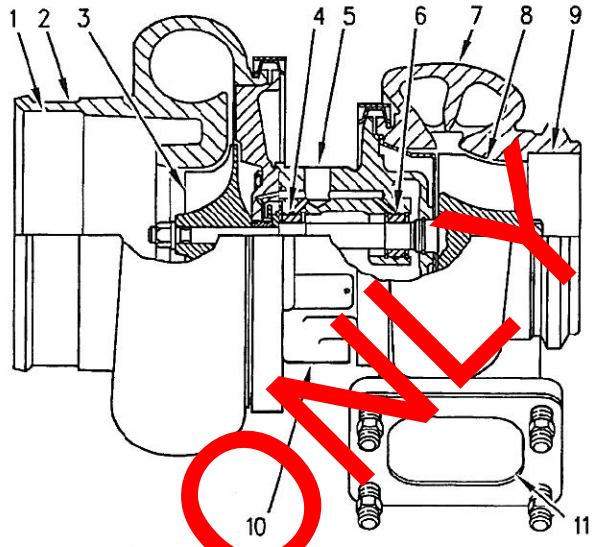



Illustration 13 g01263770

Turbocharger
(1) Air inlet
(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

The turbocharger is mounted on the outlet of the exhaust manifold in one of two positions on the right side of the engine, toward the top of the engine or to the side of the engine. The exhaust gas from the exhaust manifold enters the exhaust inlet (11) and passes through the turbine housing (7) of the turbocharger. Energy from the exhaust gas causes the turbine wheel (8) to rotate. The turbine wheel is connected by a shaft to the compressor wheel (3).

As the turbine wheel rotates, the compressor wheel is rotated. This causes the intake air to be pressurized through the compressor housing (2) of the turbocharger.

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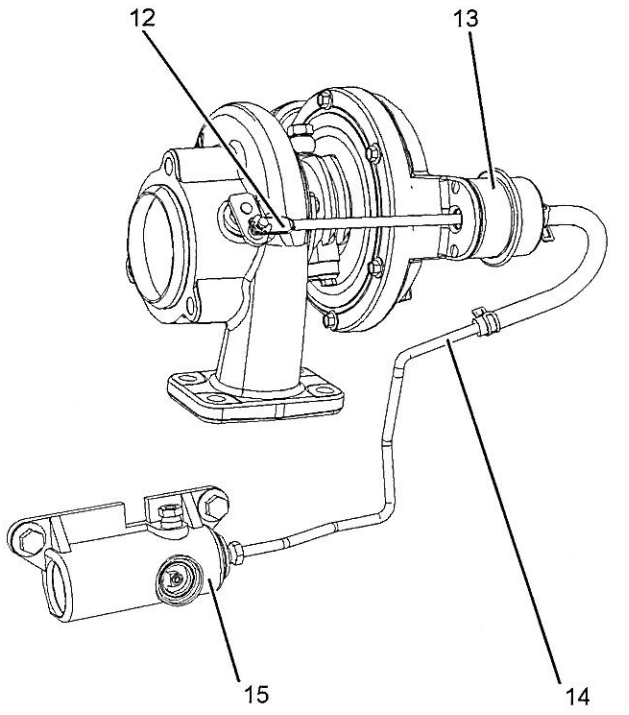



Illustration 14 g01287919

Typical turbocharger with the wastegate

(12) Actuating lever
(13) Wastegate actuator
(14) Line (boost pressure)
(15) Wastegate solenoid

When the load on the engine increases, more fuel is injected into the cylinders. The combustion of this additional fuel produces more exhaust gases. The additional exhaust gases cause the turbine and the compressor wheels of the turbocharger to turn faster. As the compressor wheel turns faster, air is compressed to a higher pressure and more air is forced into the cylinders. The increased flow of air into the cylinders allows the fuel to be burnt with greater efficiency. This produces more power.

A wastegate is installed on the turbine housing of the turbocharger. The wastegate is a valve that allows exhaust gas to bypass the turbine wheel of the turbocharger. The operation of the wastegate is dependent on the pressurized air (boost pressure) from the turbocharger compressor. The boost pressure acts on a diaphragm that is spring loaded in the wastegate actuator which varies the amount of exhaust gas that flows into the turbine.

If a wastegate solenoid (15) is installed, then the wastegate is controlled by the engine Electronic Control Module (ECM). The ECM uses inputs from a number of engine sensors to determine the optimum boost pressure. This will achieve the best exhaust emissions and fuel consumption at any given engine operating condition. The ECM controls the solenoid valve, which regulates the boost pressure to the wastegate actuator.

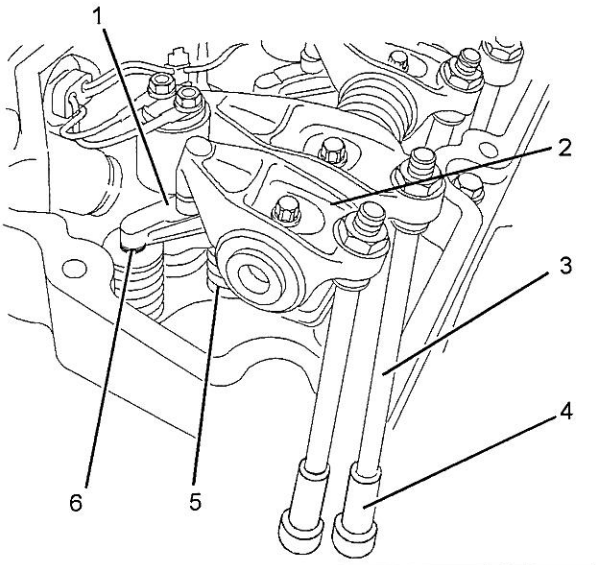
When high boost pressure is needed for the engine performance, a signal is sent from the ECM to the wastegate solenoid . This causes low pressure in the air inlet pipe (14) to act on the diaphragm within the wastegate actuator (13). The actuating rod (12) acts upon the actuating lever to close the valve in the wastegate. When the valve in the wastegate is closed, more exhaust gas is able to pass over the turbine wheel. This results in an increase in the speed of the turbocharger.

When low boost pressure is needed for the engine performance, a signal is sent from the ECM to the wastegate solenoid. This causes high pressure in the air inlet pipe (14) to act on the diaphragm within the wastegate actuator (13). The actuating rod (12) acts upon the actuating lever to open the valve in the wastegate. When the valve in the wastegate is opened, more exhaust gas from the engine is able to bypass the turbine wheel, resulting in an decrease in the speed of the turbocharger.

The shaft that connects the turbine to the compressor wheel rotates in bearings (4 and 6). The bearings require oil under pressure for lubrication and cooling. The oil that flows to the lubricating oil inlet port (5) passes through the center of the turbocharger which retains the bearings. The oil exits the turbocharger from the lubricating oil outlet port (10) and returns to the oil pan.

REFERENCE ONLY

## Valve System Components




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Illustration 15

Valve system components

(1) Bridge
(2) Rocker arm
(3) Pushrod
(4) Lifter
(5) Spring
(6) Valve

The valve system components control the flow of inlet air into the cylinders during engine operation. The valve system components also control the flow of exhaust gases out of the cylinders during engine operation.

The crankshaft gear drives the camshaft gear through an idler gear. The camshaft must be timed to the crankshaft in order to get the correct relation between the piston movement and the valve movement.

The camshaft has two camshaft lobes for each cylinder. The lobes operate either a pair of inlet valves or a pair of exhaust valves. As the camshaft turns, lobes on the camshaft cause the lifter (4) to move the pushrod (3) up and down. Upward movement of the pushrod against rocker arm (2) results in a downward movement that acts on the valve bridge (1). This action opens a pair of valves (6) which compresses the valve springs (5). When the camshaft has rotated to the peak of the lobe, the valves are fully open. When the camshaft rotates further, the two valve springs (5) under compression start to expand. The valve stems are under tension of the springs. The stems are pushed upward in order to maintain contact with the valve bridge (1). The continued rotation of the camshaft causes the rocker arm (2), the pushrods (3), and the lifters (4) to move downward until the lifter reaches the bottom of the lobe. The valves (6) are now closed. The cycle is repeated for all the valves in each cylinder.

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## Cooling System

### Introduction (Cooling System)

The cooling system has the following components:

- Radiator
- Water pump
- Cylinder block
- Oil cooler
- Cylinder head
- Water temperature regulator (thermostat)

REFERENCE ONLY

# Coolant Flow

## Coolant Flow

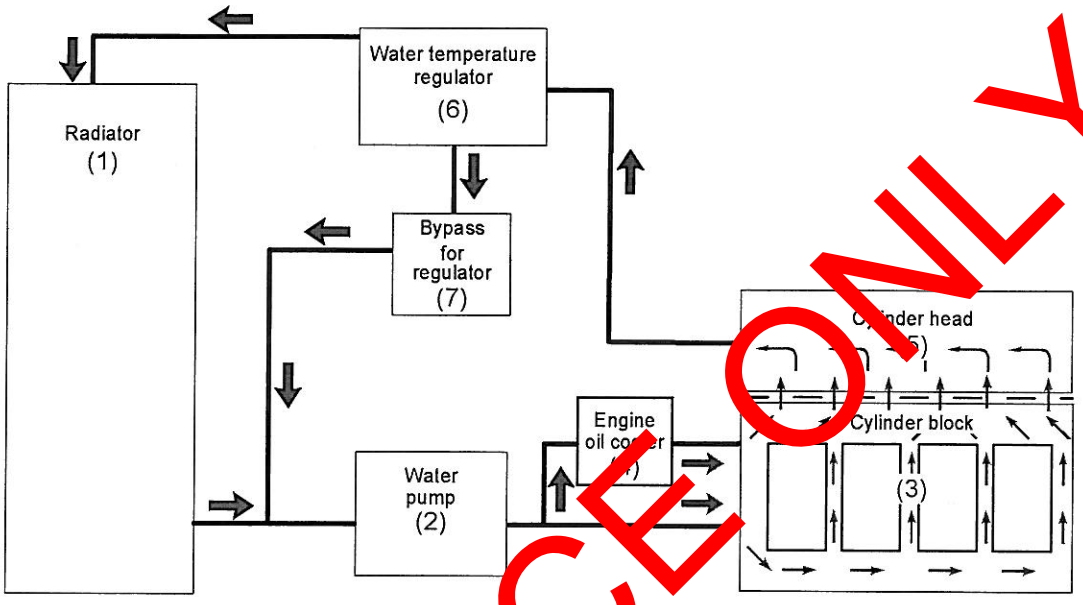



Illustration 16 g01264578

Coolant flow

(1) Radiator
(2) Water pump
(3) Cylinder block
(4) Engine oil cooler
(5) Cylinder head
(6) Water temperature regulator (thermostat) and housing
(7) Bypass for the water temperature regulator (thermostat)

The coolant flows from the bottom of the radiator (1) to the centrifugal water pump (2). The water pump (2) is installed on the front of the timing case. The water pump is driven by a gear. The gear of the fuel injection pump drives the water pump gear. The water pump forces the coolant through a passage in the timing case to the front of the cylinder block (3).

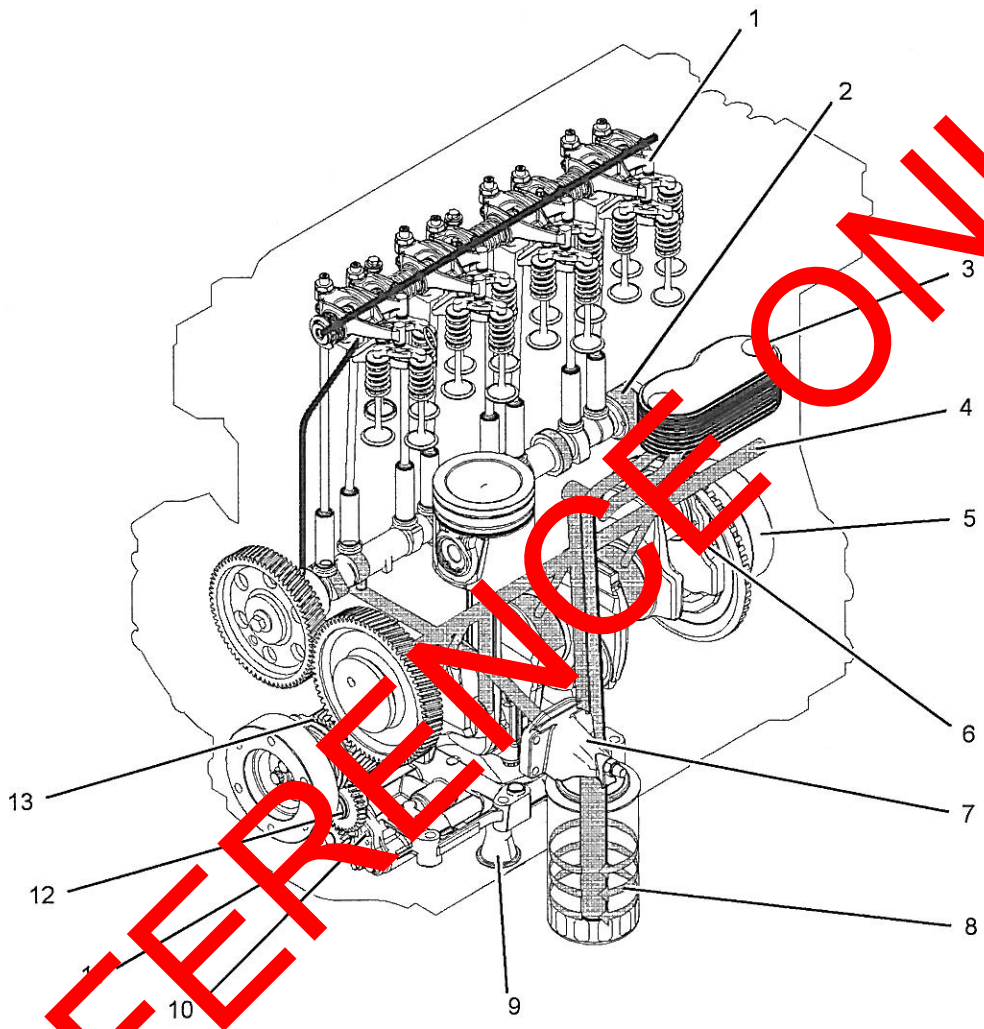
The coolant enters a passage in the left side of the cylinder block (3). Some coolant enters the cylinder block. Some coolant passes over the element of the oil cooler (4). The coolant then enters the block (3). Coolant flows around the outside of the cylinders then flows from the cylinder block into the cylinder head (5).

The coolant flows forward through the cylinder head (5). The coolant then flows into the housing of the water temperature regulator (6). If the water temperature regulator (6) is closed, the coolant goes directly through a bypass (7) to the inlet side of the water pump. If the water temperature regulator is open, and the bypass is closed then the coolant flows to the top of the radiator (1).

REFERENCE ONLY

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# Lubrication System




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Illustration 17

Flow diagram of the lubrication system

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

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

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

REFERENCE ONLY

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

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

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

Lubricating oil from the main bearings flows through passages in the cylinder block to the journals of the camshaft. Then, the oil flows from the front journal of the camshaft (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 supplies oil to the high pressure fuel pump. The oil then flows through a return line in the timing case and back 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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## 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

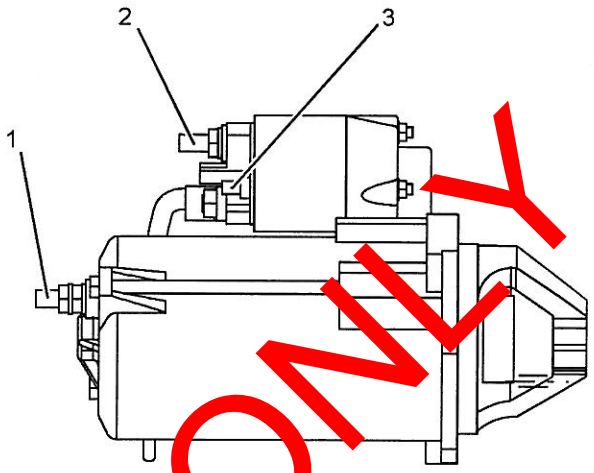



Illustration 18 g01216877

Typical example

24 Volt Starting Motor

(1) Terminal for connection of the ground cable
(2) Terminal 30 for connection of the battery cable
(3) Terminal 50 for connection of the ignition switch

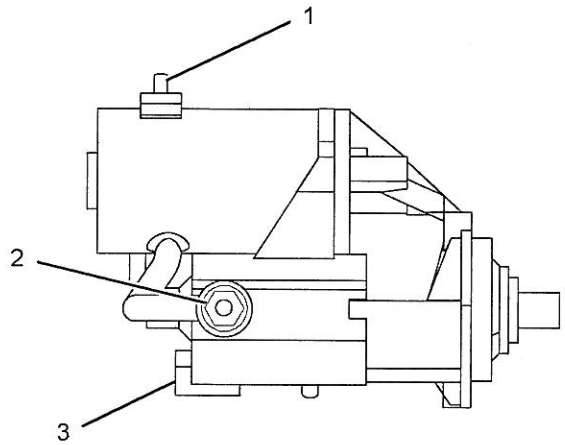



Illustration 19 g01200801

Typical example

24 Volt Starting Motor

(1) Terminal for connection of the ground
(2) Terminal 30 for connection of the battery cable
(3) Terminal 50 for connection of ignition switch

The starting motor turns the engine via a gear on the engine flywheel. The starting motor speed must be high enough in order to initiate a sustained operation of the fuel ignition in the cylinders.

REFERENCE ONLY

The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to move the pinion toward the flywheel ring gear of the engine. The electrical contacts in the solenoid close the circuit between the battery and the starting motor just before the pinion engages the ring gear. 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

The electrical outputs of the alternator have the following characteristics:

- Three-phase
- Full-wave
- Rectified

The alternator is an electro-mechanical compone The alternator is driven by a belt from the cra kshaf pulley. The alternator charges the storage batter during the engine operation.

The alternator is cooled by an exte nal fa n wh ch i mounted behind the pulley. The f n ma be mounted internally. The fan forces air th ough the holes in the front of the alternator. The a exits th ugh the holes in the back of the alterna r.

The alternator conv rts the m cha ical energy and the magnetic field to alt nating current and voltage. This conversio is d e by rotating a direct current electromagn tic field o the inside of a three-phase stator. The electr magnetic field is generated by electrical cu nt flow g through a rotor. The stator gene ates alter ating current and voltage.

The alt nating current is changed to direct current by a t ee-phase, full-wave rectifier. Direct current flows to e output terminal of the alternator. 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.

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# Cleanliness of Fuel System Components

## Cleanliness of the Engine

NOTICE
It is important to maint in cl anliness when working on the fuel syste since even tiny particles can cause engine or fue syst m problems.

The entire engine should e washed with a high pressure water syst m in order to remove dirt and loose debris before starting a repair on the fuel syst m.

## Enviro ment

When ossible, the service area should be positively pres rized in order to ensure that the components are not exposed to contamination from airborne dirt nd debris. When a component is removed from the system, the exposed fuel connections must be closed off immediately with suitable sealing plugs. The sealing plugs should only be removed when the component is reconnected. The sealing plugs must not be reused. Dispose of the sealing plugs immediately after use. Contact your nearest Perkins dealer or your nearest approved Perkins distributor in order to obtain the correct sealing plugs.

## New Components

High pressure lines are not reusable. New high pressure lines are manufactured for installation in one position only. When a high pressure line is replaced, do not bend or distort the new line. Internal damage to the pipe may cause metallic particles to be introduced to the fuel.

All new fuel filters, high pressure lines, tube assemblies and components are supplied with sealing plugs. These sealing plugs should only be removed in order to install the new part. If the new component is not supplied with sealing plugs then the component should not be used. The technician must wear suitable rubber gloves. The rubber gloves should be disposed of immediately after completion of the repair in order to prevent contamination of the system.

REFERENCE ONLY

## Refueling

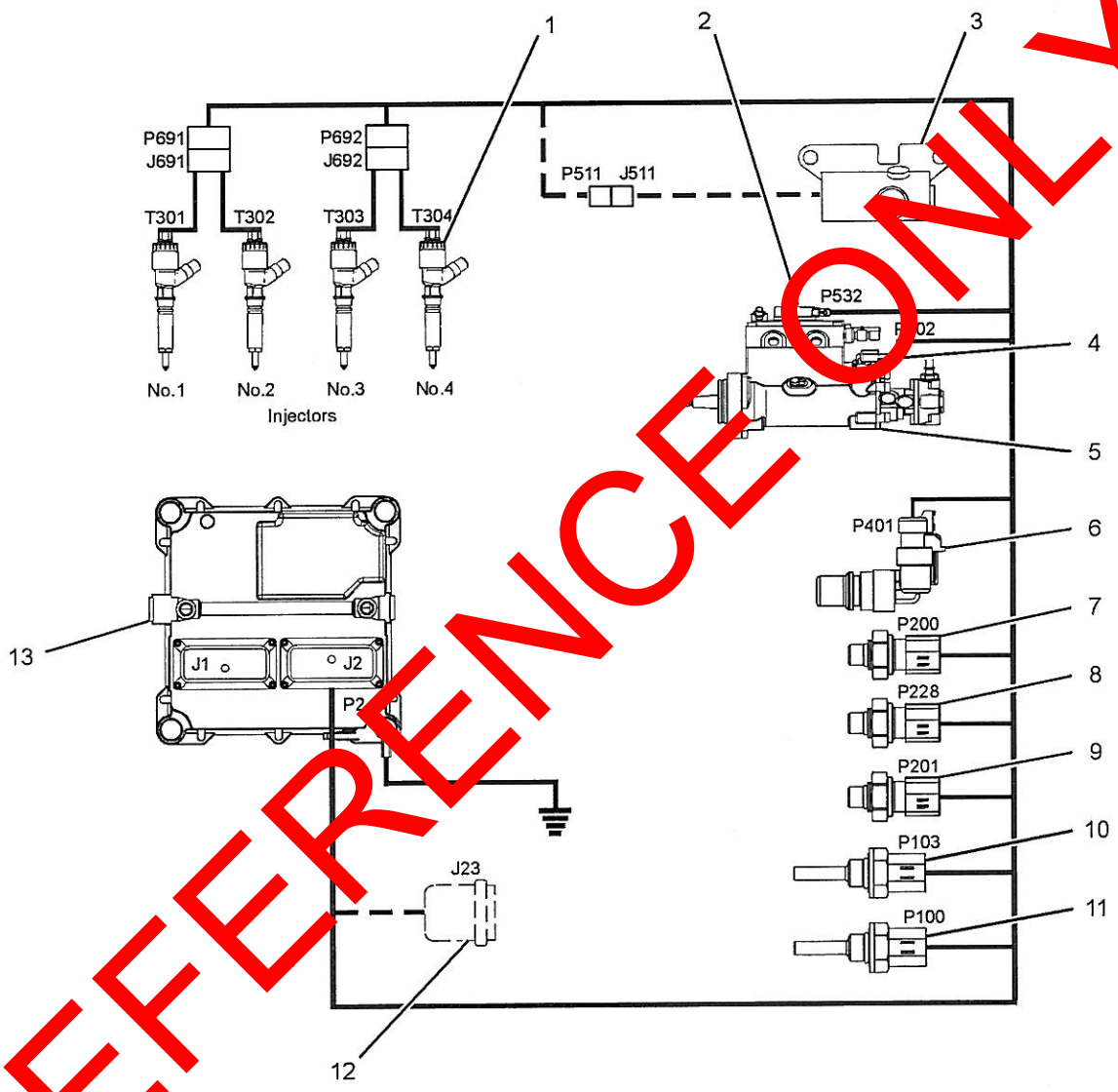
In order to refuel the diesel fuel tank, the refueling pump and the fuel tank cap assembly must be clean and free from dirt and debris. Refueling should take place only when the ambient conditions are free from dust, wind and rain. Only use fuel, free from contamination, that conforms to the specifications in the Operation and Maintenance Manual, “Fluid Recommendations” Fuel Specifications.

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# Fuel Injection

## Introduction (Fuel Injection)




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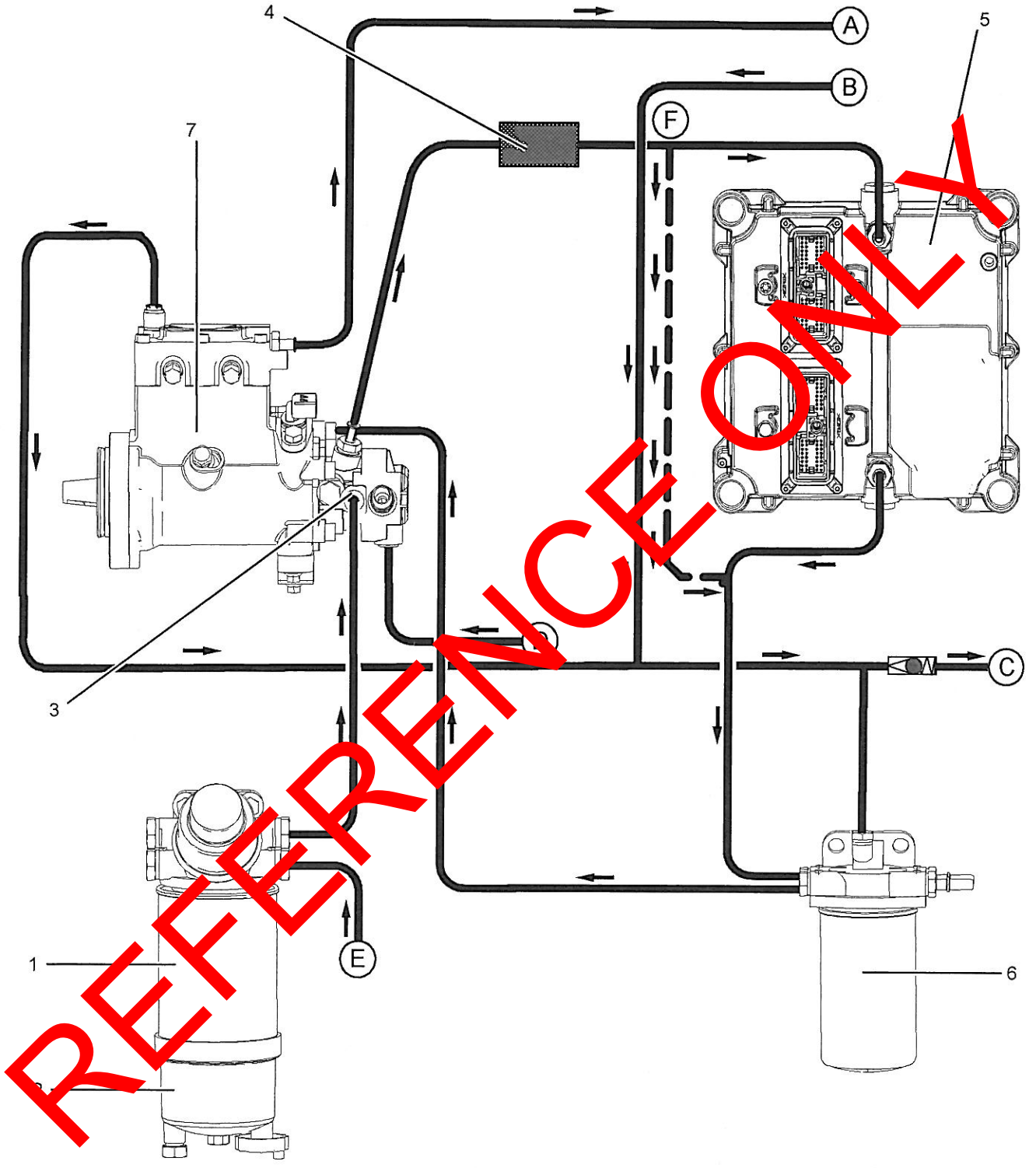
Illustration 2

Diagram of the basic fuel system (typical example)

(1) Electronic Unit Injector
(2) Solenoid for the fuel injection pump
(3) Wastegate Valve (if equipped)
(4) Secondary Speed/Timing Sensor
(5) Fuel Injection Pump
(6) Primary Speed/Timing Sensor
(7) Intake Manifold Pressure Sensor
(8) Fuel Manifold Pressure Sensor
(9) Engine Oil Pressure Sensor
(10) Intake Manifold Temperature Sensor
(11) Coolant Temperature Sensor
(12) Diagnostic Connector
(13) Electronic Control Module (ECM)

REFERENCE ONLY

## Low Pressure Fuel System




REFERENCE ONLY

Illustration 21 g01265309

Low pressure fuel system (typical example)

(1) Primary fuel filter
(2) Water separator
(3) Fuel transfer pump
(4) Fuel cooler (optional)
(5) ECM that is fuel cooled.
(6) Secondary fuel filter
(7) Fuel Injection Pump
(A) Outlet for high pressure fuel to the high pressure fuel manifold
(B) Return from the Pressure Relief Valve (PRV) on the high pressure fuel manifold
(C) Return to fuel tank
(D) Return from the Electronic Unit Injectors
(E) Fuel in from the fuel tank
(F) Alternative route for the fuel (air cooled ECM)

Fuel is drawn from the fuel tank (E) through a 20 micron Primary fuel filter (1) and the Water separator (2) to the Transfer pump (3). The transfer pump increases the fuel pressure to 25 kPa (3.6260 psi). The fuel is pumped through the fuel cooler (optional) (4) to the ECM (5). The fuel cools the ECM. The fuel passes from the ECM to a 2 micron fuel filter (6). The fuel filter removes particulates from 20 microns to 2 microns in size in order to prevent contamination of the high pressure components in the fuel system. Fuel passes from the fuel filter to the fuel injection pump (7). The fuel is pumped at an increased pressure to the high pressure fuel manifold.

Excess fuel from the high pressure fuel pump returns to the tank through a non-return valve. There is a small orifice in the fuel filter base in order to bleed any air back to the tank.

The leak off fuel from the electronic unit injectors returns from a connection in the cylinder head to the pressure side of the transfer pump.

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## High Pressure Fuel System

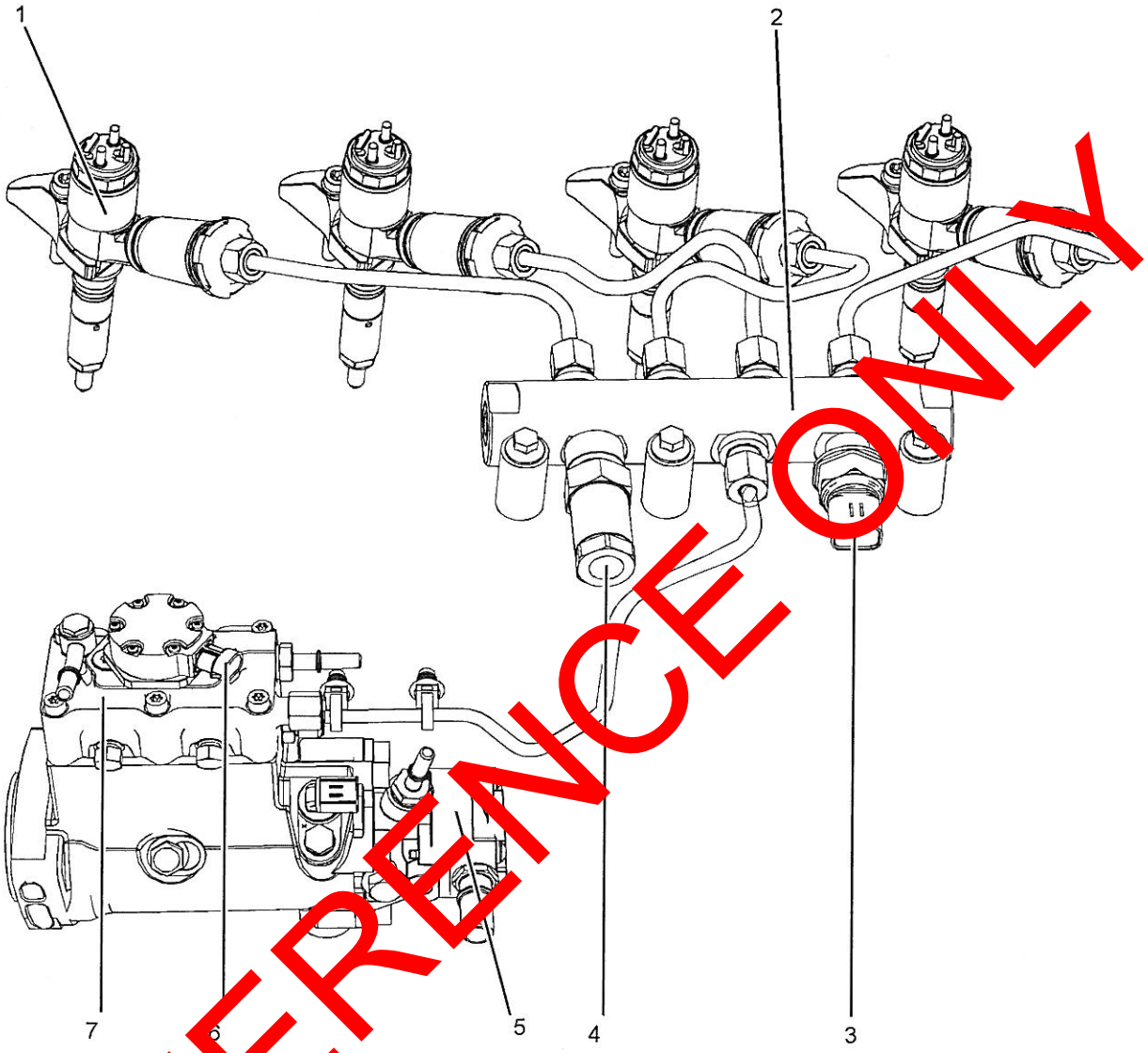



Illustration 22 g01288650

High pressure fuel system (typical example)

(1) Electronic Unit Injector
(2) High Pressure Fuel Manifold
(3) Fuel Pressure Sensor
(4) Fuel Pressure Relief Valve
(5) Fuel Transfer Pump
(6) Solenoid for the Fuel Injection Pump
(7) Fuel Injection Pump

REFERENCE ONLY

The fuel injection pump (7) feeds fuel to the high pressure fuel manifold (2). The fuel is at a pressure of 70 MPa (10152.7 psi) to 130 MPa (18855 psi). A pressure sensor (3) in the high pressure fuel manifold (2) monitors the fuel pressure in the high pressure fuel manifold (2). The ECM controls a solenoid (6) in the fuel injection pump (7) in order to maintain the actual pressure in the high pressure fuel manifold (2) at the desired level. The high pressure fuel is continuously available at each injector. The ECM determines the correct time for activation of the correct electronic unit injector (1) which allows fuel to be injected into the cylinder. The leakoff fuel from each injector passes into a drilling which runs along the inside of the cylinder head. A pipe is connected to the rear of the cylinder head in order to return the leakoff fuel to the pressure side of the fuel transfer pump.

### Components of the Fuel Injection System

**The fuel injection system has the following mechanical components:**

- Primary filter/water separator
- Fuel priming pump
- Secondary fuel filter
- Fuel injection pump
- Fuel injectors
- Fuel manifold
- Pressure relief valve
- Fuel pressure sensor

**The following list contains examples of both service and repairs when you must prime the system:**

- A fuel filter is changed.
- A fuel line is replaced.
- The fuel injection pump is replaced.

## Primary Filter/water Separator

The primary filter/water separator is located between the fuel tank and the priming pump.

## Fuel Priming Pump

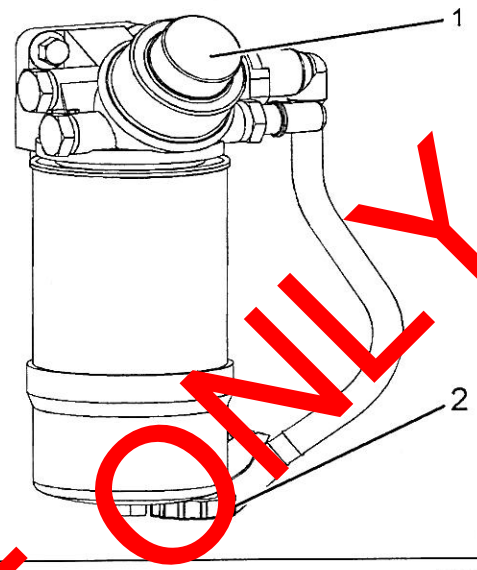



Illustration 23 g01265623
Hand Fuel Priming Pump

The pump has a plunger (1) which is manually operated in order to prime the fuel system. Air is removed from the fuel system to the fuel return line to the tank. The fuel transfer pump is located in the fuel injection pump. A water drain(2)is installed at the bottom of the filter in order to remove any water that has contaminated the fuel.

The electric fuel priming pump can be installed on some engines.

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## Secondary Fuel Filter

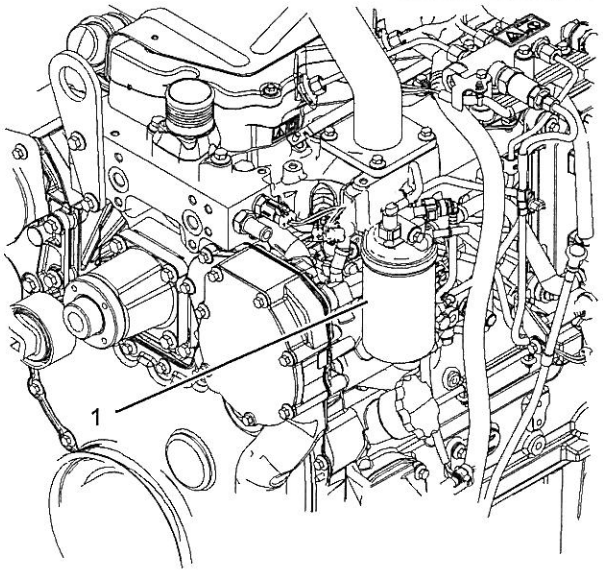



Illustration 24 g01249050
Typical example

The secondary fuel filter (1) is located after the priming pump. The filter is always before the fuel injection pump.

## Fuel Pump Assembly

The fuel pump assembly consists of a low pressure transfer pump (2) and a high pressure fuel injection pump (1). The pump assembly is driven from a gear in the front timing case at half engine speed. The fuel injection pump has two pistons that are driven by a camshaft. There is a cam for each piston and each cam has three lobes. The fuel injection pump delivers a volume of fuel four times for each revolution. The stroke of the pistons is fixed. The injector will use only part of the fuel that is delivered by each stroke of the pistons in the pump. The solenoid for the fuel injection pump is controlled by the ECM in order to maintain the fuel manifold pressure at the correct level. The solenoid allows excess fuel to be diverted away from the fuel manifold and back to the tank. A feature of the fuel injection pump allows fuel to return to the tank continuously.

## Fuel Injection Pump

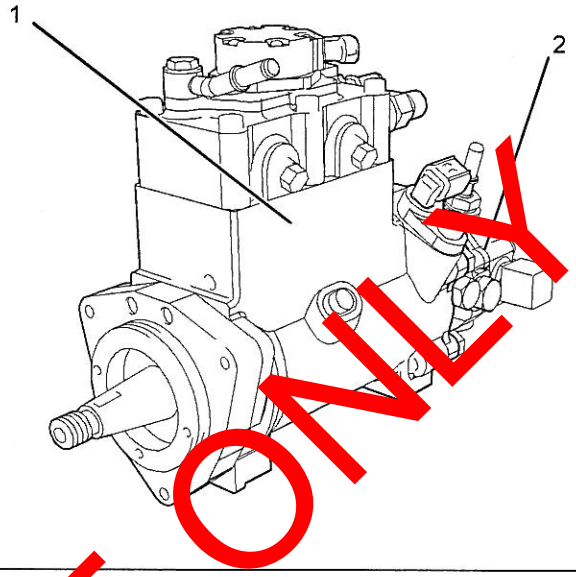



Illustration 25 g01266023
Typical example

**The fuel injection pump has the following operations:**

- Generation of high pressure fuel

The fuel output of the fuel injection pump is controlled by the ECM in response to changes in fuel pressure.

### Fuel Transfer Pump

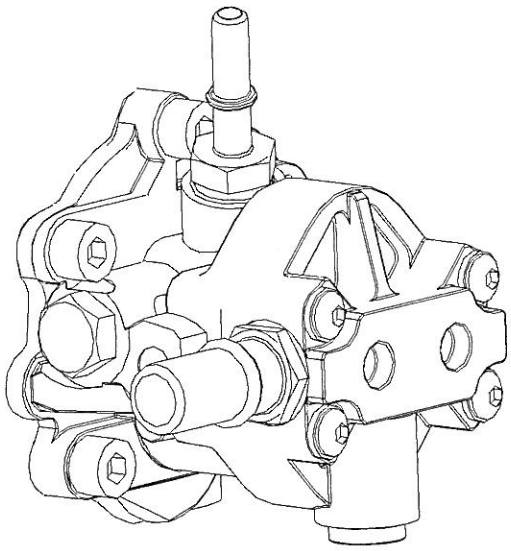


Illustration 26 g01265683

The fuel transfer pump is a serviceable component.

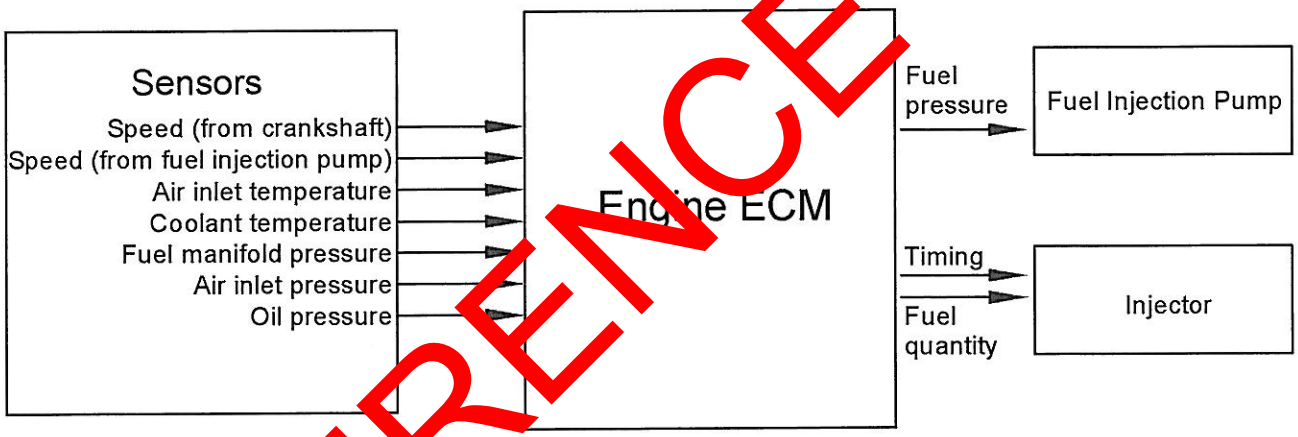
REFERENCE ONLY

The fuel transfer pump provides a relatively low fuel pressure to the fuel injection pump. The fuel transfer pump has a regulating valve in order to control the low pressure. The fuel transfer pump circulates fuel through the primary fuel filter and the secondary fuel filter. The fuel transfer pump has a fuel bypass valve in order to allow the low pressure fuel system to be primed.

### Shutoff

The engine shuts off by interrupting the fuel supply. The engine electronic control module (ECM) specifies the amount of fuel. The quantity of the fuel that is required by the ECM is set to zero.

### Control




g01216984

Illustration 27

Electronic control for the fuel system (typical example)

The ECM determines the quantity, timing and pressure of the fuel in order to be injected into the fuel injector.

The ECM uses input from the sensors on the engine. These sensors include the speed/timing sensors and the pressure sensors.

The ECM controls the fuel pressure by increasing or decreasing the flow of fuel from the fuel injection pump. The ECM controls the timing and the flow of fuel by actuating the injector solenoid.

The amount of fuel is proportional to the duration of the signal to the injector solenoid.

REFERENCE ONLY

## Fuel Injectors

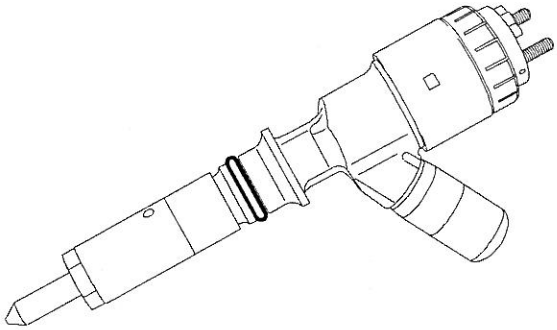


Illustration 28 g01201611

The fuel injectors are not serviceable.

When the ECM sends a signal to the injector solenoid, a valve inside the injector opens. The valve allows the high pressure fuel from the fuel manifold to enter the injector. The pressure of the fuel pushes the needle valve and a spring. When the force of the fuel pressure is greater than the force of the spring, the needle valve will lift up.

The timing and duration of injection is controlled by a solenoid valve in the injector. The valve has two positions. In the closed position, the valve closes the inlet to the injector. In this position, fuel above the injector needle is allowed to vent through the leakoff port.

In the open position, the valve opens the inlet to the injector. Simultaneously, the valve closes the leakoff port in order to allow high pressure fuel to flow to the needle. When the solenoid valve is closed, some fuel escapes past the valve in order to vent through the leakoff port. A certain volume of fuel always flows from the leakoff port. If the volume of fuel increases beyond a critical level, the high pressure fuel pump will not be able to maintain pressure in the fuel manifold. The faulty electronic unit injector must be identified and replaced.

When the signal to the injector ends, the valve closes. The fuel in the injector changes to a low pressure. When the pressure drops the needle valve will close and the injection cycle stops. When the needle valve opens, fuel under high pressure will flow through nozzle orifices into the cylinder. The fuel is injected into the cylinder through the orifices in the nozzle as a very fine spray.

The needle valve has a close fit with the inside of the nozzle. This makes a positive seal for the valve.

## Fuel Manifold

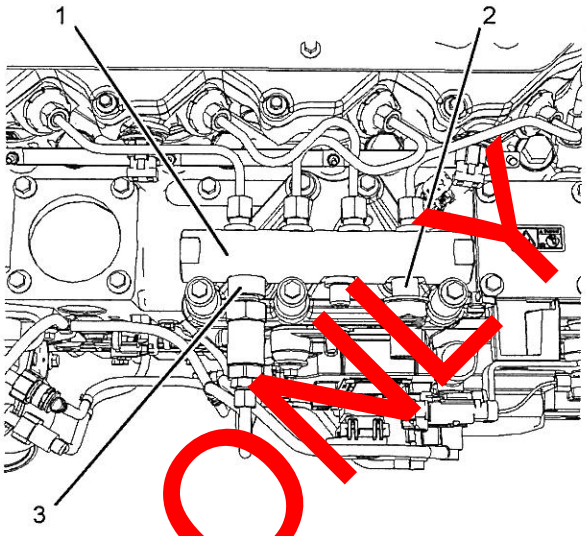



Illustration 29 g01266024
Typical example

The fuel manifold (1) stores high pressure fuel from the fuel injection pump. The high pressure fuel will flow to the injectors.

The fuel pressure sensor (2) measures the fuel pressure in the fuel manifold (1).

The relief valve (3) will prevent the fuel pressure from getting too high.

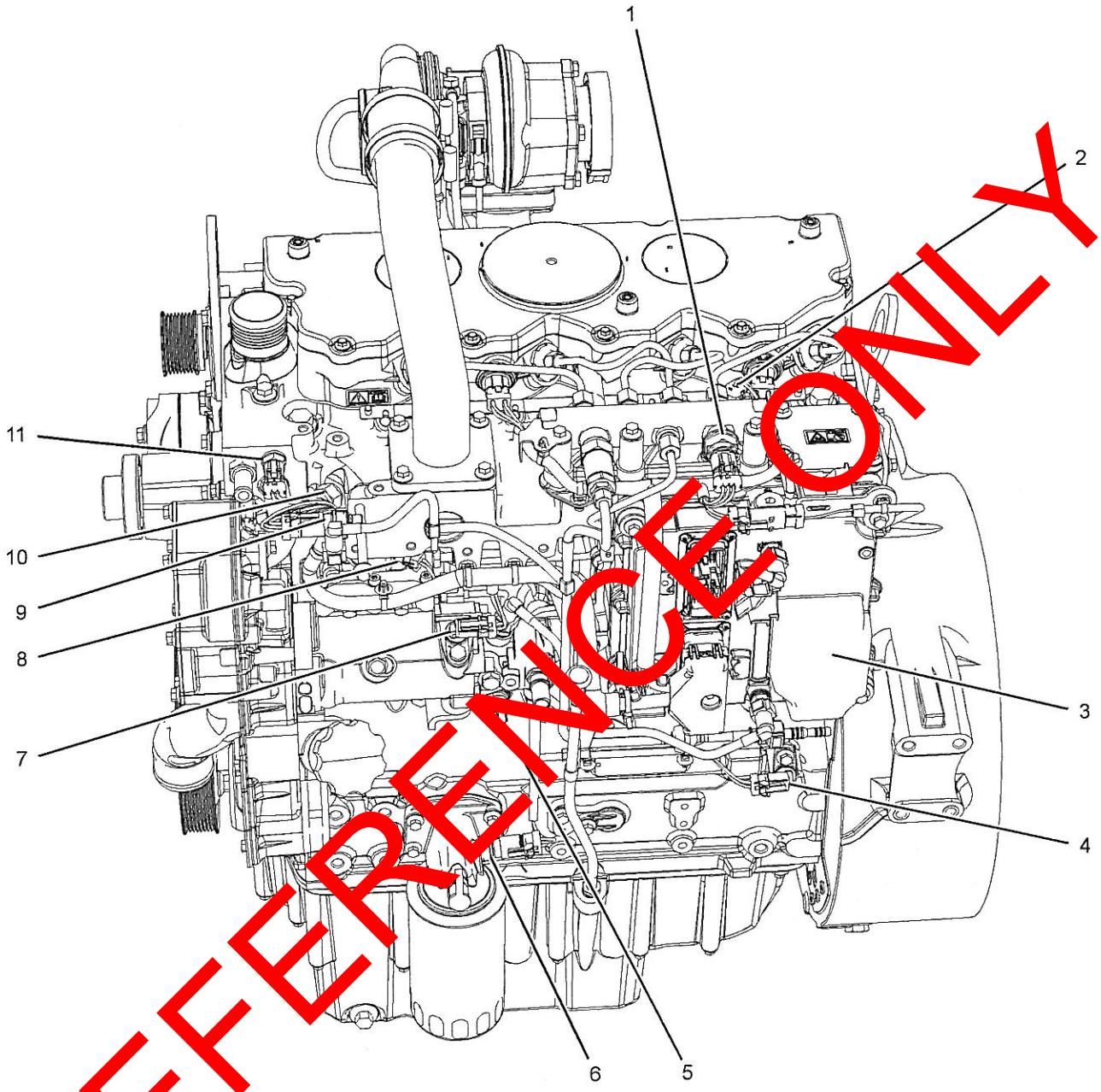
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# Electronic Control System

## Introduction (Electronic Control System)

The ECM and the sensors are located on the left side of the engine. Refer to illustration 30.

REFERENCE ONLY




g01248060

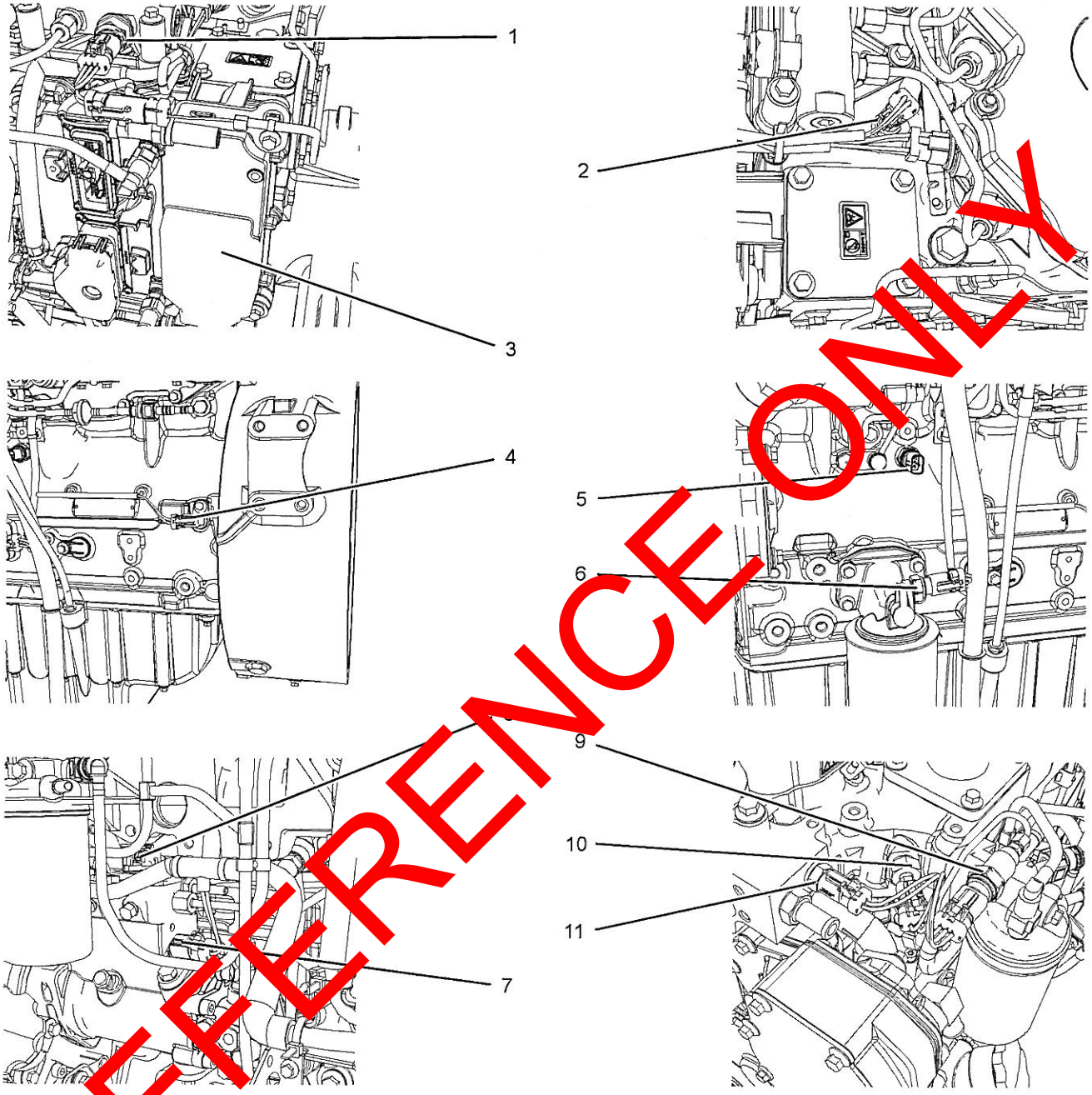
Illustration 3

A typical example of a 1104D electronic control system

(1) Fuel Pressure Sensor
(2) Intake Manifold Air Temperature Sensor
(3) Electronic Control Module (ECM)
(4) Primary Speed/Timing Sensor
(5) Oil Pressure Sensor
(6) Oil Pressure Sensor (alternative location)
(7) Secondary Speed/Timing Sensor
(8) Solenoid for the Fuel Injection Pump
(9) Intake Manifold Pressure Sensor
(10) Intake Manifold Pressure Sensor (alternative location)
(11) Coolant Temperature Sensor

**Note:** If equipped, the wastegate solenoid is installed on the right side of the engine.

REFERENCE ONLY




REFERENCE ONLY

Illustration 3

g01248066

Table 1

| Connector | Function |
|---|---|
| P1 | Machine Harness to ECM Connector (64 Pin Connector) |
| P2 | Engine Harness to ECM Connector (64 Pin Connector) |
| P532 | Fuel Injection Pump Solenoid Connector (2 Pin Connector) |
| P402 | Secondary Speed/Timing Sensor (2 Pin Connector) |
| P401 | Primary Speed/Timing Sensor (2 Pin Connector) |
| P201 | Engine Oil Pressure Sensor (3 Pin Connector) |
| P228 | Fuel Pressure Sensor (3 Pin Connector) |
| P200 | Intake Manifold Pressure Sensor (3 Pin Connector) |
| P103 | Intake Manifold Temperature Sensor (2 Pin Connector) |
| P100 | Coolant Temperature Sensor (2 Pin Connector) |
| J23 | Diagnostic Connector (if equipped) |
| P691/J691 | Electronic Unit Injectors for No. 1 and No. 2 Cylinders (4 Pin Connector) |
| P692/J692 | Electronic Unit Injectors for No. 3 and No. 4 Cylinders (4 Pin Connector) |
| P601 | Wastegate Valve (if equipped) (2 Pin Connector) |

The 1104D engine was designed for electronic control. The engine has an Electronic Control Module (ECM), a fuel injection pump and electronic unit injectors. All of these items are electronically controlled. There are also a number of engine sensors. Turbocharged engines can be equipped with an electronically controlled wastegate for the turbocharger. The ECM controls the engine operating parameters through the software within the ECM and the inputs from the various sensors. The software contains parameters that control the engine operation. The parameters include all of the operating maps and customer selected parameters.

REFERENCE ONLY

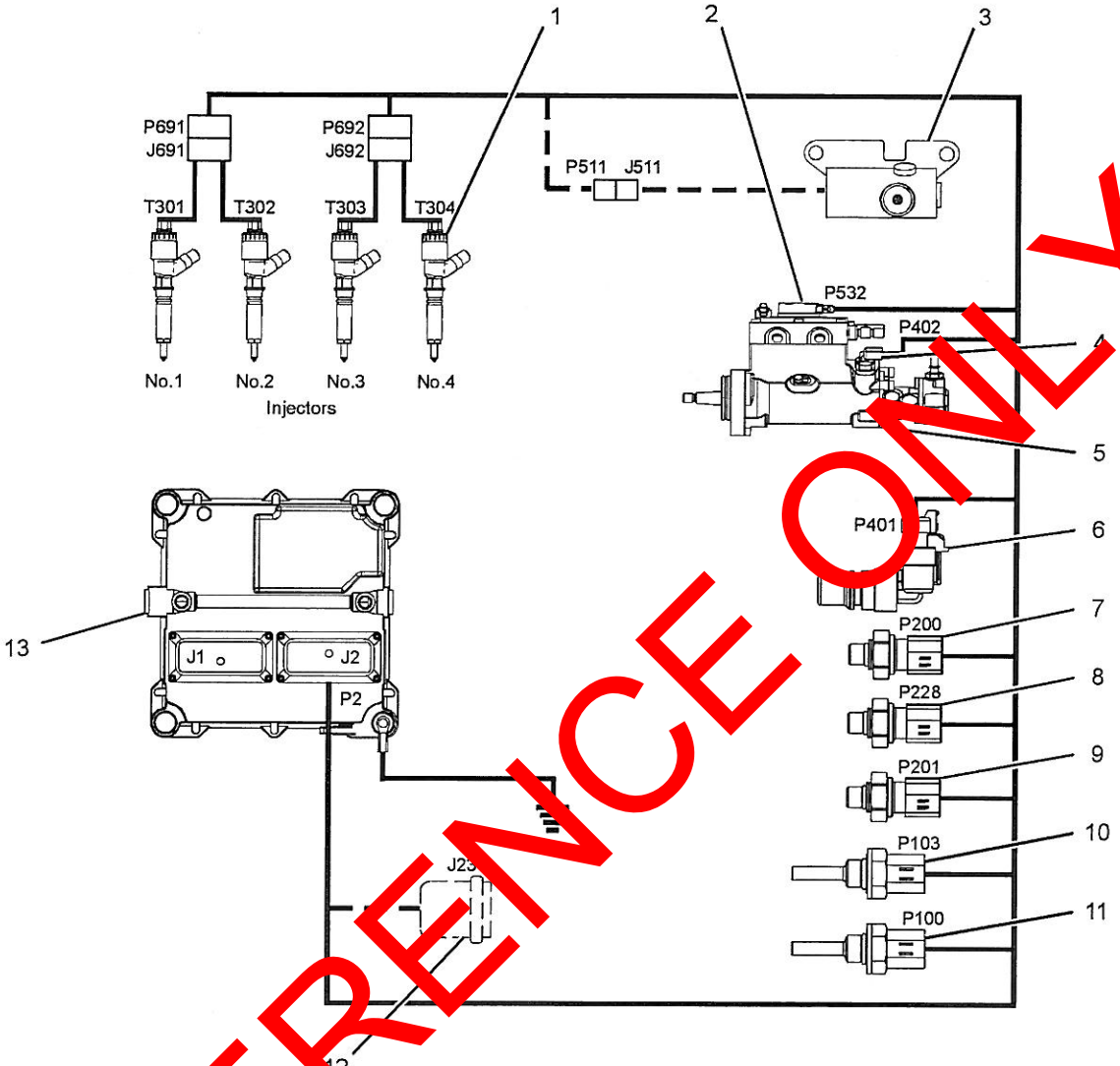



Illustration 32 g01236714

The electronic control system has the following components:

- ECM
- Pressure Sensor
- Temperature Sensors
- Crankshaft Position Sensor
- Secondary Position Sensor
- Solenoid for the Fuel Injection Pump
- Wastegate Solenoid
- Electronic Unit Injectors

REFERENCE ONLY

## ECM

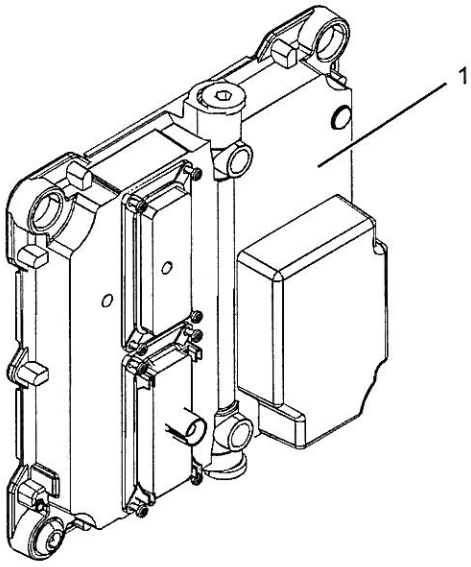



Illustration 33 g01199973
Typical example

The Electronic Control Module (ECM) (1) functions as a governor and a computer for the fuel system. The ECM receives signals from the sensors in order to control the timing and the engine speed.

The electronic system consists of the ECM, the engine sensors and inputs from the parent machine. The ECM is the computer. The personality module is the software for the computer. The personality module contains the operating maps. The operating maps define the following characteristics of the engine:

- Engine power
- Torque curves
- Engine speed (rpm)
- Engine Noise
- Smoke and emissions

The factory passwords restrict changes to authorized personnel. Factory passwords are required to clear any event code. Refer to the following Troubleshooting, "Factory Passwords" For more information on the passwords.

The ECM has an excellent record of reliability. Any problems in the system are most likely to be the connectors and the wiring harness. The ECM should be the last item in troubleshooting the engine.

The personality module contains the software with all the fuel setting information. The information determines the engine performance.

Flash programming is the method of programming or updating the personality module. Refer to the following Troubleshooting, RENR2417, "Flashing Programming " for the instructions on the flash programming of the personality module.

The ECM is sealed and the ECM needs no routine adjustment or maintenance.

### Engine Speed Governor

The electronic controls determine the injection timing, the amount of fuel that is delivered to the cylinders and the intake manifold pressure if an electronically controlled wastegate is installed on the turbocharger. These decisions are based on the actual conditions and the desired conditions at any given time.

The governor has software that compares the desired engine speed to the actual engine speed. The actual engine speed is determined through the primary speed/timing sensor and the secondary speed/timing sensor. If the desired engine speed is greater than the actual engine speed, the governor injects more fuel in order to increase engine speed.

### Timing Considerations

Once the governor has determined the amount of fuel that is required, the software must determine the timing of the fuel injection. Fuel injection timing is determined by the ECM after considering input from the following components:

- Engine coolant temperature sensor
- The sensor for the intake manifold air temperature
- The sensor for the intake manifold pressure

REFERENCE ONLY

At start-up, the ECM determines the top center position of the number 1 cylinder from the secondary speed/timing sensor in the fuel injection pump. The ECM decides when fuel injection should occur relative to the top center position. The ECM optimizes engine performance by control of each of the electronic unit injectors so that the required amount of fuel is injected at the precise point of the engine's cycle. The electronic unit injectors are supplied high pressure fuel from the fuel injection pump. The ECM also provides the signal to the solenoid in the fuel injection pump. The solenoid in the fuel injection pump controls a valve in the fuel injection pump. This valve controls the pressure in the fuel injection pump. Fuel that is not required for the engine is diverted away from the fuel injection pump back to the fuel tank.

The ECM adjusts injection timing and fuel pressure for the best engine performance, the best fuel economy and the best control of exhaust emissions. The actual timing can be viewed with an electronic service tool. Also, the desired timing can be viewed with an electronic service tool.

### Fuel Injection

The personality module software inside the ECM sets certain limits on the amount of fuel that can be injected.

The FRC Limit is a limit that is based on intake manifold air pressure and engine rpm. The FRC Limit is used to control the air/fuel ratio in order to control the engine's exhaust emissions. When the ECM senses a higher intake manifold air pressure, the ECM increases the FRC Limit. A higher intake manifold air pressure indicates that there is more air in the cylinder. When the ECM increases the FRC Limit, the ECM allows more fuel into the cylinder.

The Rated Fuel Limit is a limit that is based on the power rating of the engine and on the engine rpm. The Rated Fuel Limit enables the engine power and torque output to conform to the power and torque curves of a specific engine model.

These limits are in the personality module and these limits cannot be changed.

## Diagnostic Codes

When the ECM detects an electronic system problem, the ECM generates a diagnostic code. Also, the ECM logs the diagnostic code in order to indicate the time of the problem's occurrence. The ECM also logs the number of occurrences of the problem. Diagnostic codes are provided in order to indicate that the ECM has detected an electrical problem or an electronic problem with the engine control system. In some cases, the engine performance can be affected when the condition that is causing the code exists.

If the operator indicates that a performance problem has occurred, the diagnostic code may indicate the cause of the problem. Use a laptop computer to access the diagnostic codes. The problem should then be corrected.

### Event Codes

Event Codes are used to indicate that the ECM has detected an abnormal engine operating condition. The ECM will log the occurrence of the event code. This does not indicate an electrical malfunction or an electronic malfunction. If the temperature of the coolant in the engine is higher than the permitted limit, then the ECM will detect the condition. The ECM will then log an event code for the condition.

## Passwords

System Configuration Parameters are protected by factory passwords. This will prevent unauthorized reprogramming of the system and the unauthorized removal of logged events. Factory passwords are calculated on a computer system that is available only to Perkins distributors. Since factory passwords contain alphabetic characters, only an electronic service tool may change System Configuration Parameters. System Configuration Parameters affect the power rating or the emissions. Passwords also allow the customer to control certain programmable engine parameters.

Refer to Troubleshooting, "Programming Parameters" and Troubleshooting, "Factory Passwords".

## Speed/Timing Sensor

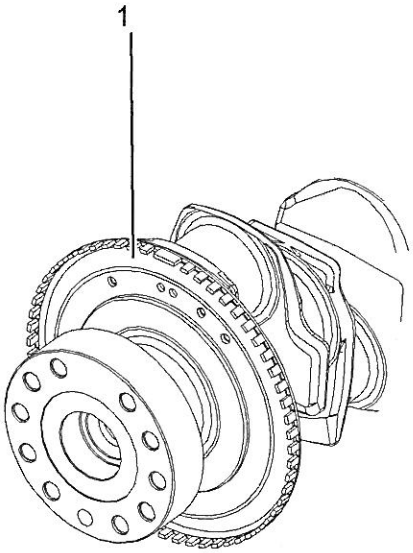
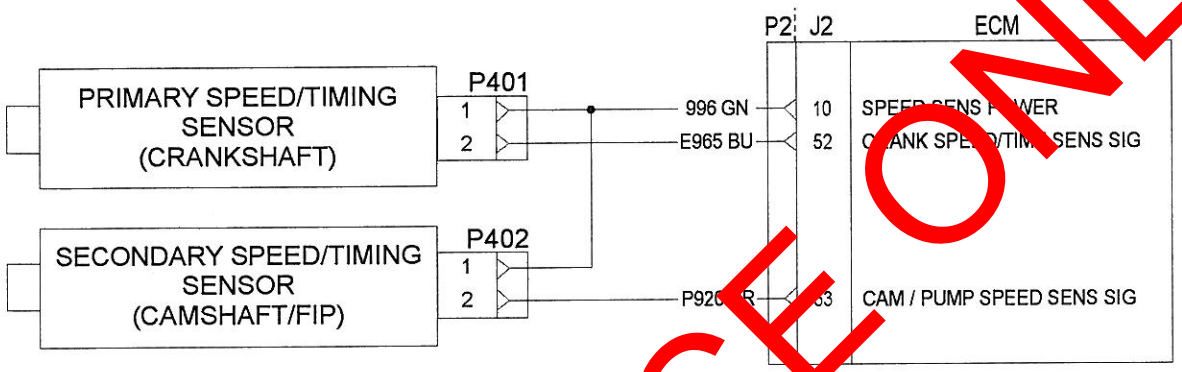



Illustration 34 g01266457

Timing wheel on the crankshaft

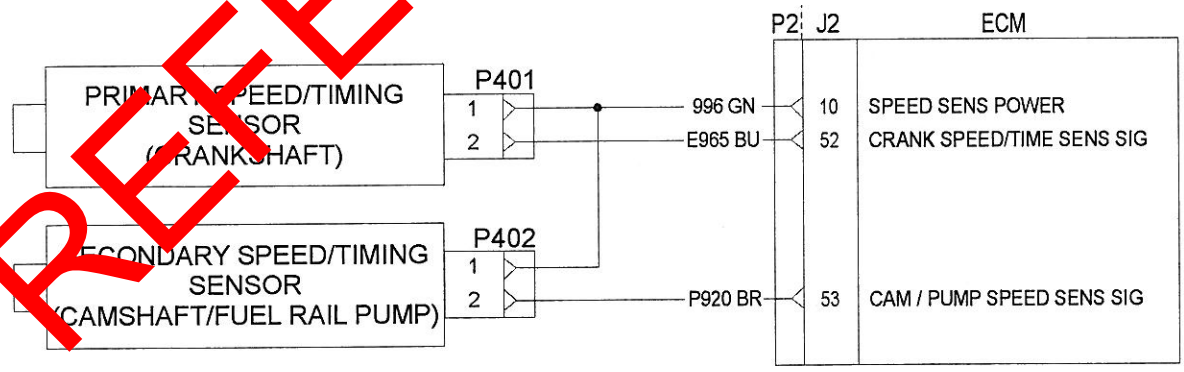
REFERENCE ONLY

The primary engine position is a passive sensor. The timing wheel (1) is located on the crankshaft. The speed/timing sensor receives a signal from the teeth on timing wheel. The extra space on the timing wheel gives one revolution per space. The space is oriented so that the space is 40 degrees after top center.




g01266905

Illustration 35
Schematic for speed/timing sensor




g01266620

Illustration 36

REFERENCE ONLY

When the engine is cranking, the ECM uses the signal from the speed/timing sensor in the fuel injection pump. When the engine is running the ECM uses the signal from the speed/timing sensor on the crankshaft. This speed/timing sensor is the primary source of the engine position.

## Pressure Sensors

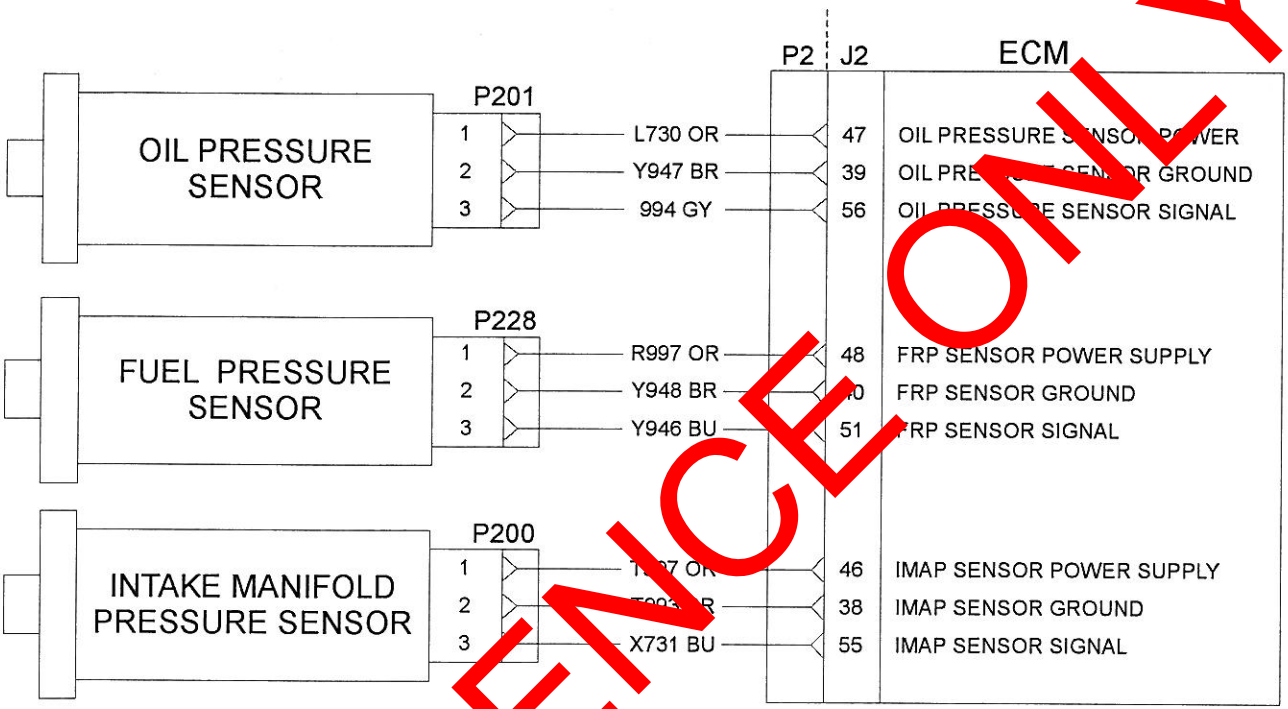



Illustration 37 g01266903

Schematic for pressure sensors

The boost pressure sensor and the engine oil pressure sensor are active sensors.

The boost pressure sensor provides the ECM with a measurement of inlet manifold pressure in order to control the air/fuel ratio. This will reduce the engine smoke during transient conditions.

The operating range of the boost pressure sensors

For standard power engines, the range is up to the following. ..... 339 kPa (49.169 psi)

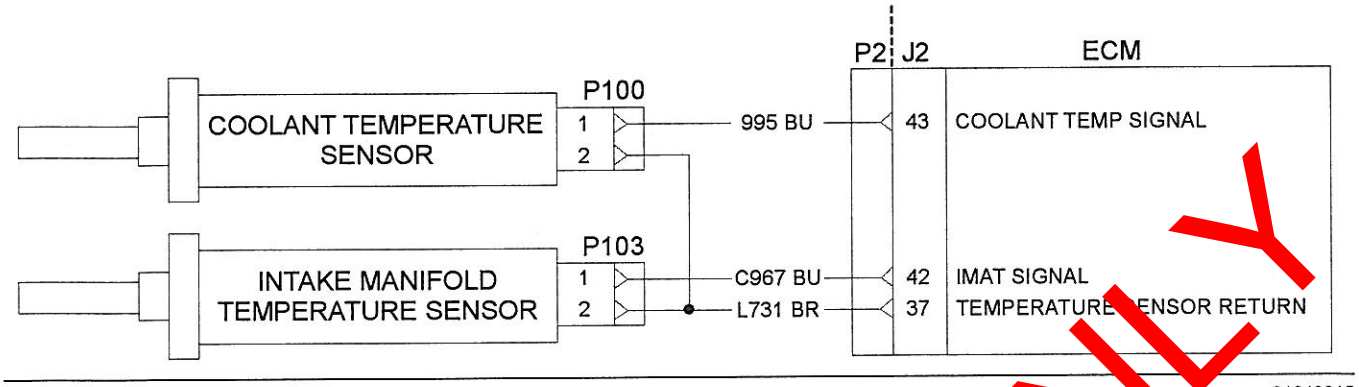
For all high power engine, the range is up to the following. ..... 440 kPa (63.818 psi)

The engine oil pressure sensor provides the ECM with a measurement of engine oil pressure. The ECM can warn the operator of possible conditions that can damage the engine. This includes the detection of an oil filter that is blocked.

The operating range for the engine oil pressure sensor ..... 55 kPa to 339 kPa (8 psi to 50 psi)

REFERENCE ONLY

## Temperature Sensors




g01249915

Illustration 38

Schematic for the temperature sensors

The air inlet temperature sensor and the coolant temperature sensor are passive sensors. Each sensor provides a temperature input to the ECM. The ECM controls following operations:

- Fuel delivery
- Injection timing

The operating range for the sensors ..... −40 °C to 150 °C (−40 °F to 302 °F)

The sensors are also used for engine monitoring.

i02532754

# Power Sources

## Introduction (Power Supplies)

The 1104D Engine supplies power to the ECM. The ECM powers the following components:

- All sensors on the engine
- The solenoid for the fuel Injection Pump
- The solenoid for the Wastegate (optional)
- Diagnostic connector
- Electronic unit injectors

The glow plugs are powered directly from the battery.

REFERENCE ONLY

## ECM Power Supply

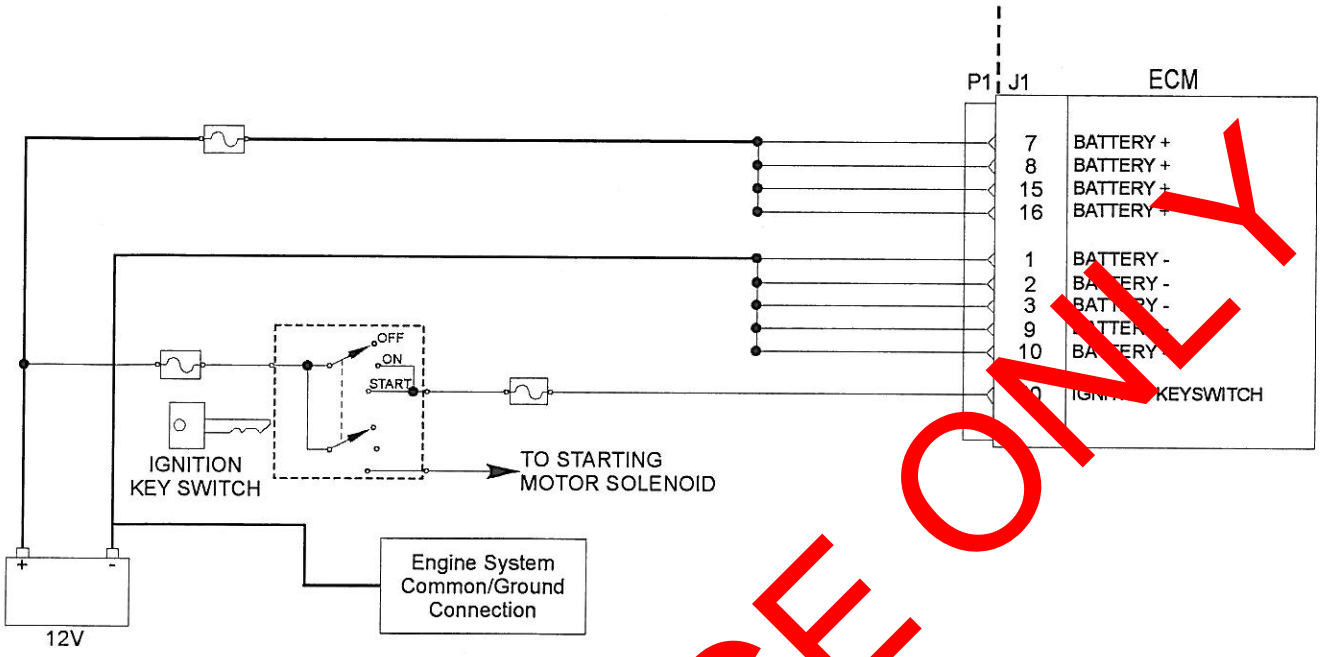



Illustration 39 g01245123

Schematic for ECM

The power supply to the ECM and the system is drawn from the 24 volt or the 12 volt battery. The power supply for the ECM has the following components:

- Battery
- disconnect switch
- Key start switch
- Fuses
- Ground bolt
- ECM connector
- Machine interface connector

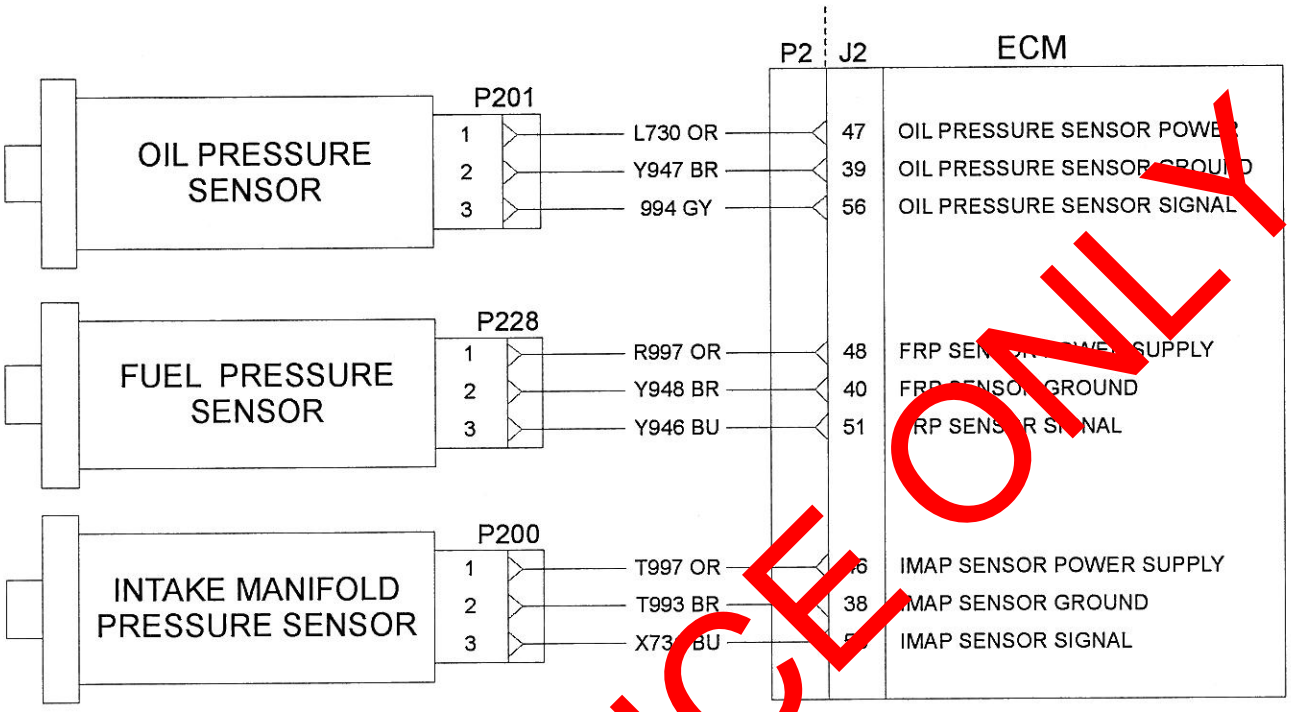
The Schematic for the ECM shows the main components for a typical power supply circuit. Battery voltage is normally connected to the ECM. The input from the key start switch turns on the ECM.

The wiring harness can be bypassed for troubleshooting purposes.

The display screen on the electronic service tool can be used in order to check the voltage supply.

REFERENCE ONLY

## Power Supply for the Pressure Sensors




g01266903

Illustration 40

Schematic for pressure sensors

The ECM supplies 5.0 ± 0.2 DC volts through the ECM connector to each sensor. The power supply is protected against short circuits. A short in a sensor or a wiring harness will not cause damage to the ECM.

REFERENCE ONLY

## Power supply for the Glow plugs

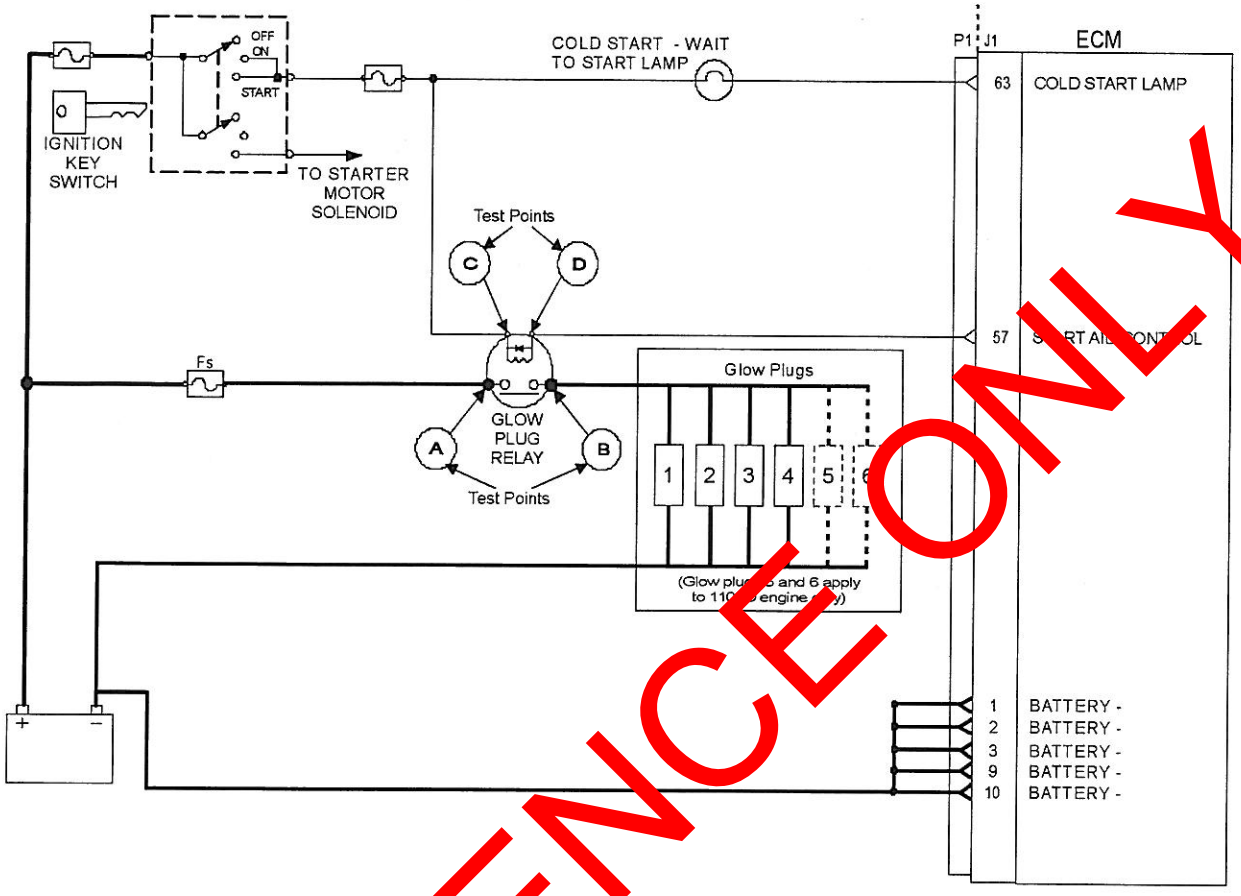



Illustration 41 g01245657

Schematic for the glow plugs

REFERENCE ONLY

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## Glossary of Electronic Control Terms

**Air-To-Air Aftercooler** – An air-to-air aftercooler is a device that is used on turbocharged engines in order to cool inlet air that has undergone compression. The inlet air is cooled after the inlet air passes through the turbocharger. The inlet air is passed through an aftercooler (heat exchanger) that uses ambient air for cooling. The inlet air that has been cooled advances to the inlet manifold.

**Active Diagnostic Code** – An active diagnostic code alerts the operator or the service technician that an electronic system malfunction is currently present. Refer to the term “Diagnostic Code” in this glossary.

**Adaptive Trim** – This is a software process that is performed in the ECM that optimizes engine performance by automatically compensating for degradation of injector components.

**Alternating Current (AC)** – Alternating current is an electric current that reverses direction at a regular interval that is reoccurring.

**Before Top Center (BTC)** – BTC is the 180 degrees of crankshaft rotation before the piston reaches the top center position in the normal direction of rotation.

**Breakout Harness** – The breakout harness is a test harness that is designed to connect into the engine harness. This connection allows a normal circuit operation and the connection simultaneously provides a Breakout T in order to measure the signals.

**Bypass Circuit** – A bypass circuit is a circuit that is used as a substitute circuit for an existing circuit. A bypass circuit is typically used as a test circuit.

**CAN Data Link (see also J1939 CAN Data Link)** – The CAN Data Link is a serial communications port that is used for communication with other microprocessor based devices.

**Code** – Refer to "Diagnostic Code" or "Event Code".

**Cold Mode** – Cold mode is a mode for cold starting and for cold engine operation. This mode is used for engine protection, reduced smoke emissions and faster warm up time.

**Communication Adapter Tool** – The communication adapter provides a communication link between the ECM and the Electronic Service Tool.

**Component Identifier (CID)** – The CID is a number that identifies the specific component of the electronic control system that has experienced a diagnostic code.

**Coolant Temperature Sensor** – The coolant temperature sensor detects the engine coolant temperature for all normal operating conditions and for engine monitoring.

**Code** – See the Diagnostic Code.

**Customer Specified Parameters** – A customer specified parameter is a parameter that can be changed in the ECM with the Electronic Service Tool. A customer specified parameter's value is set by the customer. These parameters are protected by customer passwords.

**Data Link** – The Data Link is a serial communication port that is used for communication with other microprocessor based devices.

**Derate** – Certain engine conditions will generate event codes. Also, engine derates may be applied. The map for the engine derates is programmed into the ECM software. The derate can be one or more of 3 types: reduction of rated power, reduction of rated engine speed, and reduction of rated machine speed for OEM products.

**Desired Engine Speed** – The desired engine speed is input to the electronic governor within the ECM. The electronic governor uses the signal from the throttle position sensor, the engine speed/timing sensor, and other sensors in order to determine the desired engine speed.

**Diagnostic Code** – A diagnostic code is sometimes referred to as a fault code. These codes indicate an electronic system malfunction.

**Diagnostic Lamp** – A diagnostic lamp is sometimes called the check engine light. The diagnostic lamp is used to warn the operator of the presence of an active diagnostic code. The diagnostic lamps are red and orange. The lamp may not be included in all applications.

**Digital Sensor Return** – The common line (ground) from the ECM is used as ground for the digital sensors.

**Digital Sensors** – Digital sensors produce a pulse width modulated signal. Digital sensors are supplied with power from the ECM.

**Digital Sensor Supply** – The power supply for the digital sensors is provided by the ECM.

**Direct Current (DC)** – Direct current is the type of current that flows consistently in only one direction.

**Duty Cycle** – See Pulse Width Modulation.

**DT, DT Connector, or Deutsch DT** – This is a type of connector that is used on Perkins engines. The connectors are manufactured by Deutsch.

**Electronic Service Tool** – The electronic service tool is used for diagnosing a variety of electronic controls and the electronic service tool is also used for programming a variety of electronic controls.

**Electronic Engine Control** – The electronic engine control is a complete electronic system. The electronic engine control monitors the engine operation under all conditions. The electronic engine control also controls the engine operation under all conditions.

**Engine Control Module (ECM)** – The ECM is the control computer of the engine. The ECM provides power to the electronics. The ECM monitors data that is input from the sensors of the engine. The ECM acts as a governor in order to control the speed and the power of the engine.

**Electronic Service Tool** – The electronic service tool allows a computer (PC) to communicate with the ECM.

**Engine Monitoring** – Engine Monitoring is the part of the electronic engine control that monitors the sensors. This also warns the operator of detected problems.

**Engine Oil Pressure Sensor** – The engine oil pressure sensor measures engine oil pressure. The sensor sends an electronic signal to the ECM that is dependent on the engine oil pressure.

REFERENCE ONLY

**Engine Speed/Timing Sensor** – An engine speed/timing sensor is a Hall effect sensor. The ECM interprets this signal as the crankshaft position and the engine speed. Two sensors are used to provide the speed and timing signals to the ECM. The primary sensor is associated with the crankshaft and the secondary sensor is associated with the fuel injection pump camshaft.

**Estimated Dynamic Timing** – Estimated dynamic timing is the estimate of the actual injection timing that is calculated by the ECM.

**Ether Relay** – The ether relay is used to actuate the ether injection system. The ECM controls the relay.

**Event Code** – An event code may be activated in order to indicate an abnormal engine operating condition. These codes usually indicate a mechanical problem instead of an electrical system problem.

**Failure Mode Identifier (FMI)** – This identifier indicates the type of failure that is associated with the component. The FMI has been adopted from the SAE practice of J1587 diagnostics. The FMI follows the parameter identifier (PID) in the descriptions of the fault code. The descriptions of the FMIs are in the following list.

**0** – The data is valid but the data is above the normal operational range.

**1** – The data is valid but the data is below the normal operational range.

**2** – The data is erratic, intermittent, or incorrect.

**3** – The voltage is above normal or the voltage is shorted high.

**4** – The voltage is below normal or the voltage is shorted low.

**5** – The current is below normal or the circuit is open.

**6** – The current is above normal or the circuit is grounded.

**7** – The mechanical system is not responding properly.

**8** – There is an abnormal frequency, an abnormal pulse width, or an abnormal time period.

**9** – There has been an abnormal update.

**10** – There is an abnormal rate of change.

**11** – The failure mode is not identifiable.

**12** – The device or the component is damaged.

**13** – The device or the component is not calibrated.

**14 and 15** – These locations are reserved for a future assignment.

**Flash Programming** – Flash programming is the method of programming or updating an ECM with an electronic service tool over the data link.

**Fuel Injector E-Trim** – Fuel injector E-trim is a software process that allows precise control of fuel injectors by parameters that are programmed into the ECM for each fuel injector. With the use of the electronic service tool, the service technician can read status information for the E-Trim. Data for E-Trim can also be programmed.

**Flash Memory** – See the Programmable software.

**Fuel Ratio Control (FRC)** – The FRC is a limit that is based on the control of the fuel to the air ratio. The FRC is used for emission control. When the ECM senses a higher turbocharger outlet pressure, the ECM increases the limit for the FRC in order to allow more fuel into the cylinders.

**Fuel Pump** – See "Fuel Injection Pump".

**Fuel Rail** – This item is sometimes referred to as the High Pressure Fuel Rail or high pressure fuel manifold. The fuel rail supplies fuel to the electronic unit injectors. The fuel injection pump and the fuel rail pressure sensor work with the ECM in order to maintain the desired fuel pressure in the fuel rail. This pressure is determined by calibration of the engine in order to enable the engine to meet emissions and performance requirements.

**Fuel Rail Pressure Sensor** – The fuel rail pressure sensor sends an electronic signal to the ECM that is dependent on the pressure of the fuel in the fuel rail.

**Fuel Injection Pump** – This item is sometimes referred to as the High Pressure Fuel Rail Pump. This is a device that supplies fuel under pressure to the fuel rail (high pressure fuel rail).

**The Solenoid Valve for the Fuel Injection Pump** – This is sometimes referred to as the High Pressure Fuel Rail Pump Solenoid Valve. This is a control device in the fuel injection pump. The ECM controls the pressure in the fuel rail by using this valve to divert excess fuel from the pump to the fuel tank.

**Full Load Setting (FLS)** – The FLS is the number that represents the fuel system adjustment. This adjustment is made at the factory in order to fine tune the fuel system. The correct value for this parameter is stamped on the engine information ratings plate. This parameter must be programmed.

REFERENCE ONLY

**Glow Plug** – The glow plug is an optional starting aid for cold conditions. One glow plug is installed in each combustion chamber in order to improve the ability of the engine to start. The ECM uses information from the engine sensors such as the engine temperature to determine when the glow plug relay must provide power to each glow plug. Each of the glow plugs then provides a very hot surface in the combustion chamber in order to vaporize the mixture of air and fuel. This improves ignition during the compression stroke of the cylinder.

**Glow Plug Relay** – The glow plug relay is controlled by the ECM in order to provide high current to the glow plugs that are used in the starting aid system.

**Harness** – The harness is the bundle of wiring (loom) that connects all components of the electronic system.

**Hertz (Hz)** – Hertz is the measure of frequency in cycles per second.

**High Pressure Fuel Rail Pump** – See "Fuel Rail Pump".

**High Pressure Fuel Rail Pump Solenoid Valve** – See "Fuel Rail Pump Solenoid Valve".

**High Pressure Fuel Rail** – See "Fuel Rail".

**Injector Codes** – The injector codes or injector trim codes are numeric codes or alphanumeric codes that are etched or stamped on individual electronic unit injectors. These codes are used to fine tune the fuel delivery.

**Injector Trim Files** – Injector trim files are downloaded from a disk to the ECM. The injector trim files compensate for variances in manufacturing of the electronic unit injector. The serial number for the electronic unit injector must be obtained in order to retrieve the correct injector trim file.

**Inlet Manifold Air Temperature Sensor** – The intake manifold air temperature sensor detects the air temperature in the intake manifold. The ECM monitors the air temperature and other data in the intake manifold in order to adjust injection timing and other performance functions.

**Inlet Manifold Pressure (Engines that are turbocharged)** – The difference between the turbocharger outlet pressure and atmospheric pressure is commonly referred to as inlet manifold pressure. The sensor for the inlet manifold air pressure measures the amount of boost.

**Integrated Electronic Controls** – The engine is designed with the electronic controls as a necessary part of the system. The engine will not operate without the electronic controls.

**Intake Manifold Pressure Sensor** – The Intake Manifold Pressure Sensor measures the pressure in the intake manifold. The pressure in the intake manifold may be different to the pressure outside the engine (atmospheric pressure). The difference in pressure may be caused by an increase in air pressure by a turbocharger (if equipped).

**J1939 CAN Data Link** – Logged diagnostic codes are codes which are stored in the memory. These codes are meant to be an indicator of possible causes for intermittent problems. Refer to the term "Diagnostic Code" in this glossary for more information.

**Logged Diagnostic Code** – Logged diagnostic codes are codes which are stored in the memory. These codes are meant to be an indicator of possible causes for intermittent problems. Refer to the term "Diagnostic Code" in this glossary for more information.

**Open Circuit** – An open circuit is a condition that is caused by an open switch, or by an electrical wire or a connection that is broken. When this condition exists, the signal or the supply voltage can no longer reach the intended destination.

**OEM** – OEM is an abbreviation for the Original Equipment Manufacturer. This is the manufacturer of the machine or the vehicle that uses the engine.

**Parameter** – A parameter is a value or a limit that is programmable. This helps determine specific characteristics or behaviors of the engine.

**Parameter Identifier (PID)** – A PID is a numerical code that contains two digits or three digits. A numerical code is assigned to each component. The numerical code identifies data via the data link to the ECM.

**Password** – A password is a group of numeric characters or a group of alphanumeric characters that is designed to restrict access to parameters. The electronic system requires correct passwords in order to change some parameters (Factory Passwords). Refer to Troubleshooting, "Factory Passwords" for more information.

**Personality Module** – This module is software that is inside the ECM. The module contains all the instructions (software) for the ECM and the module contains the performance maps for a specific engine. The personality module may be reprogrammed through flash programming.

REFERENCE ONLY

**Programmable Software** – The software is programmed into the ECM. The software contains all the instructions (software) for the ECM and the software contains the performance maps for a specific engine. The software may be reprogrammed through flash programming.

**Position Sensor** – This sensor determines the position of the fuel injection pump camshaft during start-up. If the speed/timing sensor fails during engine operation, the position sensor is used to provide the signal. The sensor determines the position of the fuel injection pump camshaft for injection timing and for engine speed. If the position sensor fails, the engine will continue to operate but the engine will not start.

**Power Cycled** – Power cycled happens when power to the ECM is cycled: ON, OFF, and ON. Power cycled refers to the action of cycling the keyswitch from any position to the OFF position, and to the START/RUN position.

**Primary Speed/Timing Sensor** – This sensor determines the position of the crankshaft during engine operation. If the primary speed/timing sensor fails during engine operation, the secondary speed/timing sensor is used to provide the signal.

**Pulse Width Modulation (PWM)** – The PWM is a signal that consists of pulses that are of variable width. These pulses occur at fixed intervals. The ratio of "TIME ON" versus total "TIME OFF" can be varied. This ratio is also referred to as a duty cycle.

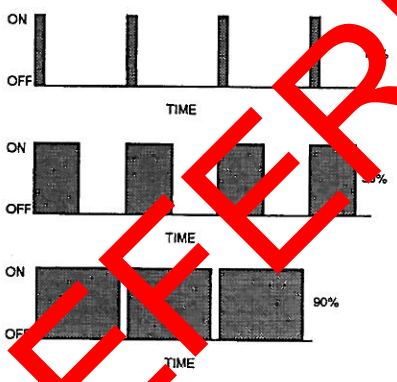



Illustration 4 g00284479

**Rated Fuel Limit** – This is a limit that is based on the power rating of the engine and on the engine rpm. The Rated Fuel Limit enables the engine power and torque outputs to conform to the power and torque curves of a specific engine model. These limits are in the personality module and these limits cannot be changed.

**Reference Voltage** – Reference voltage is a regulated voltage and a steady voltage that is supplied by the ECM to a sensor. The reference voltage is used by the sensor to generate a signal voltage.

**Relay** – A relay is an electromechanical switch. A flow of electricity in one circuit is used to control the flow of electricity in another circuit. A small current or voltage is applied to a relay in order to switch a much larger current or voltage.

**Sensor** – A sensor is used to detect a change in the pressure, in the temperature, or in mechanical movement. When any of these changes are detected, a sensor converts the change into an electrical signal.

**Short Circuit** – A short circuit is a condition that has an electrical circuit that is inadvertently connected to an undesirable point. An example of a short circuit is a wire which rubs against a vehicle frame and this rubbing eventually wears off the wire insulation. Electrical contact with the frame is made and a short circuit results.

**Signal** – The signal is a voltage or a waveform that is used in order to transmit information typically from a sensor to the ECM.

**Secondary Speed/Timing Sensor** – This sensor determines the position of the camshaft during engine operation. If the primary speed/timing sensor fails during engine operation, the secondary speed/timing sensor is used to provide the signal.

**Supply Voltage** – The supply voltage is a continuous voltage that is supplied to a component in order to provide the electrical power that is required for the component to operate. The power may be generated by the ECM or the power may be battery voltage that is supplied by the engine wiring.

**System Configuration Parameters** – System configuration parameters are parameters that affect emissions and/or operating characteristics of the engine.

**Tattletale** – Certain parameters that affect the operation of the engine are stored in the ECM. These parameters can be changed by use of the electronic service tool. The tattletale logs the number of changes that have been made to the parameter. The tattletale is stored in the ECM.

**Theft Deterrent** – This feature uses a four digit code in order to prevent the engine from starting. The feature requires a password to be entered.

**"T" Harness** – This harness is a test harness that is designed to permit normal circuit operation and the measurement of the voltage simultaneously. Typically, the harness is inserted between the two ends of a connector.

**Throttle Position** – The throttle position is the interpretation by the ECM of the signal from the throttle position sensor or the throttle switch.

REFERENCE ONLY

**Throttle Position Sensor** – The throttle position sensor is an electronic sensor that is usually connected to an accelerator pedal or a hand lever. This sensor sends a signal to the ECM that is used to calculate desired engine speed.

**Throttle Switch** – The throttle switch sends a signal to the ECM that is used to calculate desired engine speed.

**Timing Calibration** – The timing calibration is the adjustment of an electrical signal. This adjustment is made in order to correct the timing error between the camshaft and the engine speed/timing sensors or between the crankshaft and the engine speed/timing sensors.

**Top Center Position** – The top center position refers to the crankshaft position when the engine piston position is at the highest point of travel. The engine must be turned in the normal direction of rotation in order to reach this point.

**Total Tattletale** – The total tattletale is the total number of changes to all the parameters that are stored in the ECM.

**Wait To Start Lamp** – This is a lamp that is included in the cold starting aid circuit in order to indicate when the wait to start period has expired. The glow plugs have not deactivated at this point in time.

**Wastegate** – This is a device in a turbocharged engine that controls the maximum boost pressure that is provided to the inlet manifold.

**Wastegate Valve** – The wastegate valve regulates the pressure in the inlet manifold to a value that is determined by the ECM. The wastegate valve provides the interface between the ECM and the mechanical system that regulates inlet manifold pressure to the desired value that is determined by the software.

REFERENCE ONLY

# Testing and Adjusting Section

## Fuel System

i02563346

### Fuel System - Inspect

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

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

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

A problem with the components that transport 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. Install new fuel filters.
4. Cut the old filter open with a suitable filter cutter. Inspect the filter for excess contamination. Determine the source of the contamination. Make the necessary repairs.
5. Operate the hand priming pump (if equipped). If excessive resistance is felt, check that there is fuel in the fuel return line to the tank.

i02405571

### Air in Fuel - Test

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

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

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

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. 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 to tank line. When possible, install the fuel flow tube in a straight section of the fuel line that is at least 304.8 mm (12 inches) long. Do not install the fuel flow tube 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 fuel flow tube, 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.

REFERENCE ONLY

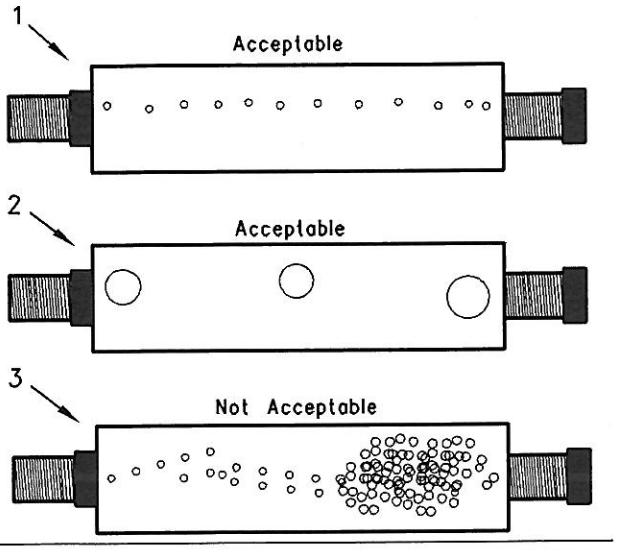



Illustration 43 g00578151

(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 fuel flow tube in the fuel return line, install a second fuel flow tube to the inlet to the fuel transfer pump. If a second fuel flow tube is not available, move the fuel flow tube from the fuel return line and install the fuel flow tube 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.

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.

i02535648

# Finding Top Center Position for No. 1 Piston

Table 2

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825576 | Crankshaft turning tool | 1 |
| B | 27610211 | Crankshaft timing pin | 1 |
| C | 27610212 | Camshaft timing pin | 1 |
| D | 27610289 | Crankshaft turning tool | 1 |
| E | 27610291 | Crankshaft turning tool | 1 |

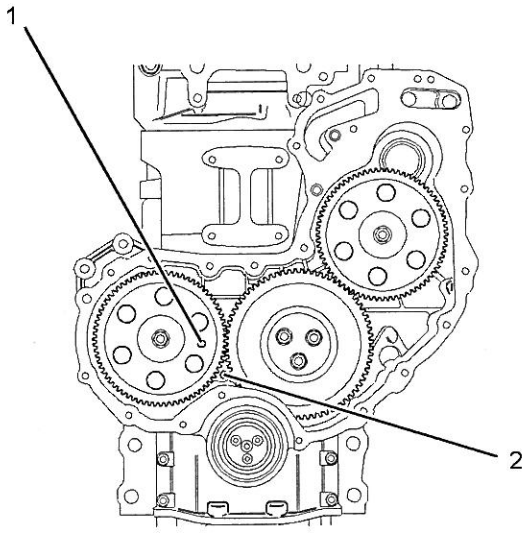



Illustration 44 g01268087

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

REFERENCE ONLY

1. Remove the valve mechanism cover, the glow plugs, and the cover for the front housing. Refer to Disassembly and Assembly Manual, "Front Cover - Remove and Install".

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

2. Use tooling (A) to 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.

**Note:** Use the alternative Tooling (D) and Tooling (E) if the access to the front of the engine is restricted.

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 (2) and the timing case. Insert Tooling (B) fully into the hole in the crankshaft web.

4. Insert Tooling (C) through the hole in the camshaft gear (1) 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.

i02536614

# Fuel Injection Timing - Check

Table 3

| Required Tool | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610302 | Fuel Injection Pump Timing Tool | 1 |

NOTICE

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

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

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

**This procedure must be done before any of the following reasons:**

- Removal of the fuel injection pump
- The bolts that hold the fuel injection pump to the front housing are loosened.

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. Carefully remove the fuel injection pump from the front housing. Refer to Disassembly and Assembly Manual, "Fuel Injection Pump - Remove" for the correct procedure.

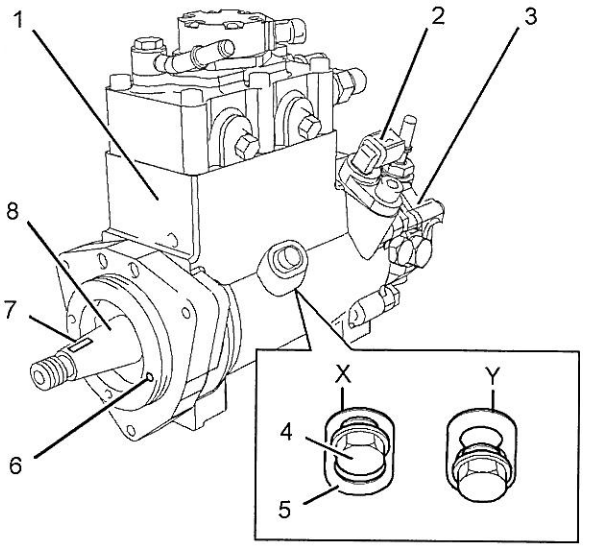



Illustration 45 g01200897

3. To check the fuel injection pump timing, follow Steps 3.a and 3.b.

REFERENCE ONLY

**a.** Position Tooling (A) onto the shaft (8) of the fuel injection pump. Align the lever of Tooling (A) with the key slot (7). Engage the lever into the key slot.

**b.** Insert the locking pin of Tooling (A) into the hole (6) in fuel injection pump.

If the locking pin can be inserted into the hole, the fuel injection pump timing is correct.

If the locking pin cannot be inserted into the hole, the fuel injection pump timing is not correct.

**Note:** There should be no resistance when the locking pin is inserted.

4. If the fuel injection pump timing has been lost follow Steps 5 through 9 in order to reset the fuel injection pump timing.

5. If necessary, loosen the locking screw (4) on the fuel injection pump. Slide the spacer (5) into position (X). Tighten the locking screw (4) to a torque of 9 N·m (80 lb in). This will prevent the locking screw from tightening against the shaft (8).

The fuel injection pump is now unlocked.

6. Position Tooling (A) onto the shaft (8) of the fuel injection pump. Align the lever of Tooling (A) with the key slot (7) in the fuel injection pump. Engage the lever into the key slot.

7. Use the lever of Tooling (A) to rotate the shaft (8) until the pin of Tooling (A) can be engaged into the hole (6). Engage the pin of Tooling (A) into the hole.

8. Loosen the locking screw (4) in the fuel injection pump. Slide the spacer (5) into position (Y). Tighten the locking screw (4) against the shaft of the fuel injection pump to a torque of 9 N·m (80 lb in).

The fuel injection pump is now locked.

9. Remove Tooling (A).

10. Install the fuel injection pump to the front housing. Refer to Disassembly and Assembly Manual, "Fuel Injection Pump - Install" for the correct procedure.

There are functional tests in order to ensure that electronic unit injectors operate correctly. Refer to Troubleshooting for further information.

i02563386

# Fuel Quality - Test

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

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

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 operating conditions.

Refer to Operation and Maintenance Manual, "Fuel Recommendations" for more information.

3. If fuel quality is still suspected as a possible cause to 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

REFERENCE ONLY

i02543918

# Fuel System - Prime

**⚠ WARNING**

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

Refer to the Operation and Maintenance Manual , "General Hazard Information and High Pressure Fuel Lines" before adjustments and repairs are performed.

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

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

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

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

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

## Hand Fuel Priming Pump

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

1. Ensure that the fuel system is in working order. Restore the fuel supply.

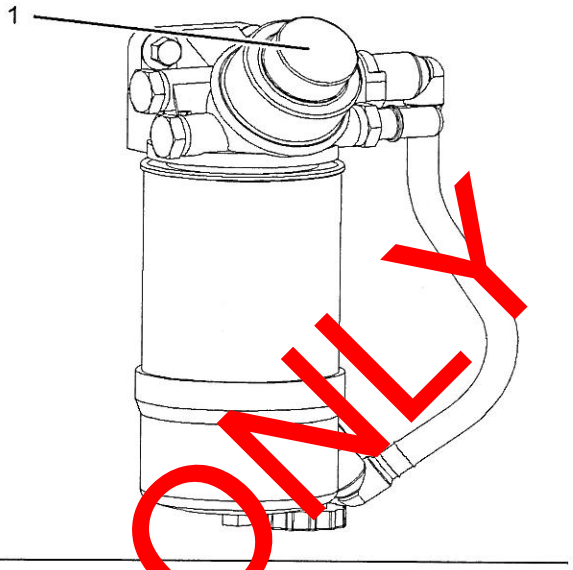



Illustration 46 g01191752
Typical example

2. Operate the fuel priming pump (1). Count the number of operations of the fuel priming pump. After 10 depressions of the fuel priming pump stop.
3. The engine fuel system should now be primed and the engine should now be able to start.

**Note:** Do not loosen the high pressure fuel line in order to purge air from the fuel system. This procedure is not required.

4. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of five minutes, immediately after air has been removed from the fuel system.

**Note:** Operating the engine for this period of time will help ensure that the fuel system is free of air.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General hazard Information".

REFERENCE ONLY

## Electric Fuel Priming Pump

1. Ensure that the fuel system is in working order. Restore the fuel supply.

NOTICE
The electric fuel priming pump will operate for 90 seconds. If necessary the electric fuel priming pump can be stopped during the 90 seconds of operation, by operation of the switch.

2. Turn the keyswitch to the "RUN" position. Operate the switch for the electric priming pump. After 100 seconds of the electric fuel priming pump operation the fuel system will be primed and the electric fuel priming pump will turn off.

3. The engine should now be able to start.

**Note:** Do not loosen the high pressure fuel line in order to purge air from the fuel system. This procedure is not required.

4. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of five minutes, immediately after air has been removed from the fuel system.

**Note:** Operating the engine for this period of time will help ensure that the fuel system is free of air.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, "Fuel Injection Lines - Install".

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, "General hazard Information".

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## Gear Group (Front) - Time

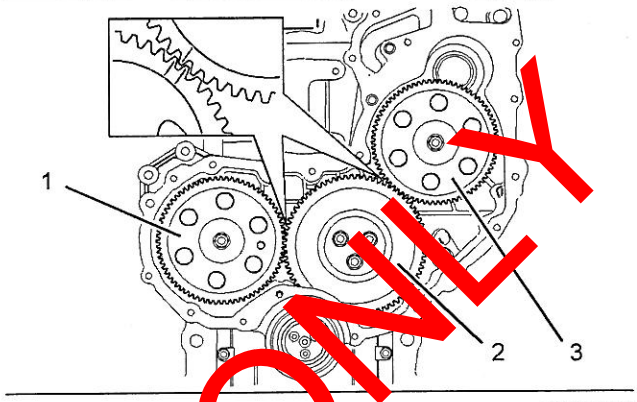



Illustration 47 g01194949

(1) Camshaft gear
(2) Idler gear
(3) Fuel Injection Pump gear

1. Install the camshaft gear (1) onto the camshaft. Refer to Disassembly and Assembly Manual, "Camshaft Gear - Remove and Install" for the correct procedure.

2. Ensure that the crankshaft and the camshaft are locked in the correct position. Refer to Disassembly and Assembly Manual, "Gear Group (Front) - Remove and Install" for the correct procedure. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly Manual, "Fuel Injection Pump - Remove" for the correct procedure.

3. Install the idler gear (2). Refer to Disassembly and Assembly Manual, "Idler Gear - Remove and Install" for the correct procedure.

4. Install the fuel injection pump gear (3). Refer to Disassembly and Assembly Manual, "Fuel Injection Pump Gear - Install" for the correct procedure.

5. Make sure that the timing marks on the gears (1), (2) and (3) are in alignment. If the timing marks are not aligned, refer to Disassembly and Assembly Manual, "Gear Group (Front) - Remove and Install".

REFERENCE ONLY

# Air Inlet and Exhaust System

i02553540

## 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 engine air cleaner element with a clean engine air cleaner 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 engine air cleaner element and/or the seal for the engine air cleaner element.

**Note:** There are two types of open circuit crankcase breather that may be installed on the engine, a filtered breather and an unfiltered breather.

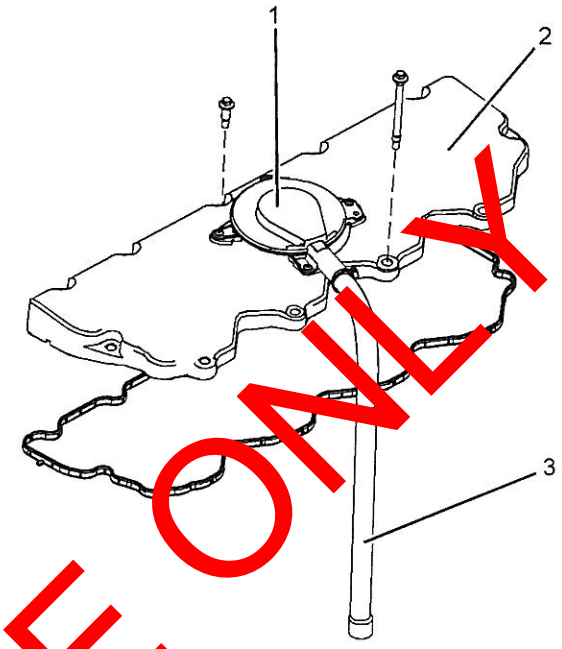



Illustration 48 g01274757
Typical unfiltered breather (open circuit)

REFERENCE ONLY

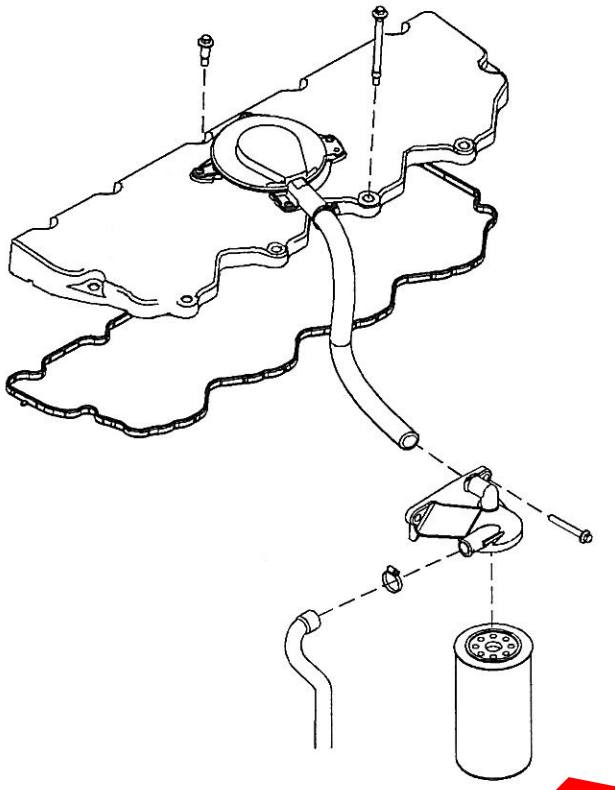


Illustration 49
Typical filtered breather (Open circuit)

4. If there is excessive crankcase pressure, check the breather for blockages, and debris. Refer to Disassembly and Assembly Manual, "Valve Mechanism Cover - Remove and Install (Filtered Breather) or Remove and Install (Unfiltered Breather)" for the correct procedure. Inspect the inside of the valve mechanism cover for debris. Ensure that all of the debris is removed.

**Note:** The breather (1) that is within the valve mechanism cover (2) is not a serviceable item. The breather should only be renewed if the breather is damaged.

5. Remove the breather tube (3) from the breather (1) and check for obstructions. If the breather tube is obstructed, use low pressure air to remove the obstruction. If a filtered breather assembly is installed, check that the filter element is free from oil. Ensure that the filter has been renewed at the correct service interval. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule - 500 hours Service" for the correct procedure. If a blockage is inside the cover (2), remove the cover. Refer to Disassembly and Assembly Manual, "Crankcase Breather - Remove and Install" for the correct procedure. Check the breather for cracks or external damage. If the breather is faulty, renew the breather.

**Note:** The new filter must be filled with oil when the canister is renewed.

i02554967

## Turbocharger - Inspect

**WARNING**

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

Dispose of all fluids according to local regulations and mandates.

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

REFERENCE ONLY

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

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

## Inspection of the Compressor and the Compressor Housing

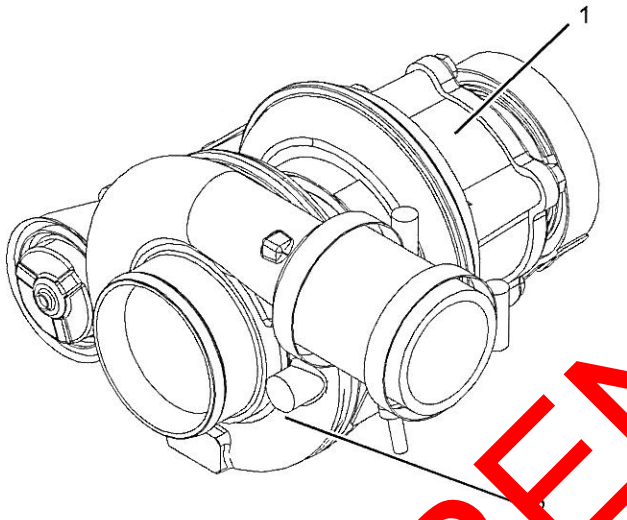



Illustration 50

Typical example of a turbocharger

(1) Turbine housing
(2) Compressor housing

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

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

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

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

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

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

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

## Inspection of the Turbine Wheel and the Turbine Housing

Remove the air piping from the turbine housing.

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

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

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

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

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

REFERENCE ONLY

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

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

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

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

## Inspection of the Wastegate

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

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

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

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

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

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

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

## Check the Wastegate for Proper Operation

Table 4

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

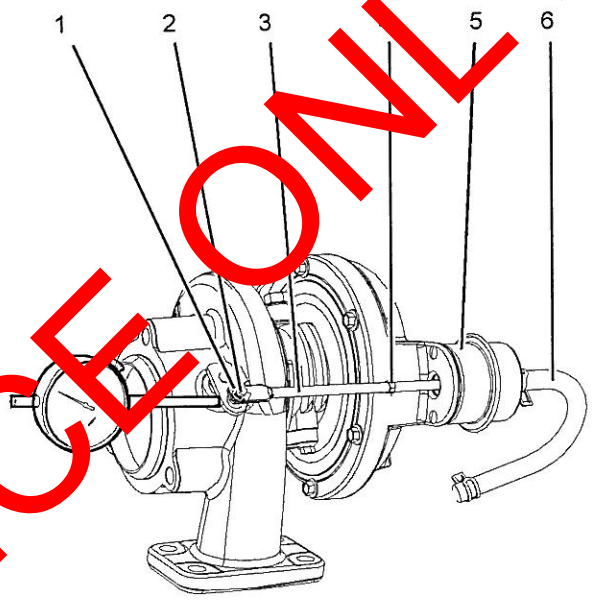



Illustration 51 g01289484
Typical example

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

**1.** Disconnect the pipe for the boost sensor (6) at the wastegate actuator (5). Connect an air supply to the wastegate actuator that can be adjusted accurately.

**2.** Install Tooling (A) to the turbocharger so that the end of the actuator rod (1) is in contact with Tooling (A). This will measure axial movement of the actuator rod (4).

REFERENCE ONLY

3. Slowly apply air pressure to the wastegate so that the actuator rod (4) moves 1.0 mm (0.039 inch). The air pressure should be within 107 to 117 kPa (15.5 to 17.0 psi). Ensure that the dial indicator returns to zero when the air pressure is released. Repeat the test several times. This will ensure that an accurate reading is obtained.

4. If the operation of the wastegate is not correct, the actuator rod (4) can be adjusted.

5. Remove Tooling (A) from the turbocharger.

6. When the air pressure is applied, loosen the nut on the actuator. Remove the circlip (1). Remove the pin (2) from the actuator rod (4).

7. When the air pressure is too low, adjust the end of the actuator rod (4) in order to reduce the length of the actuator rod (4). If the air pressure is too high, adjust the end of the actuator rod (4) in order to increase the length of the actuator rod (4).

8. Install the pin (2) to the actuator rod (4). Install the circlip (1) to the actuator rod (4). Tighten the nut to a torque of 5 N·m (44 lb in).

9. Repeat steps 2 to 3 in order to repeat the pressure test.

10. If the air pressure is correct, remove the air supply. Remove Tooling (A). Install the pipe for the boost sensor (7).

i06256221

## 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 glow plugs are removed.
- The fuel supply is disconnected.

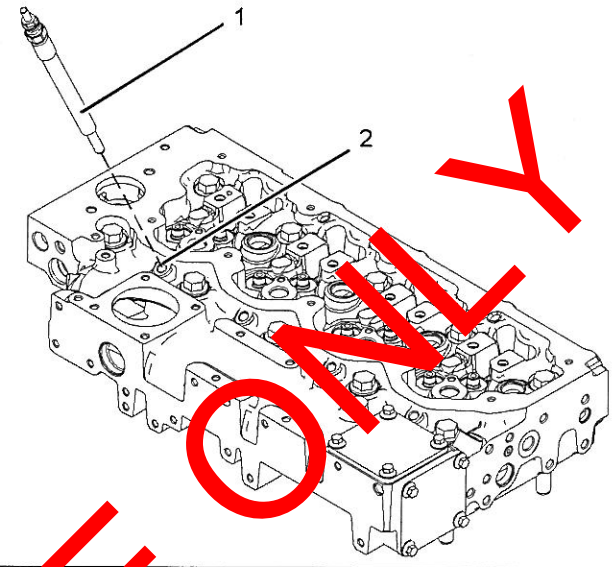



Illustration 52 g01282556
Typical example

1. Remove the glow plug (1) from the hole in the cylinder head (2). Refer to Disassembly and Assembly Manual, "Glowplugs - Remove and Install" for the correct procedure for the removal of the glow plug (1).

2. Install a suitable gauge for measuring the cylinder compression in the hole for a glow plug.

3. Operate the starting motor in order to turn the engine. Record the maximum pressure which is indicated on the compression gauge.

4. Repeat steps 1 to 3 for all cylinders.

REFERENCE ONLY

i02556539

# Engine Valve Lash - Inspect/Adjust

Table 5

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610298 | Angled feeler gauge | 1 |

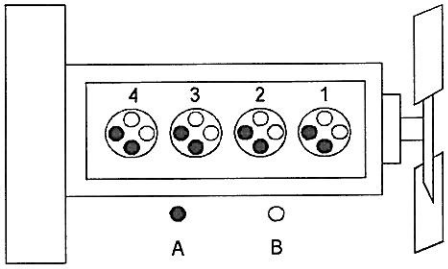



Illustration 53
Cylinder and valve location
(A) Exhaust valve
(B) Inlet valve

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 injection nozzles that operate incorrectly
- Excessive dirt and oil are present on the filters for the inlet air.
- The load capacity of the engine is frequently exceeded.

Too much valve lash can cause broken valve stems, springs, and spring retainers. This will produce emissions in excess of the correct specification.

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

## Valve Lash Check

An adjustment is NOT NECESSARY if the measurement of the valve lash is in the acceptable range. Check the valve lash while the engine is stopped. The temperature of the engine does not change the valve lash setting.

If the measurement is not within the acceptable clearance, adjustment is necessary. Refer to "Valve Lash Adjustment".

## Valve Lash Adjustment

Table 6

| | Inlet Valves | Exhaust Valves |
|---|---|---|
| Valve Lash | 0.35 ± 0.05 mm (0.0138 ± 0.0020 inch) | 0.35 ± 0.05 mm (0.0138 ± 0.0020 inch) |
| Firing Order | 1-3-4-2(2) | |

(2) The No. 1 Cylinder is at the front of the engine.

**Note:** When the engine is new, the valve lash should be checked and reset after a service interval of 1000 hours.

**Note:** For example, if the pushrods in a remanufactured engine have been replaced with new parts then Adjust the valve lash to 0.25 ± 0.05 mm (0.0098 ± 0.0020 inch) for the initial rebuild. The tappets should be reset to 0.35 ± 0.05 mm (0.0138 ± 0.0020 inch) at the normal service intervals thereafter.

REFERENCE ONLY

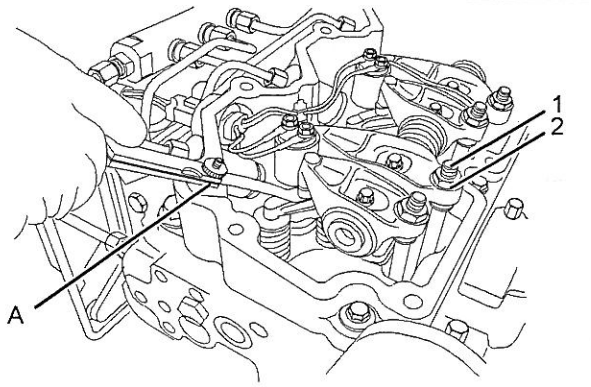



Illustration 54 g01193809

Setting the valve lash

(A) Angled feeler gauge
(1) Adjustment screw
(2) Locking screw

**⚠ WARNING**

**Accidental engine starting can cause injury or death to personnel.**

**To prevent accidental engine starting, turn the ignition switch to the OFF position and place a do not operate tag at the ignition switch location.**

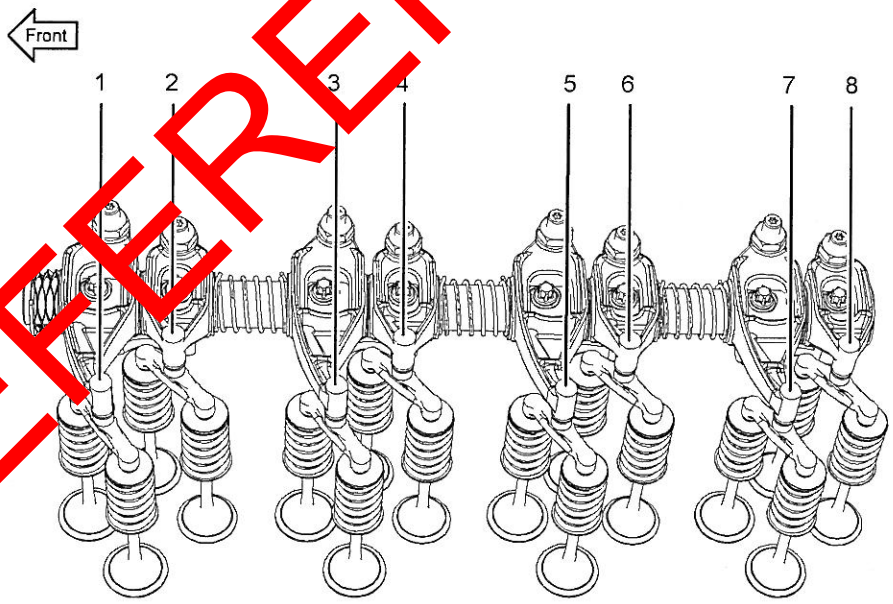



Illustration 55 g01278980

REFERENCE ONLY

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly , "Valve Mechanism Cover - Remove and Install" for the removal procedure.

**Note:** When the valve mechanism cover is removed or installed, the electrical harness must be checked. Do not trap the injector harness when the valve mechanism cover is installed. Do not allow the harness to be in contact with the valve mechanism cover. Renew the harness, if the harness is damaged.

Table 7

| Piston in top center position and inlet and exhaust valves in valve overlap | Set valve lash for the following : | |
|---|---|---|
| | Exhaust valves (Cylinder number) | Inlet valves (Cylinder number) |
| 4 | 1 (1) | 2 (1) |
| 2 | 5 (3) | 6 (3) |
| 1 | 7 (4) | 8 (4) |
| 3 | 3 (2) | 4 (2) |

2. See illustration 55. Rotate the crankshaft clockwise until the piston of No. 1 cylinder is at the top center position on the compression stroke. The exhaust valves and the inlet valves of No. 4 cylinder are in valve overlap. Measure the valve lash on the pair of exhaust valves (3) and the pair of inlet valves (2) of No. 1 cylinder. If necessary, adjust the valve lash to the setting in Table 6.

   a. See illustration 55. Loosen the valve adjustment locknut that is on the adjustment screw (1).

   b. Place Tooling (A) between the rocker arm and the valve. Turn the adjustment screw (1) while the valve adjustment screw locknut (2) is prevented from turning. Adjust the valve lash until the correct specification is achieved.

   c. After each adjustment, tighten the valve adjustment screw locknut to 21.5 to 32.5 N·m (15.9 to 24 lb ft) while the valve adjustment screw (1) is held in position.

3. Rotate the crankshaft by 180 degrees in the direction of engine rotation, until the piston of No. 3 cylinder is at the top center position on the compression stroke. The exhaust valves and the inlet valves of No. 2 cylinder are in valve overlap. Adjust the valve lash for both the inlet valves (5) and the exhaust valves (6) of No. 3 cylinder. Complete the sequence of checks according to Table7 until all the cylinders have been checked or adjusted. Reinstall the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install" for the installation procedure.

i02556543

## Valve Depth - Inspect

Table 8

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 18256[illegible]7 | Dial gauge | 1 |
| B | 2[illegible]5496 | Dial gauge holder | 1 |

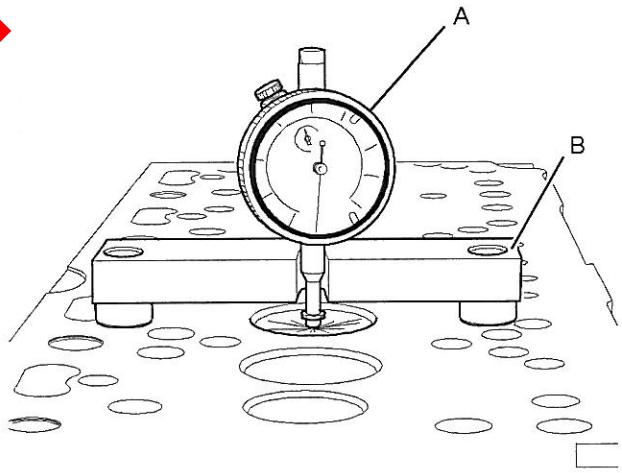



Illustration 56 g01201916

Typical example

1. Ensure that the face of the valves are clean. Ensure that the bottom face of the cylinder head is clean. Ensure that the cylinder head is not distorted. Refer to Testing and Adjusting, "Cylinder Head - Inspect" for the procedure to measure flatness of the cylinder head.

REFERENCE ONLY

2. Use the Tooling (A) to check the depths of the inlet valves and the exhaust valves below the face of the cylinder head. Use Tooling (B) to zero Tooling (A).

3. Measure the depth of the inlet valve and the exhaust valve below the cylinder head face. The minimum and maximum limits for a new engine follow:

   Inlet valves

   Minimum ..... 0.905 mm (0.0356 inch)
   Maximum ..... 1.163 mm (0.0458 inch)

   Exhaust valves

   Minimum ..... 0.876 mm (0.0345 inch)
   Maximum ..... 1.131 mm (0.0445 inch)

4. Service wear occurs on an engine which has been in operation. If the valve depth below the cylinder head face on a used engine exceeds the specification for service wear, the following components must be replaced.

   - Valves
   - Valve inserts

   Wear limit for inlet valves .. 1.41 mm (0.0555 inch)

   Wear limit for exhaust valves ..... 1.88 mm (0.0743 inch)

5. Check each valve for cracks. Check the stems of the valves for wear. Ensure that the valves are the correct fit in the valve guides. Refer to Testing and Adjusting, "Valve Guide - Inspect" for the procedure to inspect the valve guides.

6. Check the load on the valve springs. Refer to Specifications, "Cylinder Head Valves" for the correct lengths and specifications for the valve springs.

i02400035

## Valve Guide - Inspect

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

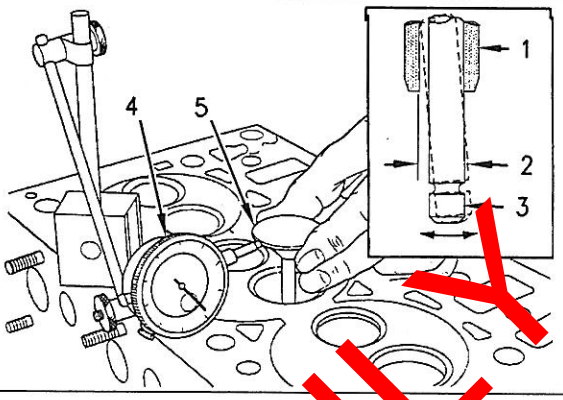



Illustration 57 g00314806

Measure the radial movement of the valve in the valve guide.

(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 dial indicator with a magnetic base on the face of the cylinder head.

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

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

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

   The maximum clearance for the inlet valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. ..... 0.08 mm (0.0031 inch)

   The maximum clearance for the exhaust valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. ..... 0.09 mm (0.0035 inch)

REFERENCE ONLY

The original valve guides are bored into the cylinder head. When new valve guides(1) are installed, new valves and new valve seat inserts must be installed. The cylinder head must be rebored in order to install the new valve guide. 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 Disassembly and Assembly, “Inlet and Exhaust Valve Guides - Remove and install” for the replacement of the valve guides.

REFERENCE ONLY

# Lubrication System

i02557748

## Engine Oil Pressure - Test

### Low Oil Pressure

The following conditions will cause low oil pressure.

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

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

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

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

### High Oil Pressure

High oil pressure can be caused by the following conditions.

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

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.



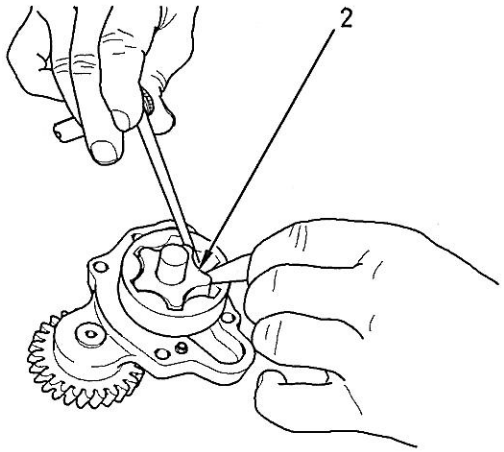

Illustration 58 g00985779

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).

REFERENCE ONLY



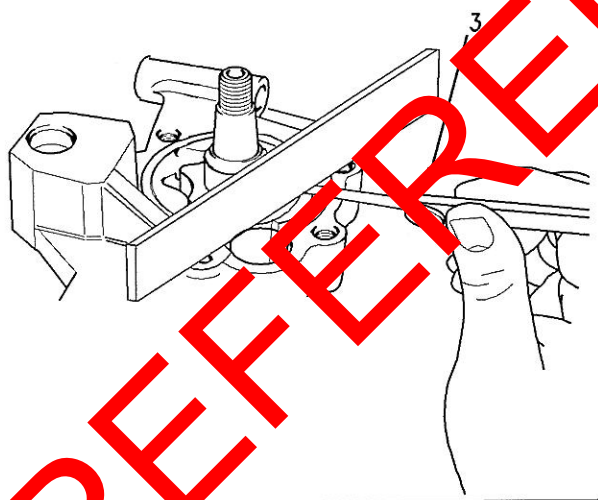

g00985780

Illustration 59

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).




g00989217

Illustration 60

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.

i02414692

## 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:

- Failed valve stem seals
- 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

REFERENCE ONLY

- 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.

REFERENCE ONLY

# Cooling System

i02419296

## Cooling System - Check

### Engine And Cooling System Heat Problems

1. The following conditions indicate that a heat problem exists.

   a. Hot coolant is released through the pressure cap during the normal operation of the engine. Hot coolant can also be released when the engine is stopped.

   b. Hot coolant is released from the coolant system but not through the pressure cap during normal operation of the engine. Hot coolant can also be released when the engine is stopped.

   c. Coolant must be added frequently to the cooling system. The coolant is not released through the pressure cap or through an outside leak.

2. If any of the conditions in Step 1 exist, perform the following procedures:

   a. Run the engine at medium idle, which is approximately 1200 rpm, for three minutes after the high idle shuts off. Running the engine at medium idle will allow the engine to cool before the engine is stopped.

   b. Inspect the poly v-belt for wear or for damage. If necessary, replace the poly v-belt. Refer to Disassembly and Assembly Manual, "Alternator Belt - Remove and Install" for the correct procedure.

3. Refer to "Visual Inspection Of The Cooling System" in order to determine if a leak exists in the cooling system.

   a. Refer to "Testing The Radiator And Cooling System For Leaks" procedures.

4. If the coolant does not flow through the radiator and through other components of the cooling system, perform the following procedures.

   a. Perform the "Testing The Water Temperature Regulator " procedures.

   b. Clean the radiator and other components with hot water or steam at low pressure. Detergent in the water may also be used. Compressed air may be used to remove materials from the cooling system. Identify the cause of the restriction before you choose the method for cleaning.

   c. Straighten any fins of the radiator if the fins are bent.

5. Check the high idle of the engine. The engine may overheat if the high idle rpm is set too high.

i01889427

## Cooling System - Inspect

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

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

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

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

### Visual Inspection Of The Cooling System

1. Check the coolant level in the cooling system.
2. Look for leaks in the system.
3. Inspect the radiator for bent fins and other restriction to the flow of air through the radiator.
4. Inspect the drive belt for the fan.
5. Inspect the blades of the fan for damage.
6. Look for air or combustion gas in the cooling system.
7. Inspect the radiator cap for damage. The sealing surface must be clean.

REFERENCE ONLY

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 61. 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.

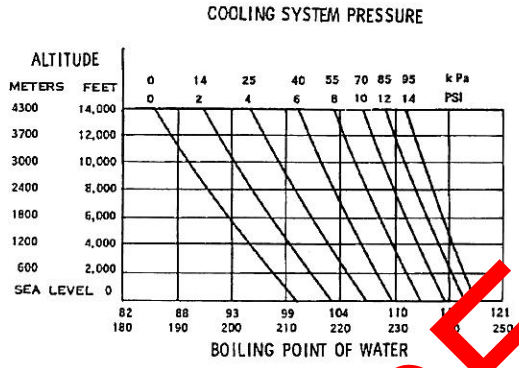



Illustration 61 g00[illegible]266

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.

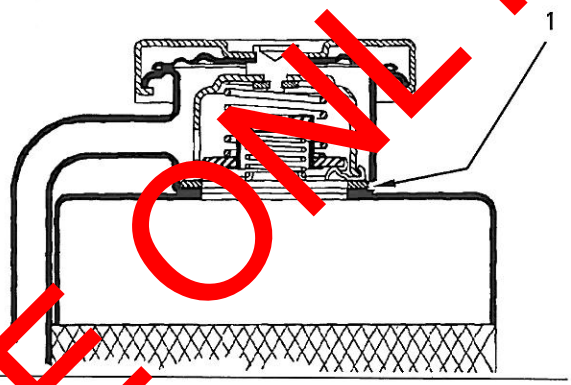



Illustration [illegible] g00296067

Typical schematic of filler cap

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

**WARNING**

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

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

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

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

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

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

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

   - Filler cap

REFERENCE ONLY

- 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.

i02558841

## 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.**

There is only one type of engine oil cooler that can be installed on this engine.

REFERENCE ONLY

## Mounted Filter

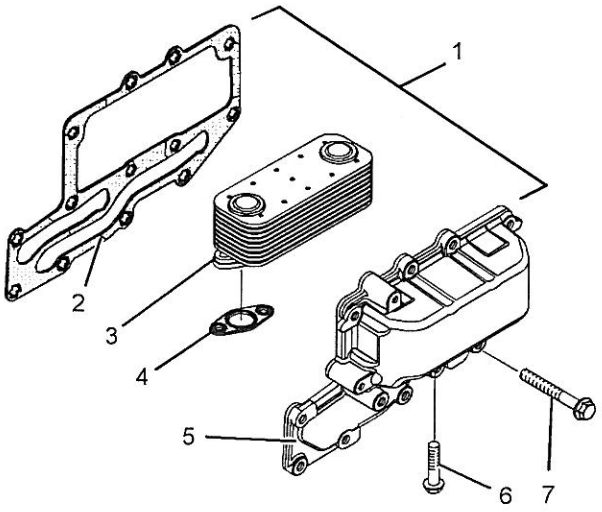



Illustration 63 g01254472

Typical example

(1) Oil cooler
(2) Joint
(3) Cooler matrix
(4) Joints
(5) Housing
(6) Four setscrews
(7) Setscrews (different lengths)

Perform the following procedure in order to inspect the engine oil cooler:

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 oil cooler (1) 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 oil cooler (1) for cracks and dents. Replace the oil cooler (1) if cracks or dents exist. Ensure that no restrictions for the flow of lubricating oil exist in the oil cooler (1).

   Dry the oil cooler (1) with low pressure air. Flush the inside of the oil cooler (1) 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 of the engine is filled to the correct level. Operate the engine.

**Note:** Refer to the Operation And Maintenance Manual, "Refill Capacities" for additional information.

Check for oil or coolant leakage.

i02414647

## Water Temperature Regulator - Test

**WARNING**

**Personal injury can result from escaping fluid under pressure.**

**If a pressure indication is shown on the indicator, push the release valve in order to relieve pressure before removing any hose from the radiator.**

1. Remove the water temperature regulator from the engine. Refer to Disassembly and Assembly Manual, "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 in the pan of water. The water temperature regulator must be below the surface of the water. The water temperature regulator must be away from the sides and the bottom of the pan.

4. Keep the water at the correct temperature for ten minutes.

REFERENCE ONLY

5. After ten minutes, remove the water temperature regulator. 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.

i01628133

## Water Pump - Inspect

1. Inspect the water pump for leaks at vent hole. The water pump seal is lubricated by 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.

2. Refer to Disassembly and Assembly, "Water Pump - Remove " and Disassembly and Assembly, "Water Pump - Install".

3. Inspect the water pump shaft for unusual noise, excessive looseness and/or vibration of the bearings.

REFERENCE ONLY

# 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 64 g00905732

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

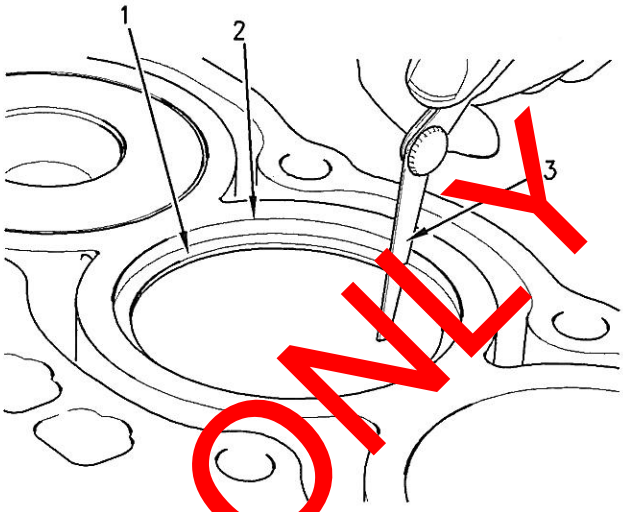



Illustration 65 g00983549

(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.

i02560333

## Connecting Rod - Inspect

These procedures determine the following characteristics of the connecting rod:

- The length of the connecting rod
- The distortion of the connecting rod
- The parallel alignment of the bores of the connecting rod

**Note:** If the crankshaft or the cylinder block are replaced, the piston height for all cylinders must be measured. The grade of length of the connecting rods may need to be changed in order to obtain the correct piston height.

REFERENCE ONLY

If the grade of length must be changed, one of the following actions must be taken:

- New connecting rod assemblies that are the correct grade of length must be installed. Refer to "Length Of The Connecting Rod".
- New piston pin bearings must be bored after installation in the original connecting rods. Refer to "Piston Pin Bearings".

**Note:** When the piston pin is installed, always install new retaining rings on each end of the piston pin. If the piston pin cannot be removed by hand, heat the piston to a temperature of 45° ± 5 °C (113° ± 9 °F) in order to aid the removal of the piston pin. Heating the piston to this temperature may also aid the installation of the piston pin.

## Length of The Connecting Rod

The connecting rod length (CRL) is the length of the connecting rod. Refer to Table 9 for each grade of length of connecting rod.

In order to ensure that the piston height above the cylinder block is correct, three grades of connecting rods "F" to "L" are used during manufacture at the factory. Replacement connecting rods are available in six grades. These grades of connecting rod are "F" to "L". The grade of length is identified by a letter or a color which is marked on the side of the connecting rod. The longest grade is marked with the letter "F". The shortest grade is marked with the letter "L". The difference in length between each grade of connecting rods is the following value: 0.046 mm (0.0018 inch)

The grade of length of a connecting rod is determined in the factory by machining an eccentric hole in a semi-finished piston pin bushing. Therefore, the grade of length is determined by the position of the center of the hole in the piston pin bearing.

If the connecting rod must be replaced, a new connecting rod assembly must be purchased and installed. Refer to Table 9 for more information.

A new piston pin bearing is installed in the new connecting rod at the factory. The bore of the piston pin bearing is reamed to the correct eccentricity.

### Piston Pin Bearings

**Note:** This procedure requires personnel with the correct training and the use of specialized equipment for machining.

If the piston pin bearing requires replacement but the original connecting rod is not replaced, the following procedures must be performed:

1. Determine the grade of length of the connecting rod. Use one of the following characteristics:
   - The mark
   - The color
   - Measuring the length
2. Ensure that the connecting rod is aligned parallel and that the connecting rod is not distorted. Refer to "Distortion Of A Connecting Rod" in this service module.
3. Remove the piston pin bearing from the connecting rod. Install a new bearing in the connecting rod. The new bearing is partially finished. The new bearing must be bored off-center to the correct diameter. This off-center position is determined by the grade of length of the connecting rod. Refer to Table 9. The correct diameter of the bore in the piston pin bearing is given in the Specifications Module "Connecting Rod".

   Surface finish of the bored hole in the piston pin bearing ..... Ra 0.8 micrometers
4. Machine the ends of the piston pin bearing to the correct length. Remove any sharp edges. Refer to the Specifications Module, "Connecting Rod".
5. If the grade of length of the connecting rod is changed, the letter that is stamped on the connecting rod must be removed. Etch a letter that is for the new grade of length on the side of the connecting rod.

**Note:** Do not stamp a new letter on the connecting rod. The force of stamping may damage the connecting rod.

Table 9 references the following information: Grade of letter of the connecting rod, the color code of the connecting rods, and the lengths of the connecting rods.

PREFERENCE ONLY

Table 9

| Length Grades for Connecting Rods | | |
|---|---|---|
| **Grade Letter** | **Color Code** | **Length Of The Connecting Rod (CRL)** |
| F | Red | 165.728 to 165.761 mm (6.5247 to 6.5260 inch) |
| G | Orange | 165.682 to 165.715 mm (6.5229 to 6.5242 inch) |
| H | White | 165.637 to 165.670 mm (6.5211 to 6.5224 inch) |
| J | Green | 165.591 to 165.624 mm (6.5193 to 6.5206 inch) |
| K | Purple | 165.545 to 165.578 mm (6.5175 to 6.5188 inch) |
| L | Blue | 165.499 to 165.532 mm (6.5157 to 6.5170 inch) |

## Measure The Length Of The Connecting Rod

If the mark or the color of the grade of length cannot be observed on the connecting rod, perform the following procedure:

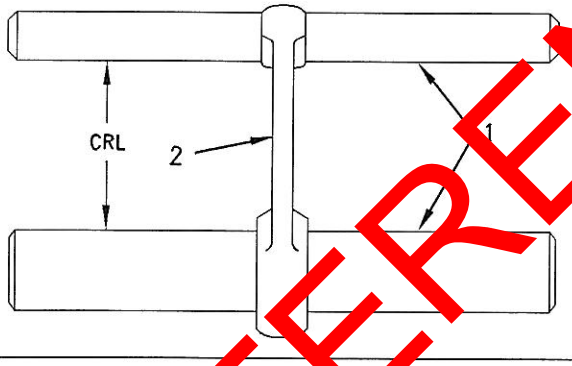



Illustration 66 g00326546

Measure the length of the connecting rod.

(1) Measuring pins
(2) Connecting rod
(CRL) Connecting Rod Length

1. Refer to Illustration 66. Use the following tools in order to measure the length of the connecting rod:
   - Appropriate gauges for measuring distance
   - Measuring pins (1)
2. Ensure that the measuring pins (1) are parallel. "CRL" is measured when the bearing for the crankshaft journal is removed and the original piston pin bearing is installed.

   Measure "CRL". Compare the "CRL" that is given in Table 9. The grade of length of the connecting rod is determined by the "CRL". Refer to Table 9 for the correct grade of length.

## Distortion of The Connecting Rod

1. Use the following tools in order to measure the distances for the connecting rod (2) which are specified in Illustration 66:
   - Appropriate gauges for measuring distance
   - Measuring pins (1)

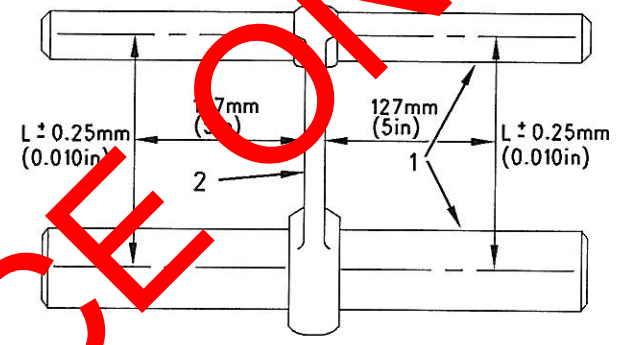



Illustration 67 g00326423

Measure the connecting rod for distortion.

(1) Measuring pins
(2) Connecting rod
(L) The length between the centers of the piston pin bearing and the crankshaft journal bearing is shown in Illustration 67.

2. Refer to illustration 67. Measure the connecting rod for distortion and parallel alignment between the bores.

   The bores for the crankshaft bearing and the bearing for the piston pin must be square and parallel with each other within the required limits. If the piston pin bearing is removed, the limit "L" is the following value: ± 0.25 mm (± 0.010 inch)

   The limits are measured at a distance of 127 mm (5.0 inch) from each side of the connecting rod.

   If the piston pin bearing is not removed, the limit "L" is the following value: ± 0.06 mm (± 0.0024 inch)

   L is equal to 219.08 ± 0.03 mm (8.625 ± 0.001 inch).
3. Inspect the piston pin bearing and the piston pin for wear.
4. Measure the clearance of the piston pin in the piston pin bearing. Refer to the Specifications Module, "Connecting Rod" for dimensions.

REFERENCE ONLY

i02399735

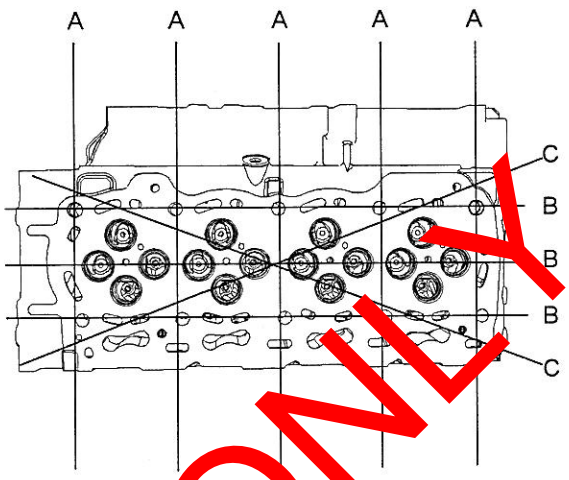
## Cylinder Block - Inspect

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 depth of the cylinder liner flange and the piston height above the cylinder block.
4. Check the front camshaft bearing for wear. Refer to Specifications, "Camshaft Bearings" for the correct specification of the camshaft bearing. 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.

i02560426

## 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 injector nozzles carefully.
7. Test the cylinder head for leaks at a pressure of 200 kPa (29 psi).




g01254471

Illustration 68

Flatness of the cylinder head (typical example)

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

8. Measure the cylinder head for flatness. Use a straight edge and a feeler gauge to check the cylinder head for flatness.
   - 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.

i01889496

## Piston Height - Inspect

Table 10

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

REFERENCE ONLY

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 69 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 holder (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".

i02243991

## Flywheel - Inspect

Table 11

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825617 | Dial Indicator Group | 1 |

### Alignment of the Flywheel Face

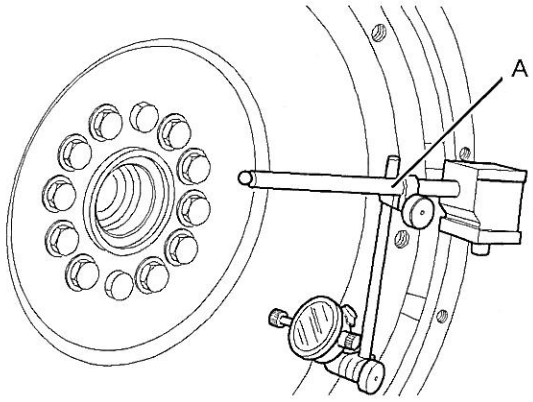



Illustration 70 g01273119

Typical example

1. Install Tooling (A) in illustration 70, as shown.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 45 degrees.

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

REFERENCE ONLY

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

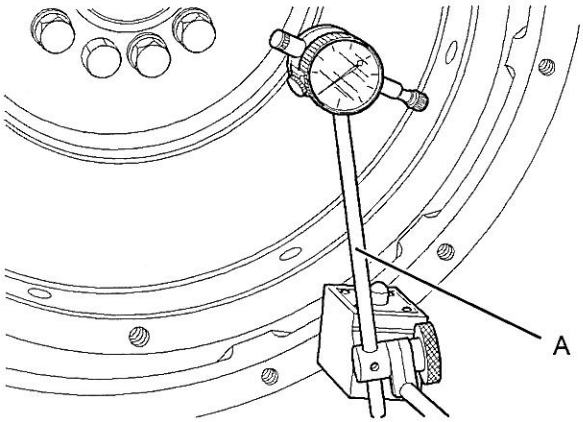



Illustration 71 g0127[illegible]20
Typical example

1. Install Tooling (A) in illustration 71, as shown.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 45 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).

i02544044

## Flywheel Housing - Inspect

Table 12

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

## Concentricity of the Flywheel Housing

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

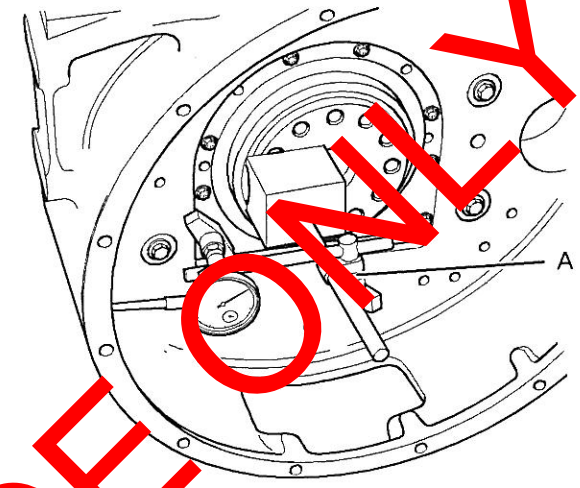



Illustration 72 g01199468
Typical example

1. Install Tooling (A). See illustration 72.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Check the concentricity at intervals of 45 degrees around the flywheel housing.
4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 13.

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

## Alignment of the Flywheel Housing

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

REFERENCE ONLY

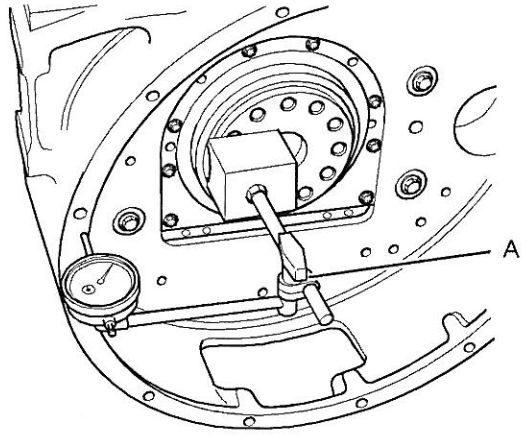



Illustration 73 g01199467

Typical example

1. Install Tooling (A). See illustration 73.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Check the alignment at intervals of 45 degrees around the flywheel housing.
4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 13.

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

Table 13

| Limits for Flywheel Housing Runout and Alignment (Total Indicator Reading) | |
|---|---|
| **Bore of the Housing Flange** | **Maximum Limit (Total Indicator Reading)** |
| 410 mm (16.14 inch) | 0.25 mm (0.010 inch) |
| 438 mm (17.24 inch) | 0.28 mm (0.011 inch) |

i02543954

# Gear Group - Inspect

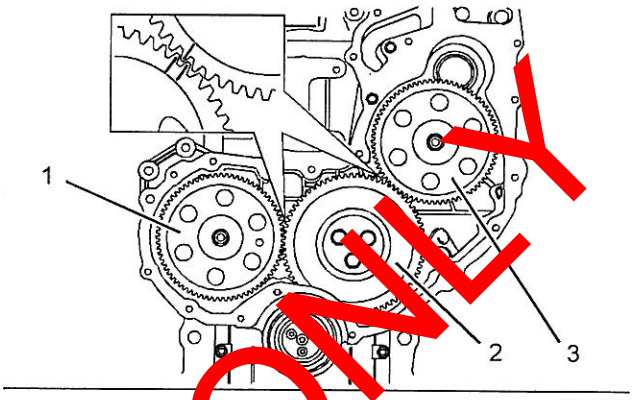



Illustration 74 g01273087

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

**Note:** If one or more of the gears need to be removed for repair, refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install" in order to properly remove the gears. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install" in order to properly install the gears.

1. Inspect the gears for wear or for damage. If the gears are worn or damaged, use new parts for replacement.
2. Measure the backlash between the camshaft gear (1) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
3. Measure the backlash between the idler gear (2) and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
4. Measure the backlash between the fuel injection pump gear (3) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.

REFERENCE ONLY

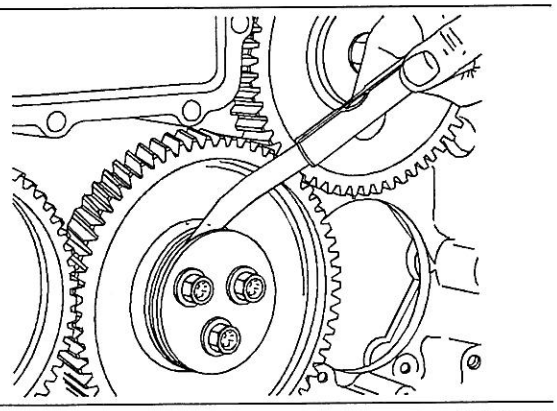


Illustration 75 g01273091

5. Measure the end play on idler gear (2). Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure. Refer to Specifications, "Gear Group (Front)" for the end play measurement.

i02545551

## Crankshaft Pulley - Check

The crankshaft pulley is installed on the front of the crankshaft. There are two types of crankshaft pulley that can be installed to the engine.

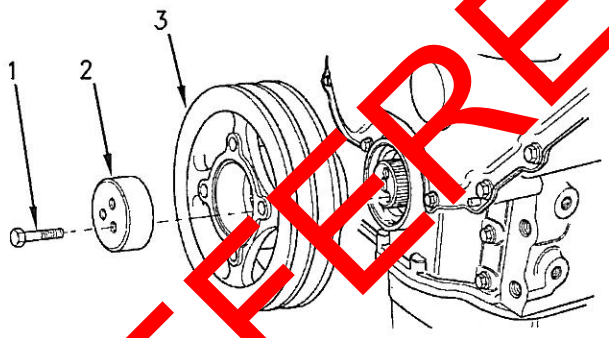



Illustration 76 g01273827

A standard pulley
(1) Bolt
(2) Thrust block
(3) Crankshaft pulley

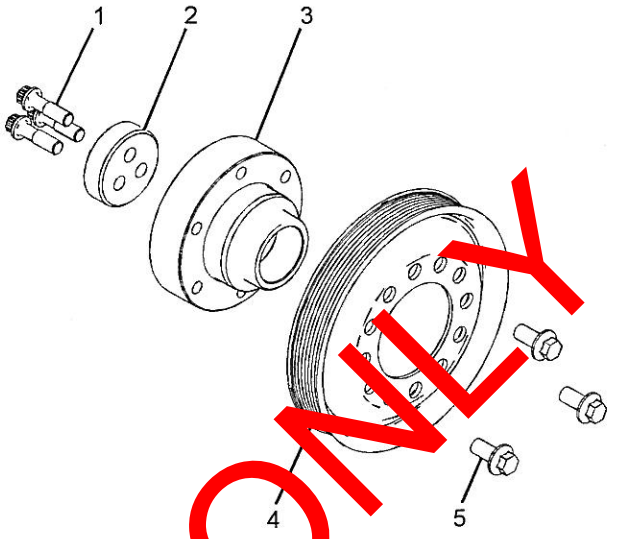



Illustration 77 g01273828

Typical example of a crankshaft pulley with poly v-belt
(1) Bolt
(2) Thrust block
(3) Crankshaft adapter
(4) Crankshaft pulley
(5) Bolt

Replace the crankshaft pulley if any of the following conditions exist:

- There is any impact damage to the outer casing.
- There is leakage of the viscous fluid from the cover plate.
- There is movement of the pulley.
- There is a large amount of gear train wear that is not caused by lack of oil.
- Analysis of the engine oil has revealed that the front main bearing is badly worn.
- The engine has had a failure because of a broken crankshaft.

Check the areas around the holes for the bolts in the crankshaft pulley for cracks or for wear and for damage.

Use the following steps in order to check the alignment and the runout of the crankshaft pulley:

1. Remove any debris from the front face of the crankshaft pulley. Remove any debris from the circumference of the crankshaft pulley.

REFERENCE ONLY

2. Mount the dial indicator on the front cover. Use the dial indicator to measure the outer face of the crankshaft pulley. Set the dial indicator to read 0.00 mm (0.00 inch).

3. Rotate the crankshaft at intervals of 45 degrees and read the dial indicator.

4. The difference between the lower measurements and the higher measurements that are read on the dial indicator at all four points must not be more than 0.18 mm (0.007 inch).

   If the reading on the dial indicator is more than 0.18 mm (0.007 inch), inspect the pulley for damage. If the pulley is damaged, use new parts for replacement.

5. Move the dial indicator so that the dial indicator will measure the circumference of the crankshaft pulley. Set the dial indicator to read 0.00 mm (0.00 inch).

6. Slowly rotate the crankshaft in order to measure the runout of the circumference of the crankshaft pulley. Use the highest reading and the lowest reading on the dial indicator. The maximum and the minimum readings on the dial indicator should not vary more than 0.12 mm (0.005 inch).

   If the reading on the dial indicator is more than 0.12 mm (0.005 inch), inspect the pulley for damage. If the pulley is damaged, use new parts for replacement.

REFERENCE ONLY

# Electrical System

i02544065

## Alternator - Test

1. Put the positive lead "+" of a suitable multimeter on the "B+" terminal of the alternator. Put the negative "-" lead on the ground terminal or on the frame of the alternator. Put a suitable ammeter around the positive output wire of the alternator.

2. Turn off all electrical accessories. Turn off the fuel to the engine. Crank the engine for 30 seconds. Wait for two minutes in order to cool the starting motor. If the electrical system appears to operate correctly, crank the engine again for 30 seconds.

**Note:** Cranking the engine for 30 seconds partially discharges the batteries in order to do a charging test. If the battery has a low charge, do not perform this step. Jump start the engine or charge the battery before the engine is started.

3. Start the engine and run the engine at full throttle.

4. Check the output current of the alternator. The initial charging current should be equal to the minimum full load current or greater than the minimum full load current. Refer to Specifications, "Alternator and Regulator" for the correct minimum full load current.

Table 14

**lt C nditi s And Possible Causes**

| Current At Start-up | The Vol ge Is Below Sp cificat ns After 10 inutes | The Voltage Is Within Specifications After 10 Minutes. | The Voltage Is Above Specifications After 10 Minutes. |
|---|---|---|---|
| **Less than the specifications** | R plce the alternator. Check the circuit of the ignition switch. | Turn on all accessories. If the voltage decreases below the specifications, replace the alternator. | - |
| **Decreases aft matching spec tions** | Replace the alternator. | The alternator and the battery match the specifications. Turn on all accessories in order to verify that the voltage stays within specifications. | Replace the alternator. |
| **The vo ge consistently exceeds specifications.** | Test the battery. Test the alternator again. | The alternator operates within the specifications. Test the battery. | Replace the alternator. Inspect the battery for damage. |

REFERENCE ONLY

5. After approximately ten minutes of operating the engine at full throttle, the output voltage of the alternator should be 14.0 ± 0.5 volts for a 12 volt system and 28.0 ± 1 volts for a 24 volt system. Refer to the Fault Conditions And Possible Causes in Table 14.

6. After ten minutes of engine operation, the charging current should decrease to approximately 10 amperes. The actual length of time for the decrease to 10 amperes depends on the following conditions:

   - The battery charge
   - The ambient temperature
   - The speed of the engine

   Refer to the Fault Conditions And Possible Causes in Table 14.

i01126605

## 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.

See Special Instruction, SEHS7633, "Battery Test Procedure" for the correct procedures to use to test the battery. This publication also contains the specifications to use when you test the battery.

i02545695

## V-Belt - Test

Table 15

**Required Tools**

| Tool | Part Number | Part Description | Qty |
|---|---|---|---|
| A | - | Belt Tension Gauge | 1 |
| | | | |

REFERENCE ONLY

Table 16

| 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.

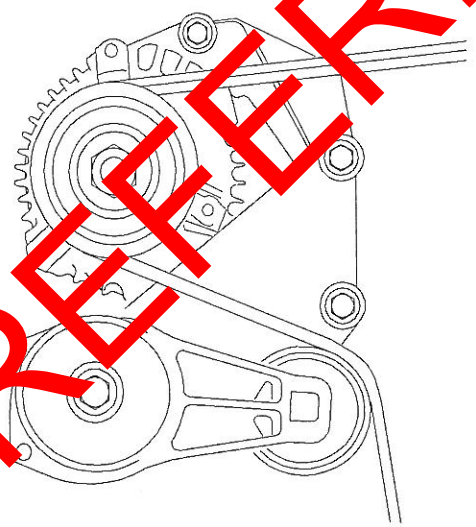
Install Tooling (A) at the center of the longest free length of belt and check the tension on both belts. Check and adjust the tension on the tightest belt. To adjust the belt tension, refer to Disassembly and Assembly, "Alternator - Install".

## Poly V-Belt

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

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

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



g01216014
Illustration 78
Typical example

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

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

i02418527

## Charging System - Test

The condition of charge in the battery at each regular inspection will show if the charging system is operating correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed. A large amount of water would be more than one ounce of water 28 ml per cell per week or per every 100 service hours. There are no adjustments on maintenance free batteries.

When it is possible, make a test of the charging unit and voltage regulator on the engine, and use wiring and components that are a permanent part of the system. Off-engine testing or bench testing will give a test of the charging unit and voltage regulator operation. This testing will give an indication of needed repair. After repairs are made, perform a test in order to prove that the units have been repaired to the original condition of operation.

## Alternator Regulator

The charging rate of the alternator should be checked when an alternator is charging the battery too much or not charging the battery enough.

Alternator output should be 28 ± 1 volt on a 24 volt system and 14 ± 0.5 volt on a 12 volt system. No adjustment can be made in order to change the rate of charge on the alternator regulators. If the rate of charge is not correct, a replacement of the regulator is necessary. For individual alternator output, refer to Specification, "Alternator and Regulator".

REFERENCE ONLY

See Special Instruction, REHS0354, "Charging System Troubleshooting" for the correct procedures to use to test the charging system. This publication also contains the specifications to use when you test the charging system.

i02399802

# Electric Starting System - Test

## General Information

All electrical starting systems have four elements:

- Keyswitch
- Start relay
- Starting motor solenoid
- Starting motor

Keyswitches 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 keyswitch.

Power which is available during cranking varies according to the temperature and condition of the batteries. Table 17 shows the voltages which are expected from a battery at the various temperature ranges.

Table 17

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

Table 18 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 18

| 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 18 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.

REFERENCE ONLY

NOTICE
If equipped with electric start, do not crank the engine for more than 30 seconds. Allow the starter to cool for two minutes before cranking again.

Never turn the disconnect switch off while the engine is running. Serious damage to the electrical system can result.

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 to or greater than the voltage in Table 17, then go to Step 2.

   b. The battery voltage is less than the voltage in Table 17.

      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 17.
- 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 or voltmeter to measure the voltage of the starting motor, when you are cranking or attempting to crank the engine.

   b. If the voltage is equal to or greater than the voltage that is given in Table 17, 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 17. 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 18.

   b. Voltage drops are equal to the voltage drops that are given in Table 18 or the voltage drops are less than the voltage drops that are given in Table 18. 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 18. 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.

REFERENCE ONLY

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.

i02404326

# 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 sou Replace the glow plug if there is no conti ty.
4. Check the continuity on each the glow lugs

## Checking The Operati n of The Glow Plug

The following test will che k the peratio of the glow plugs.

1. Disconnect the ower upply nd the bus bar.
2. Connect t e power s pply to only one glow plug.
3. Place a s ble am eter on the power supply wi .
4. C nect a s itable digital multimeter to the ter nal 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 19

| 12 Volt System | |
|---|---|
| **Amp** | **Time (sec)** |
| 16.6 | Initial |
| 12 | 5.7 |
| 9 | 11.1 |
| 7 | 20 |
| 6 | 60 |

Table 20

| 24 Volt Sys m | |
|---|---|
| **Amp** | **ime (sec)** |
| 9 | Initial |
| 7 | 3.3 |
| 6 | 5.3 |
| 3 | 60 |

6. C ck he reading on each glow plugs.
7. If there no reading on the ammeter check the elec ical connections. If the readings on the amm eter are low replace the faulty glow plug. If th e is still no reading replace the faulty glow plug.

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RENR8913
September 2006

# Specifications

## 1104D Industrial Engine

NH□(Engine)
NJ (Engine)

REFERENCE ONLY

# Important Safety Information

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

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

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

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

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

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

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

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

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

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

**⚠ WARNING**

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

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

REFERENCE ONLY

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# Specifications Section

i02503001

## Engine Design

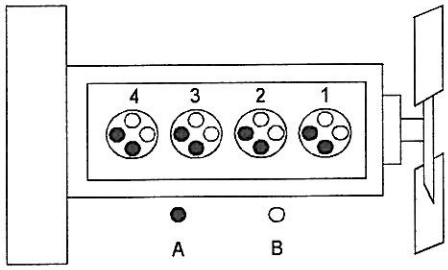



Illustration 1 g011[illegible]
Cylinder and valve location
(A) Exhaust valve
(B) Inlet valve

Bore ..... 1[illegible] mm (4.13[illegible] inch)

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

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

Cylinder arrangement ..... In-line

Type of combustion ..... Direct injection

Compression ratio

Turbocharged engines and turbocharged aftercooled engines ..... 16.2:1

Number of cylinders ..... 4

Valves per cylinder ..... 4

Valve lash

Inlet valve ..... 0.35 mm (0.0138 inch)
Exhaust valve ..... 0.35 mm (0.0138 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.

i02519279

## Fuel Injection Lines

**WARNING**

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

Refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" before adjustments and repairs are performed.

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

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

REFERENCE ONLY

## Manifold to Injector

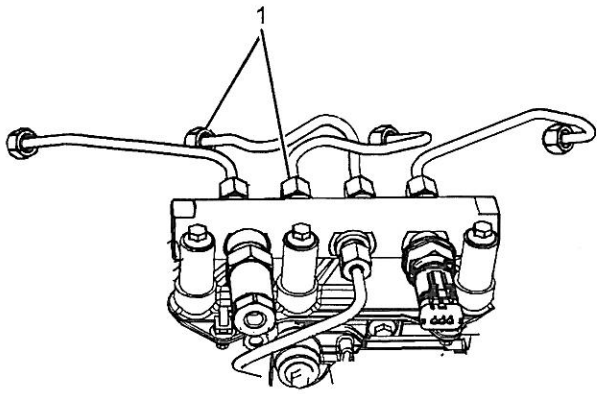



Illustration 2 g01260742
Typical example

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

## Pump to Manifold




Illustration 3 g01260743
Typical example

(1) Tighten the union nuts for the high pressure fuel line (2) to the following torque. .. 30 N·m (22 lb ft)

i02519422

## Fuel Injection Pump

**Note:** Before the 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. In order to time the fuel injection pump, refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

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

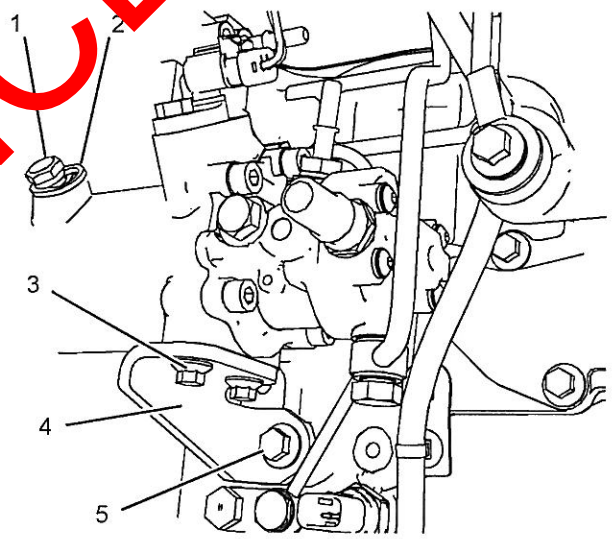



Illustration 4 g01260784
Typical example

(1) Locking screw

(2) Washer

(3) Setscrews

(4) Support bracket

(5) Setscrew

Locking the shaft

REFERENCE ONLY

Loosen locking screw (1) and move the washer (2) to the locked position. Tighten the locking screw to the following torque. .... 9 N·m (79 lb in)

Unlocking the shaft

Loosen locking screw (1) and move the washer (2) to the unlocked position. Tighten the locking screw to the following torque. ..... 9 N·m (79 lb in)

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

(5) Tighten the mounting setscrew to the following torque. ..... 44 N·m (32 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 setscrew (5) and then tighten the setscrews (3).

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

i02519280

## Fuel Injectors

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

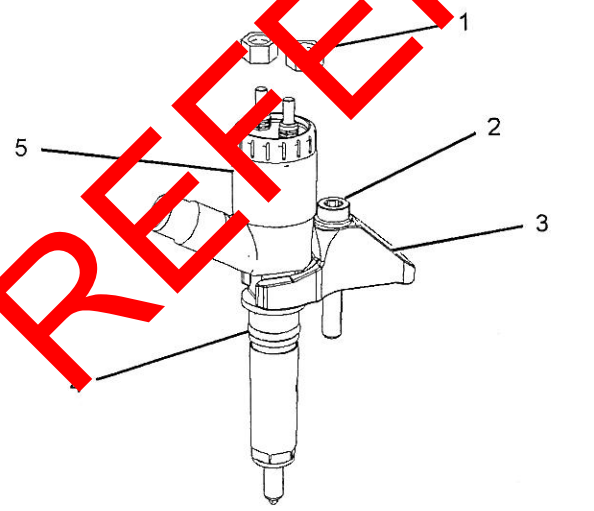



Illustration 5 g01179017

(1) Tighten the nuts to the following torque 2.4 N·m (21 lb in).

(2) Tighten the bolt in the clamp for the fuel injection nozzle to the following torque. .. 27 N·m (19 lb ft)

(3) Clamp

(4) O ring seal

(5) Trim code

**Note:** Refer to the Troubleshooting, "Injector Trim File" for more information.

i02519286

## Fuel Transfer Pump

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

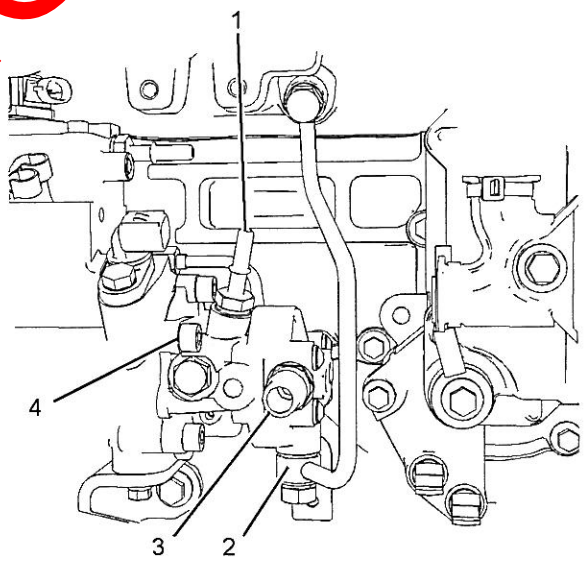



Illustration 6 g01260765

(1) Fuel outlet
(2) Fuel return from cylinder head
(3) Fuel supply
(4) Retaining setscrew

(4) Retaining setscrew ..... 30 N·m (22 lb ft)

The outlet pressure for the fuel ..... 400 to 500 kPa (58.0160 to 72.5200 psi)

REFERENCE ONLY

i02519336

## Fuel Filter Base

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

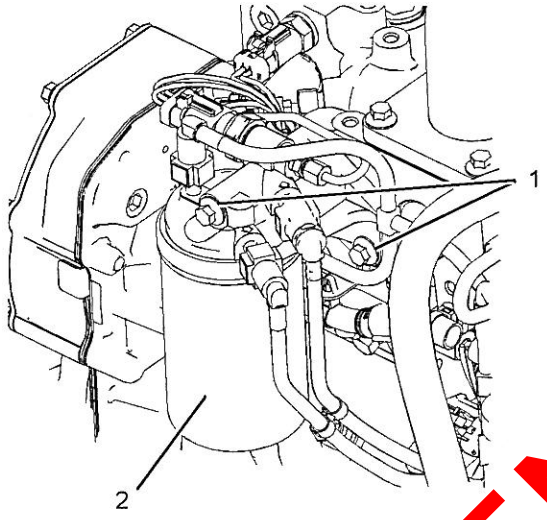



Illustration 7 g0[illegible]60768
Typical example

(1) Retaining setscrews ..... 44 N·m ([illegible] lb ft)

(2) The canister for the fuel filter

i02519432

## Fuel Priming Pump

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

## Hand Fuel Priming Pump

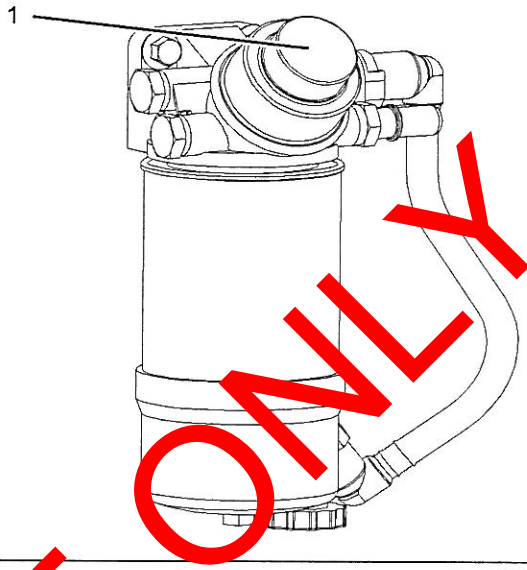



Illustration 8 g01265616
Typical example

(1) The plunger that is hand operated.

### Electric fuel Priming Pump

The electric fuel priming pump operates on 12 volts or 24 volts.

i02392326

## Lifter Group

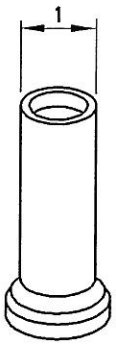



Illustration 9 g00629433

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

Bore diameter in the cylinder block ..... 19.05 to 19.082 mm (0.7500 to 0.7513 inch)

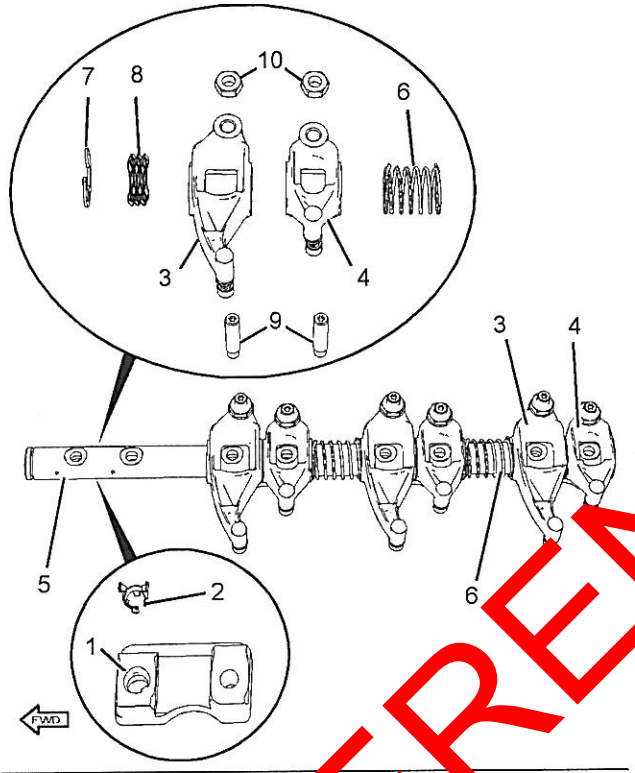
REFERENCE ONLY

Clearance

Clearance of the lifter ..... 0.038 to 0.095 mm (0.0015 to 0.0037 inch)

i02504776

## Rocker Shaft




g01253910

Illustration 10
Typical example

(1) Pedestal

(2) Locator

(3) Inlet rocker arm

Diameter of the rocker arm bore ..... 25.031 to 25.051 mm (0.9855 to 0.9863 inch)

(4) Exhaust rocker arm

Diameter of the rocker arm bore ..... 25.031 to 25.051 mm (0.9855 to 0.9863 inch)

Clearance

Maximum clearance of both the rocker arm bores ..... 0.089 mm (0.0035 inch)

The service limit for both rocker arm bores ..... 0.17 mm (0.0067 inch)

(5) Rocker shaft

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

(6) Spring

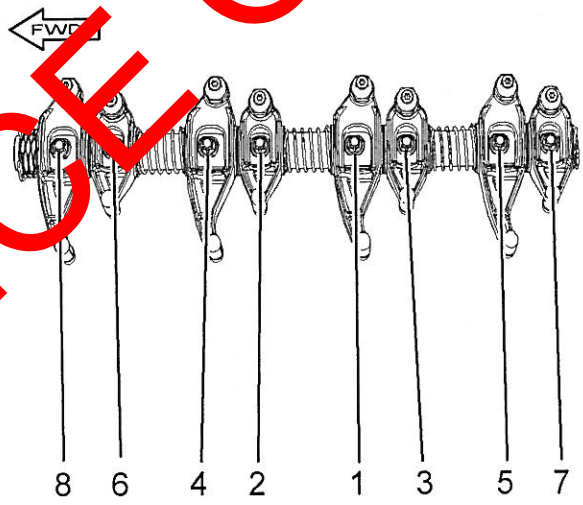
(7) Snap ring

(8) Spring

(9) Adjuster

(10) Locknut

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




g01254105

Illustration 11
Tightening sequence

Tighten the fasteners in the sequence that is in illustration 11. Tighten the fasteners to the following torque. ..... 35 N·m (25 lb ft)

REFERENCE ONLY

i02503083

# Valve Mechanism Cover

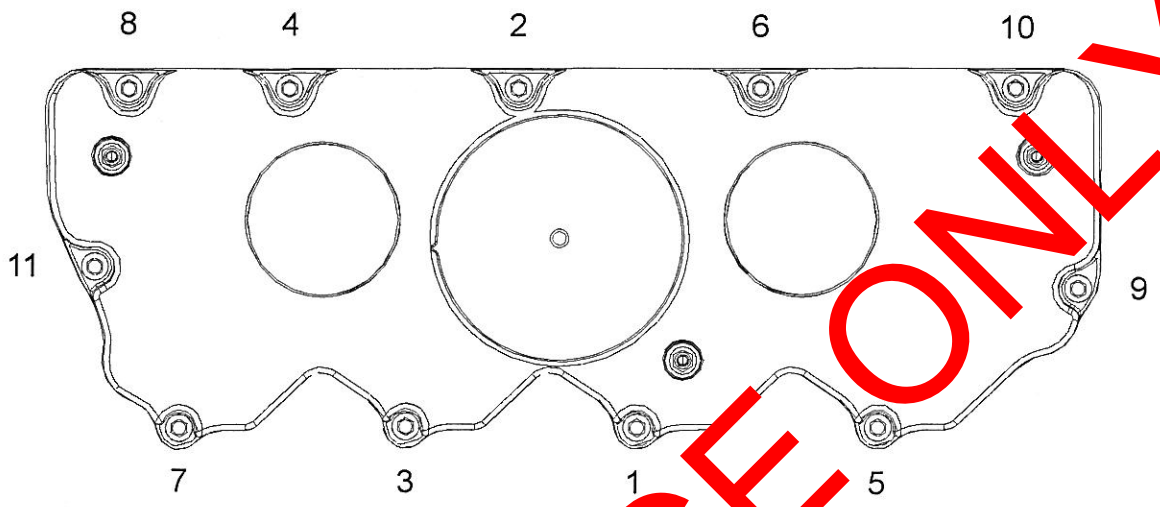



Illustration 12 g01252367

Typical example

Tighten the bolts for the valve mechanism cover in the sequence that is shown in illustration 12 to the following torque. ..... 6 N·m (53 lb in)

REFERENCE ONLY

i02503124

# Cylinder Head Valves

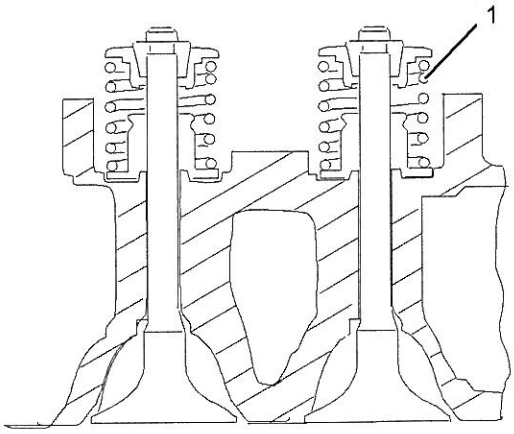



Illustration 13 g01164[illegible]

Typical example

The valve spring (1) may be used on the inlet valve or the exhaust valve. When the valve springs are replaced the valve springs must be replaced in pairs.

Table 1

| The load for the valve spring | The length of the valve spring |
|---|---|
| 161.5 to 178.5 N (36.3 to 40.1 lb) | 31.5 mm (1.2402 inch) |
| 337.9 ± 37[illegible] N (76 ± 84 l[illegible] | 21.5 mm (0.8465 inch) |

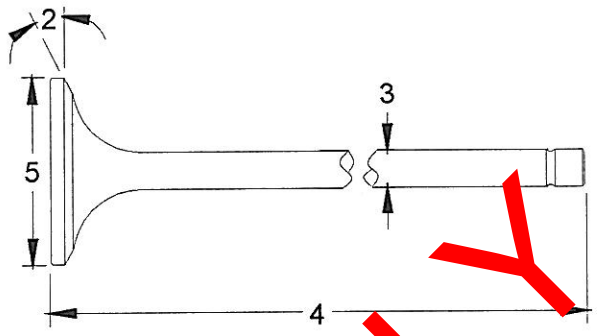



Illustration 14 g01193821

(2) Valve face angle

Inlet ..... 30 degrees
Exhaust ..... 45 degrees

(3) Valve stem diameter

Inlet .. 5.942 to 5.957 mm (0.2339 to 0.2345 inch)
Exhaust ..... 5.927 to 5.942 mm (0.2333 to 0.2339 inch)

Clearance

Maximum clearance of the inlet valve stem ..... 0.05 mm (0.0020 inch)
The service limit for the inlet valve stem ..... 0.08 mm (0.0031 inch)

Clearance

Maximum clearance of the exhaust valve stem ..... 0.065 mm (0.0026 inch)
The service limit for the inlet valve stem ..... 0.09 mm (0.0035 inch)

(4) Length of valve

Inlet valve ..... 107.925 to 108.375 mm (4.2490 to 4.2667 inch)
Exhaust valve ..... 107.703 to 108.153 mm (4.2403 to 4.2580 inch)

(5) Valve head

Diameter of inlet valve head ..... 35 mm (1.3780 inch)
Diameter of exhaust valve head ..... 33 mm (1.2992 inch)

REFERENCE ONLY

i02505671

# Cylinder Head

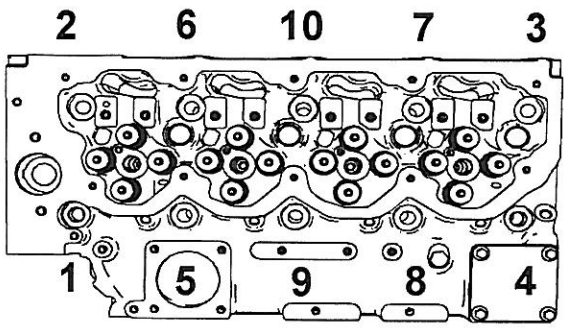



Illustration 15 g01250785
Typical example

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

Tighten the bolts in the sequence that is shown in illustration 15 to the following torque. ..... 50 N·m (37 lb ft)

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

Tighten the head bolts to the additional amount. ..... 2[illegible] degrees

Minimum thickness of cylinder head ..... 100.95 mm (3.9744 inch)

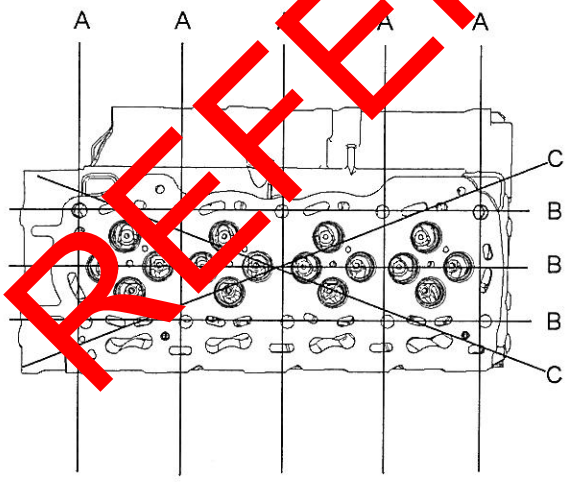



Illustration 16 g01254471
Typical example

**Note:** The maximum distortion of the bottom face of the cylinder head is given in table 2.

Table 2

| Dimension | Maximum Permissible Distortion |
|---|---|
| Width (A) | 0.03 mm (0.0018 inch) |
| Length (B) | 0.05 mm (0.001[illegible] inch) |
| Diagonal Line (C) | 0.05 mm (0.001[illegible] inch) |




Illustration 17 g01185843
Typical example

(1) Valve guide bores

Inlet and exhaust ..... 5.979 to 5.992 mm (0.2354 to 0.2359 inch)

(2) Valve depths

Inlet .. 0.905 to 1.163 mm (0.0356 to 0.0458 inch)
The service limit for the depth of the inlet valve ..... 1.41 mm (0.0555 inch)
Exhaust ..... 0.876 to 1.131 mm (0.0345 to 0.0445 inch)
The service limit for the exhaust valve depth ..... 1.38 mm (0.0543 inch)

REFERENCE ONLY

i02527109

# Turbocharger

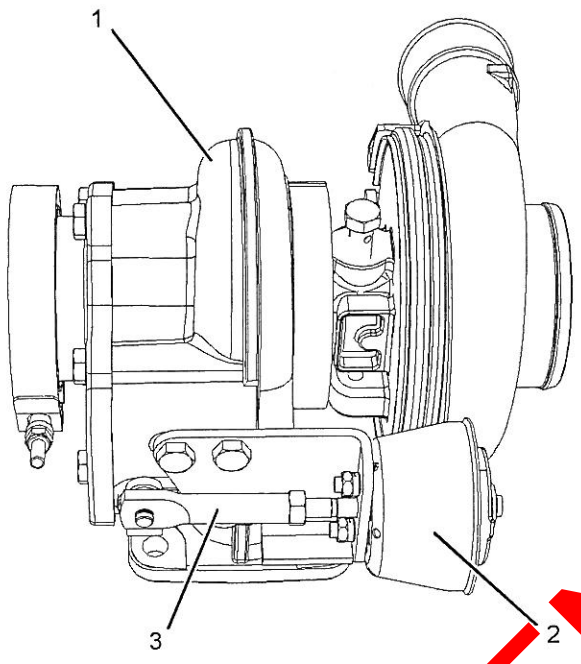



Illustration 18
Typical example

(1) Turbocharger

(2) Actuator

(3) Actuator rod

The maximum test pressure for the wastegate ..... 112 kPa (16.2445 psi)

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

Table 3

| The part number for the turbocharger | The pressure for the wastegate |
|---|---|
| 2674A804 | 112 kPa (16.2445 psi) |
| 2674A805 | 112 kPa (16.2445 psi) |
| 2674A806 | 112 kPa (16.2445 psi) |
| 2674A607 | 112 kPa (16.2445 psi) |
| 2674A608 | 112 kPa (16.2445 psi) |
| 2674A609 | 100 kPa (14.5040 psi) |
| 2674A611 | 100 kPa (14.5040 psi) |
| 2674A612 | 100 kPa (14.5040 psi) |

i02504751

# Exhaust Manifold

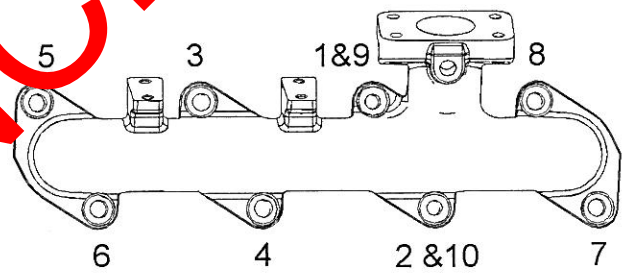



Illustration 19
g01253896
Typical example

Tighten the exhaust manifold bolts in the sequence that is shown in illustration 19 to the following torque. ..... 40 N·m (30 lb ft)

REFERENCE ONLY

i02526614

# Camshaft

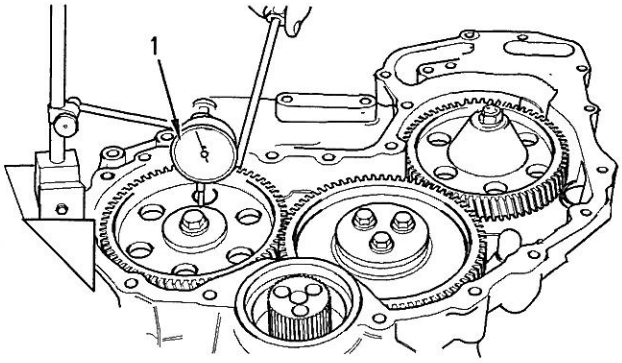



Illustration 20 g00987750

Checking the end play of the camshaft

(1) End play of a camshaft ..... 0.126 to 0.558 mm (0.0050 to 0.0220 inch)

Maximum permissible end play of a worn camshaft ..... 0.62 mm (0.0244 inch)

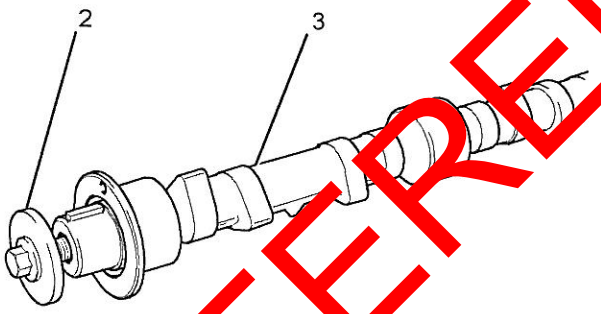



Illustration 21 g01195129

Typical exam[illegible]e

(2) Bo[illegible]

Tight[illegible] bolt to the following torque. ... 95 N·m (70 lb ft)

(3) The diameters of the camshaft journals are given in the following tables.

Table 4

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

Maximum wear on the camshaft journals ... 0.[illegible] mm (0.0021 inch)

Check the camshaft lobes for visible damage. If a new camshaft is installed you must install new lifters.

i02505262

# Camshaft Bearings

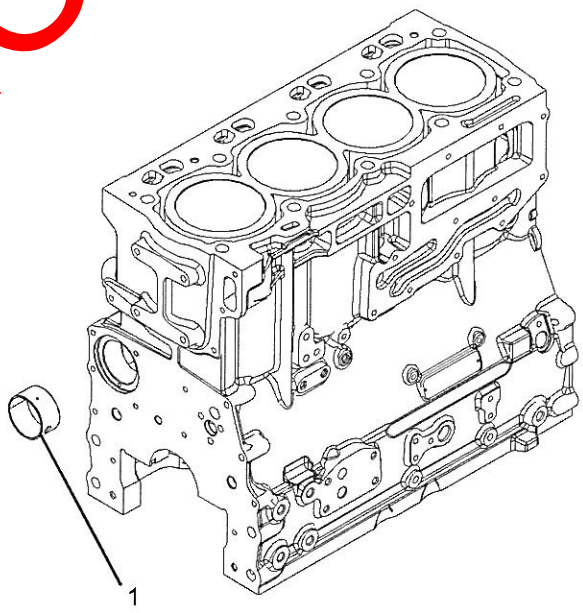



Illustration 22 g01254209

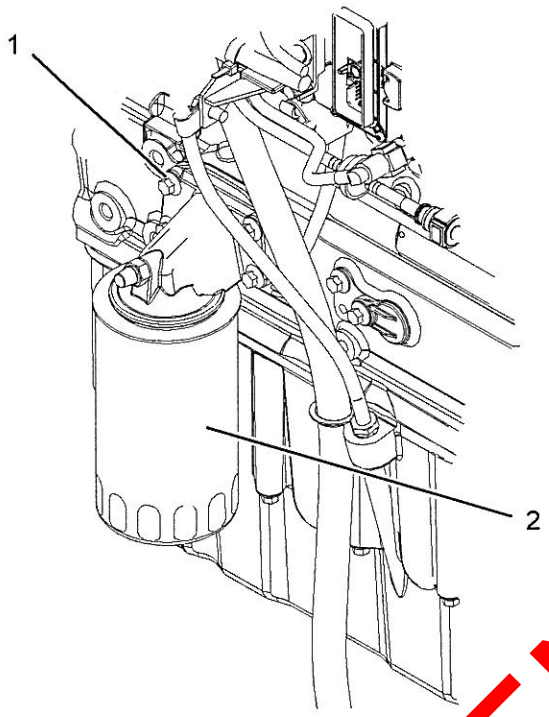
Typical example

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

REFERENCE ONLY

i02505073

# Engine Oil Filter Base




g01254114

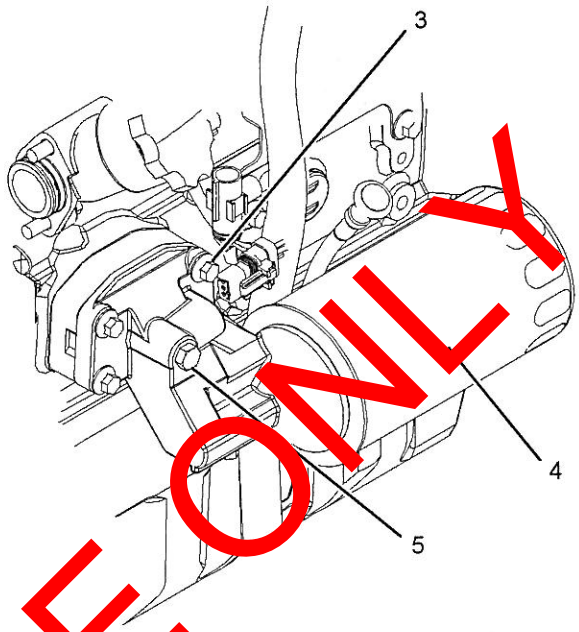
Illustration 23
Typical example

(1) Setscrew

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

(2) Engine oil filter

Tighten the engine oil filter to the following torque ..... 12 N·m (8 lb ft)




g01254115

Illustration 24
Typical example

(3) Setscrew

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

(4) Engine oil filter

Tighten the engine oil filter to the following torque. ..... 12 N·m (8 lb ft)

(5) Plug

Tighten the plug to the following torque. .. 12 N·m (8 lb ft)

REFERENCE ONLY

i02505212

# Engine Oil Cooler

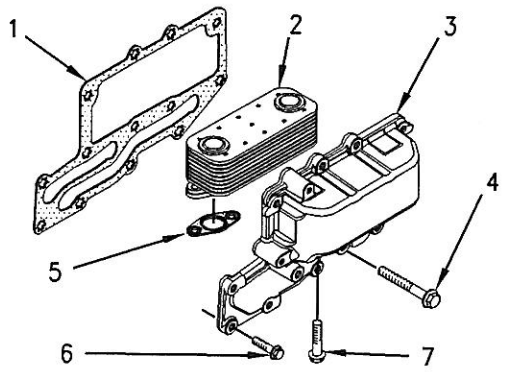



Illustration 25 g00952614

Typical example

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

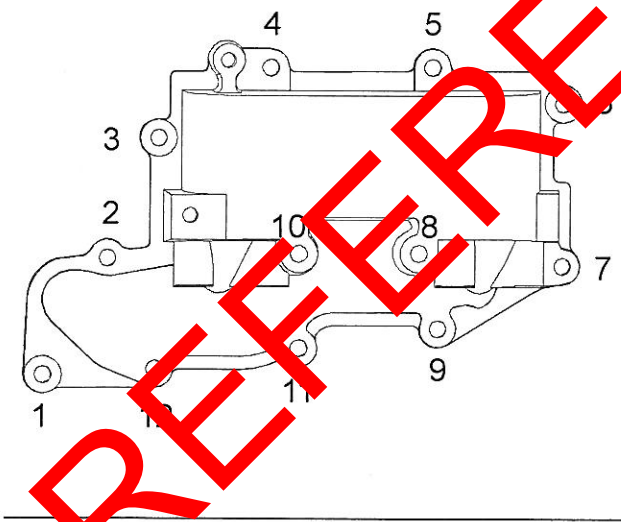



Illustration 26 g01254185

Setscrews

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

Setscrews

Tighten the setscrews (4) and (6) in the sequence that is in illustration 26 to the following torque. ..... 22 N·m (16 lb ft)

i02505677

# Engine Oil Pump

## Engines with Balancer Group

Type ..... Gear-driven [illegible]ial rotor

Number of lobes

Inner rotor ..... 6
Outer rotor ..... 7

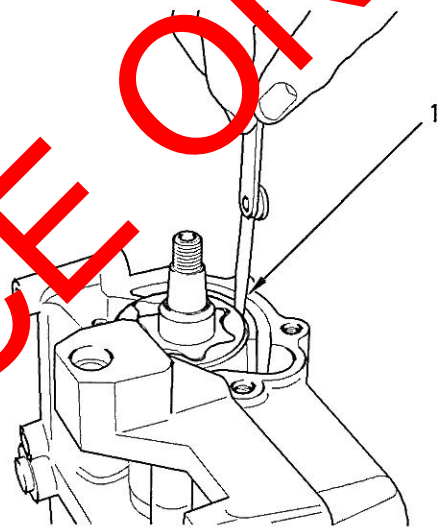



Illustration 27 g00989248

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)

REFERENCE ONLY

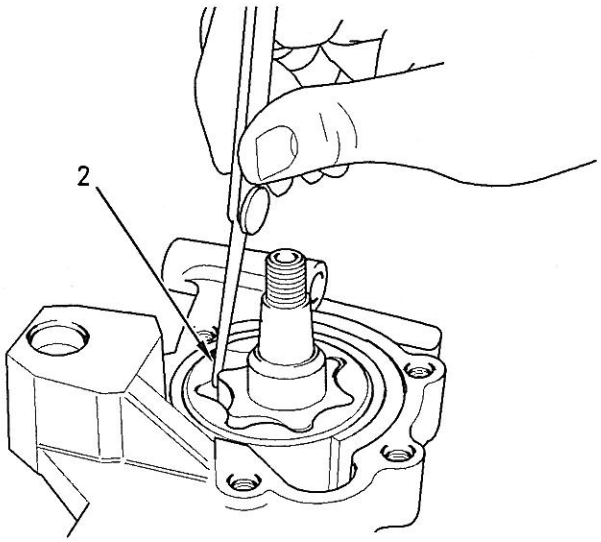



Illustration 28 g00989236
Inner rotor

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




Illustration 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)

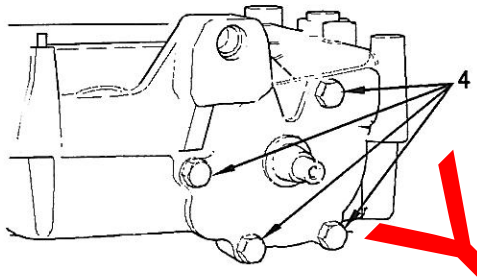



Illustration 30 g00938724
The end cover

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

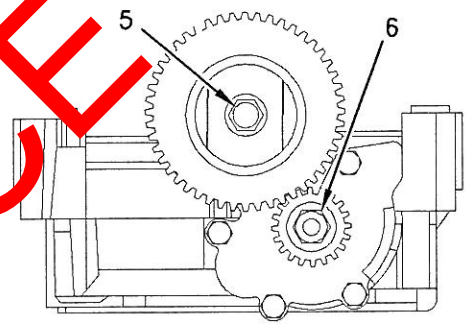



Illustration 31 g00989519
Idler gear and pump gear

**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 Systems Operation, Testing and Adjusting Manual, "Finding Top Center Position for No. 1 Piston". Install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". Install the gear for the oil pump and tighten the nut (6).

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

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

## Engines without Balancer Group

Type ..... Gear-driven differential rotor

REFERENCE ONLY

Number of lobes

Inner rotor ..... 5
Outer rotor ..... 6

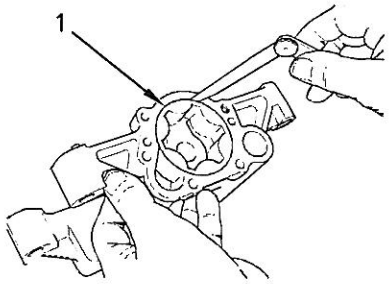



Illustration 32 g00938064
The oil pump

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

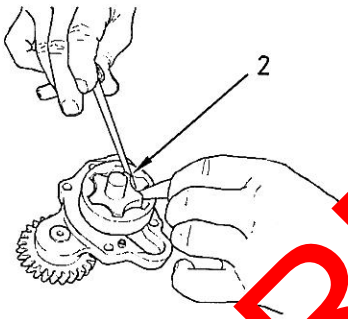



Illustration 33 g00938061
Checking the clearance

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

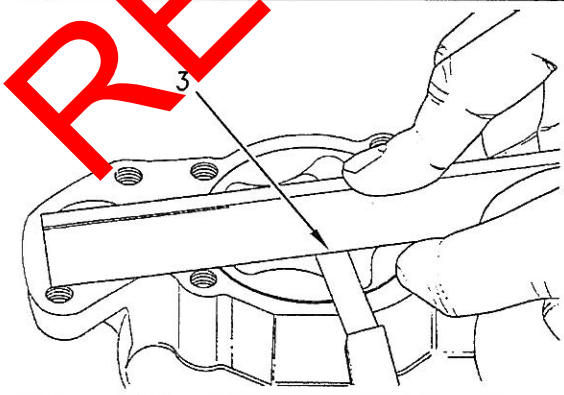



Illustration 34 g00938799
Checking the end play

(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)

i0[illegible]58104

## 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)

i02506230

## Engine Oil Pan

Table 5

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

REFERENCE ONLY

## Front sealant

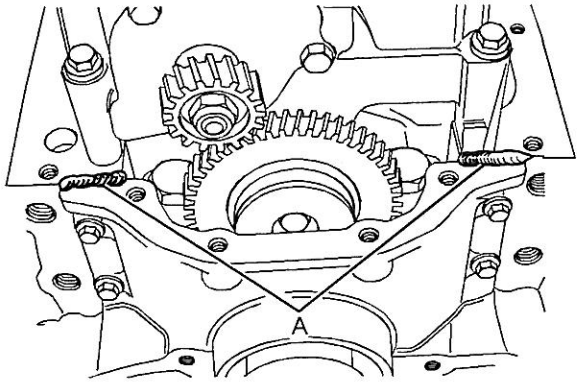



Illustration 35 g01254690
Applying sealant

Apply Tooling (A) 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 35.

## Rear sealant

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

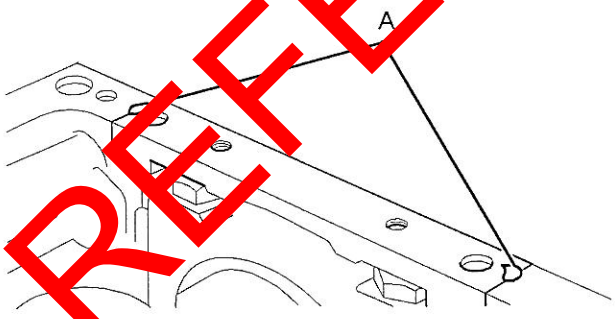



Illustration 36 g01254887
Applying sealant

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

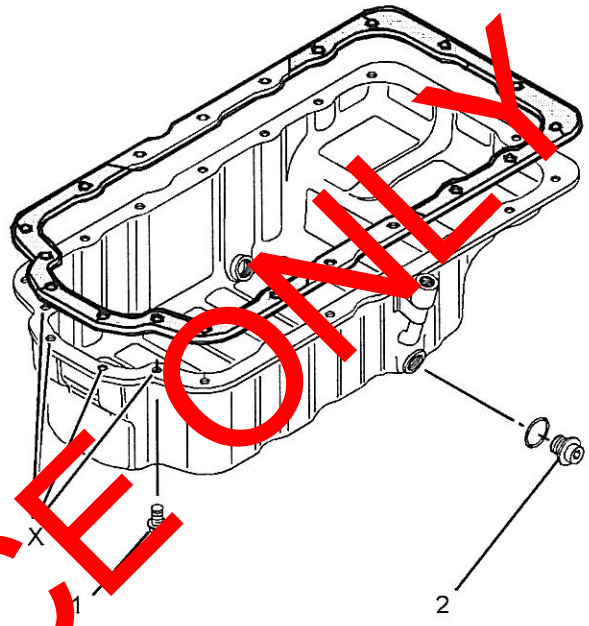



Illustration 37 g01255016
Typical example

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

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

(2) Drain plug

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

REFERENCE ONLY

i02505676

# Engine Oil Bypass Valve

## Installed in the Oil Pump

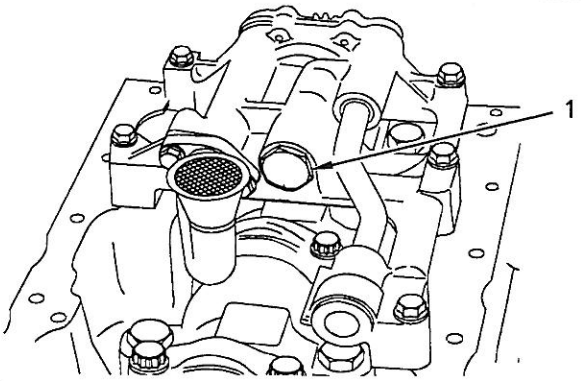



Illustration 38 g00919893
Typical engine oil pump

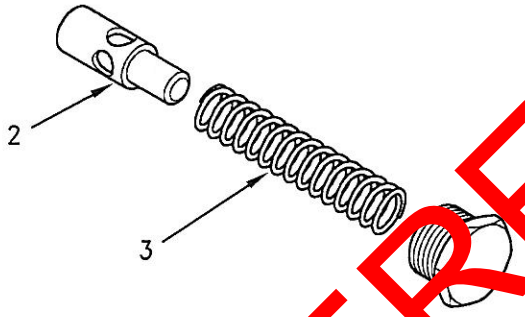



Illustration 39 g00921377
Relief valve and spring

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

(2) Plunger

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

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

(3) Spring

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

## Installed in the Balancer

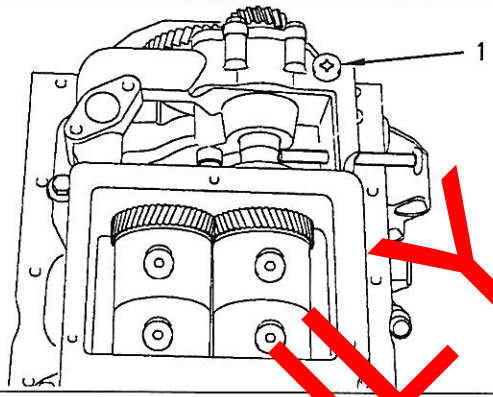



Illustration 40 g00919890
Plug

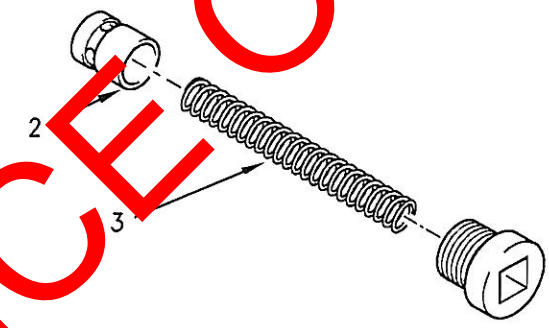



Illustration 41 g00921379
The relief valve for the balancer

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

(2) Plunger

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

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

(3) Spring

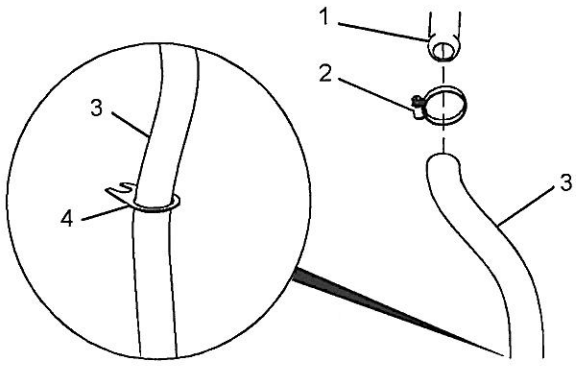
Length of the spring ..... 67 mm (2.6378 inch)

REFERENCE ONLY

i02527053

# Crankcase Breather

## Open crankcase breather




g01277901

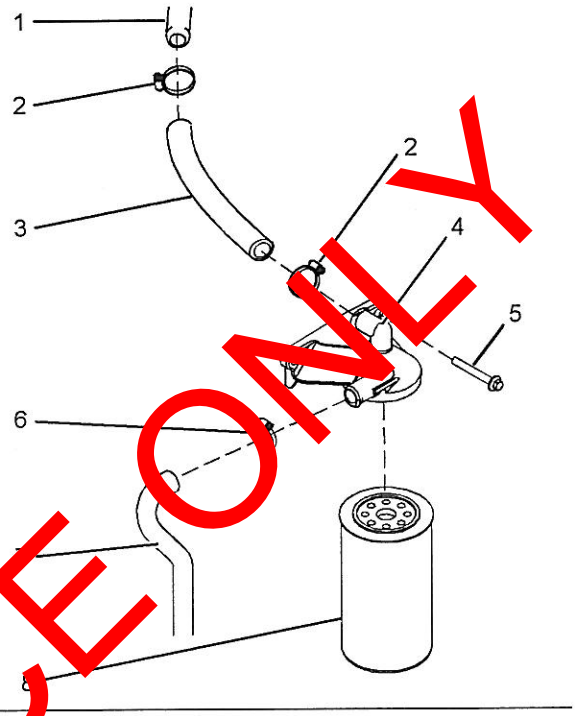
Illustration 42

Typical example

(1) Connection
(2) Clamp
(3) Hose
(4) Clip

(2) Tighten the clamp to the following torque. .. 5 N·m (44 lb in)

## Breather Canister




g01277902

Illustration 43

Typical example

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

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

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

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

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

REFERENCE ONLY

i02504533

# Water Temperature Regulator and Housing

Table 6

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

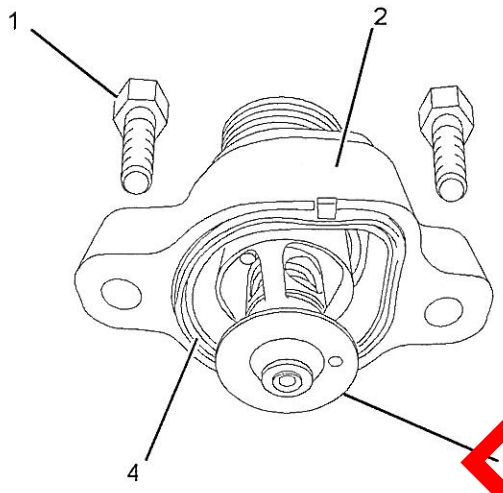



Illustration 44 g01203716
Typical example

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

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

(2) Water temperature regulator housing

(3) Water temperature regulator

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

i02363605

# Water Pump

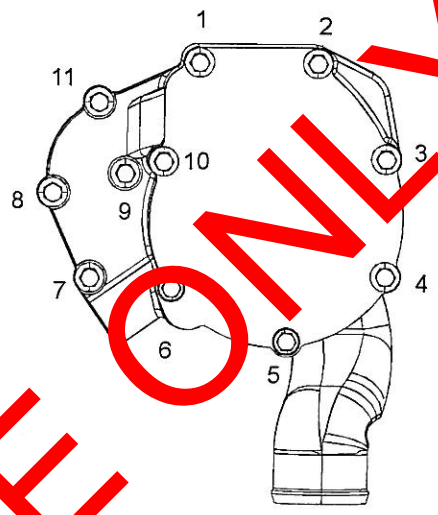



Illustration 45 g01183807
Tightening sequence

Tighten the setscrews in the numerical sequence that is shown in illustration 45 to the following torque. ..... 22 N·m (16 lb ft)

REFERENCE ONLY

i02505673

# Cylinder Block

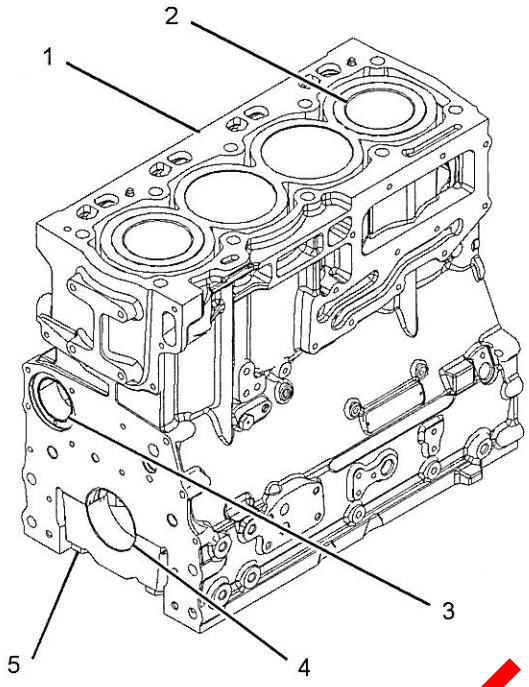



Illustration 46
Cylinder block

(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 ..... 0.15 mm (0.0059 inch)

(3) Camshaft bearings

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

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

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

(4) Main bearings

Bore in the cylinder block for the main bearings ..... 88.246 to 88.272 mm
(3.4742 to 3.4753 inch)

Install the main bearing cap bolts (5). Refer to Disassembly and Assembly, "Crankshaft Main Bearings - Remove and Install" or Disassembly and Assembly, "Crankshaft - Install" for the correct procedure.

(5) Main bearing cap bolts

Evenly tighten the main bearing cap bolts. Torque for the main bearing cap bolts. .. 80 N·m (59 lb ft)

**Note:** Tighten the bolts for the main bearing cap for an additional 90 degrees.

Ensure that the crankshaft can rotate freely.

REFERENCE ONLY

i02506995

# Crankshaft

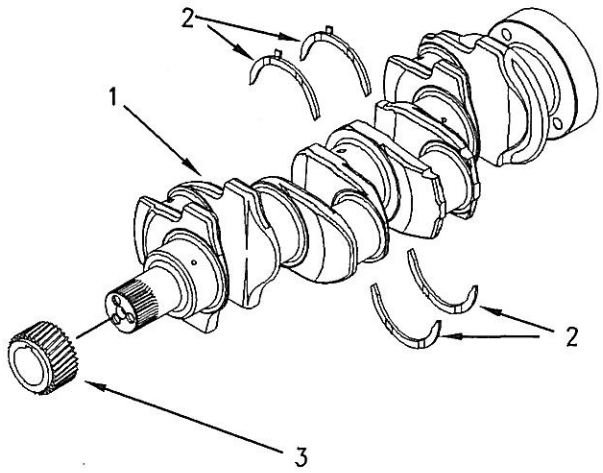



Illustration 47 g01255050

Typical example

(1) Crankshaft gear
(2) Crankshaft
(3) Crankshaft thrust washers

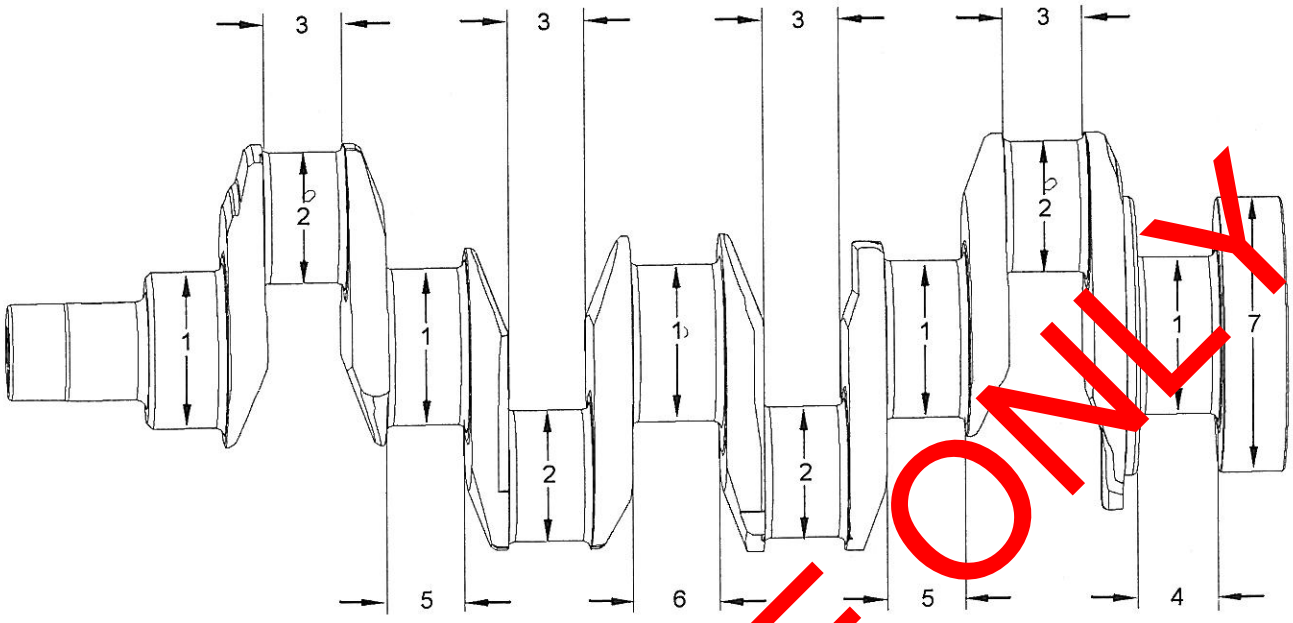
Maximum permissible temperature of the gear for installation on the crankshaft ..... 180 °C (356 °F)

The end play of a new crankshaft ... 0.16 to 0.38 mm (0.0063 to 0.0150 inch)

Standard thickness of thrust washers ... 2.26 to 2.31 mm (0.0890 to 0.0909 inch)

Oversize thickness of thrust washers ..... 2.45 to 2.50 mm (0.0965 to 0.0984 inch)

REFERENCE ONLY




g01261588

Illustration 48

Typical example

REFERENCE ONLY

Table 7

| 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 to 75.905 mm (2.9892 to 2.9884 inch) | 75.672 to 75.651 mm (2.9792 to 2.9784 inch) | 75.418 to 75.397 mm (2.9692 to 2.9684 inch) |
| 2 | 63.236 to 63.216 mm (2.4896 to 2.4888 inch) | 62.982 to 62.962 mm (2.4796 to 2.4788 inch) | 62.728 to 62.708 mm (2.4696 to 2.4688 inch) |
| 3 | 39.551 mm (1.5965 inch) maximum | N/A | N/A |
| 4 | 39.47 mm (1.5539 inch) maximum | N/A | N/A |
| 5 | 39.47 mm (1.5539 inch) maximum | N/A | N/A |
| 6 | 44.68 mm (1.7591 inch) maximum | N/A | N/A |
| 7 | Do not machine this diameter. | Do not machine this diameter. | Do not machine this diameter. |

Item (6) in table 7 can be repaired with a crankshaft wear sleeve. Refer to Disassembly and Assembly, "Crankshaft Wear Sleeve (Rear) - Remove and Install" for more information.

Table 8

| Minimum Width of machined Area of Crankshaft Web | | | |
|---|---|---|---|
| Web | 1, 2, 3, 6 and 7 | 4 and 5 | 8 |
| | 18.31 mm (0.7209 inch) | 19.11 mm (0.7524 inch) | 26.61 mm (1.0476 inch) |

If necessary, machine the thrust face in order to remove damage. Refer to table 8 for information.

Refer to table 9 for the run out of the crankshaft journals.

Table 9

| Journal | Run out of the Journals |
|---|---|
| (1) | Mounting |
| (2) | 0.08 mm (0.0031 inch) |
| (3) | 0.15 mm (0.0059 inch) |
| (4) | 0.08 mm (0.0031 inch) |
| (5) | Mounting |

The radii of all the crankshaft journals must be machined. This machining must return the crankshaft to the original standard. The radii must give a smooth transition from the journal to the side machined face.

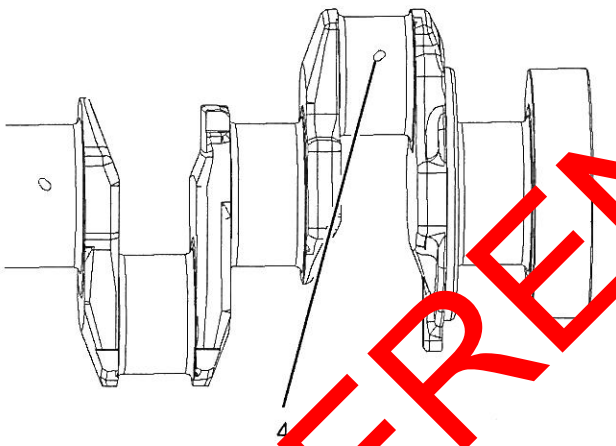



Illustration 49 g01261590
Typical example

The edge of the oil holes (4) must be machined to the original standard after machining of the crankshaft.

Oil hole

The maximum radius of the edge of the oil hole ..... 0.5 mm (0.0197 inch)

Surface finish of all journals ..... Ra 0.2 microns

Surface finish of all radii ..... Ra 0.4 microns

Inspect the crankshaft for structural cracking after machining.

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

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

i02504536

## Crankshaft Seals

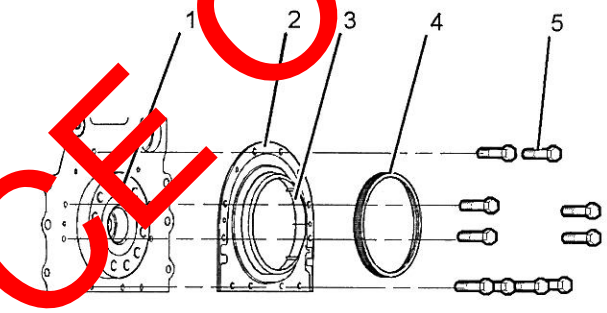



Illustration 50 g01253721
Typical example

(1) Crankshaft

(2) Crankshaft seal

(3) Plastic sleeve

(4) Alignment tool

REFERENCE ONLY

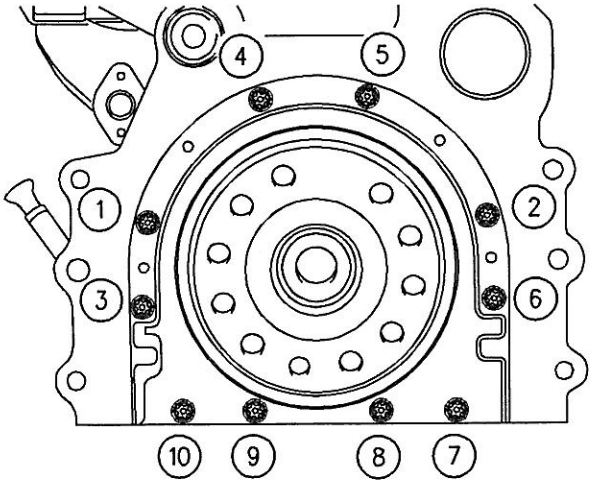



Illustration 51 g00915076

(5) Tighten bolts 1, 2, 3, 4, 5, 6, 7, and 10 in the sequence that is shown in Illustration 51 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 51 to the following torque. ..... 22 [illegible] (16 lb ft)

[illegible]2506934

## Crankshaft Pulley

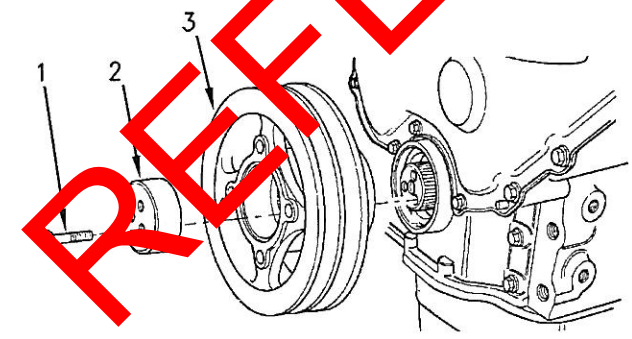



Illustration 52 g00915497

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) once.

(2) Thrust block

(3) Crankshaft pulley

## Crankshaft Pulley for the Poly V-Belt

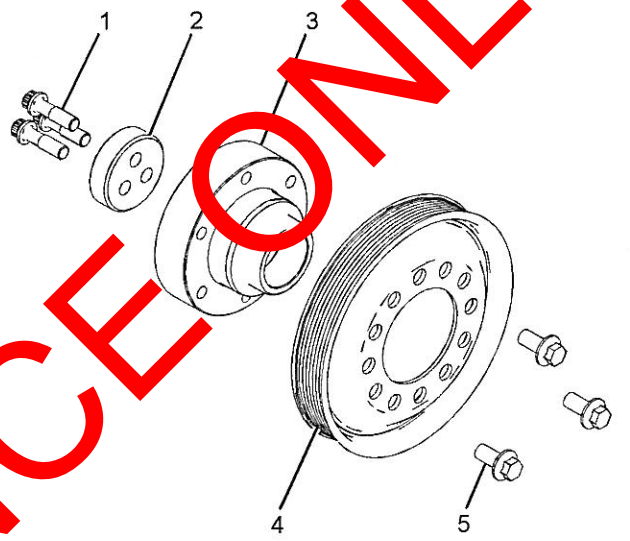



Illustration 53 g01254970

Typical example

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

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

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

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

REFERENCE ONLY

i02504771

# Connecting Rod Bearing Journal

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

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

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

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

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

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

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

i02506007

# Main Bearing Journal

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

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

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

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

Surface finish of bearing journals and crank pins ..... 0.4 microns

Surface finish of radii ..... 1.3 microns

Width of new main bearing journal ... 39.34 to 39.24 mm (1.5488 to 1.5449 inch)

Width of new center main bearing journal ... 44.22 to 44.15 mm (1.7409 to 1.7382 inch)

## 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 .... 0.76 mm (0.0299 inch)

Thickness at center of the shell ... 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 ..... 0.117 to 0.058 mm (0.0046 to 0.0023 inch)

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# Connecting Rod

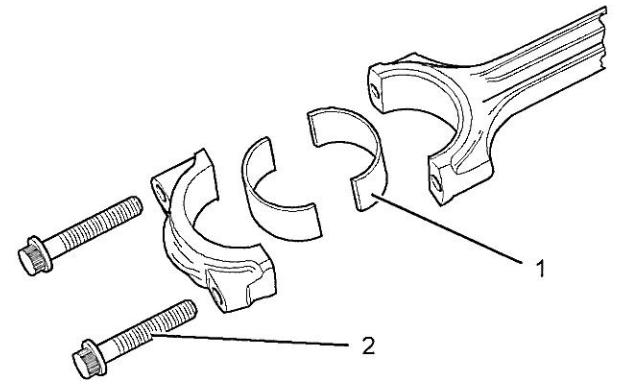



Illustration 54 g01254512
Typical example

(1) The bearing shell for the connecting rod

REFERENCE ONLY

Table 10

| | |
|---|---|
| **Thickness of Connecting Rod Bearing at the Center** | 1.8352 to 1.8415 mm (0.0723 to 0.0725 inch) |
| **Thickness of Connecting Rod Bearing for the Cap at the Center** | 1.8352 to 1.8415 mm (0.0723 to 0.0725 inch) |
| **Bearing Clearance** | 0.034 ± 0.081 mm (0.0013 ± 0.0032 inch) |

Table 11

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

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

(2) Tighten the setscrews for the connecting rod to the following torque. ..... 18 N·m (13 lb ft)

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

Tighten the setscrews for the connecting rod for an additional 120 degrees. The setscrews for the connecting rod (2) 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).

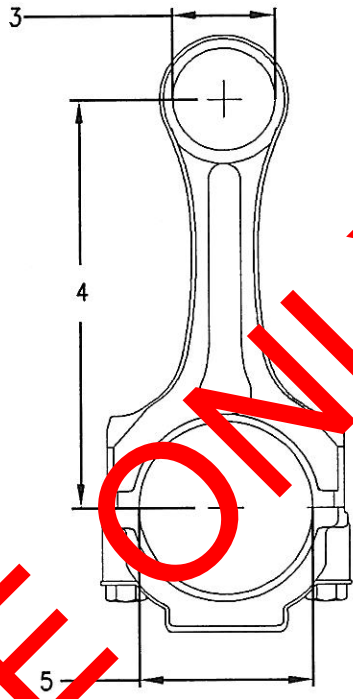



Illustration 55 g01254518
Typical example

(3) Diameter of the finished bore for the piston pin ..... 39.738 to 39.723 mm (1.5645 to 1.5639 inch)

(4) Distance between the parent bores ..... 219.05 to 219.1 mm (8.6240 to 8.6260 inch)

(5) Diameter for the finished bore for the connecting rod bearing ..... 67.208 to 67.221 mm (2.6460 to 2.6465 inch)

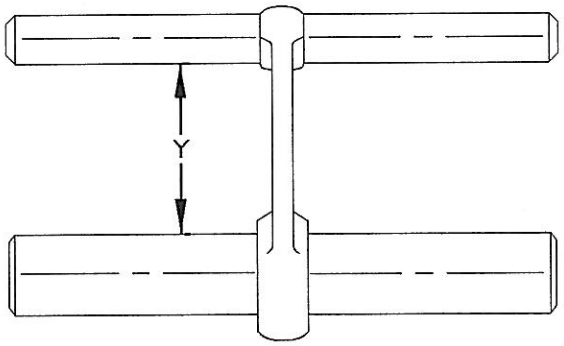



Illustration 56 g00915056

REFERENCE ONLY

Connecting rods are color coded. The color code is a reference for the length (Y) of the connecting rod. Refer to table 12 for the different lengths of connecting rods.

Table 12

| Length Grades for Connecting Rods | | |
|---|---|---|
| **Grade Letter** | **Color Code** | **Length (Y)** |
| F | Red | 165.761 to 165.728 mm (6.5260 to 6.5247 inch) |
| G | Orange | 165.715 to 165.682 mm (6.5242 to 6.5229 inch) |
| H | White | 165.670 to 165.637 mm (6.5224 to 6.5211 inch) |
| J | Green | 165.624 to 165.591 mm (6.5206 to 6.5193 inch) |
| K | Purple | 165.578 to 165.545 mm (6.5188 to 6.5175 inch) |
| L | Blue | 165.532 to 165.499 mm (6.5170 to 6.5157 inch) |

i02363087

## Piston and Rings

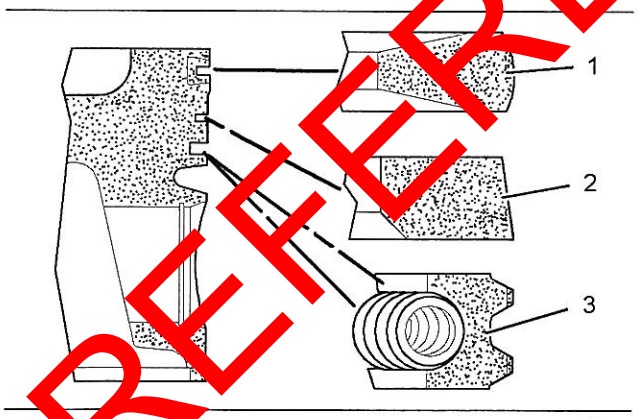



Illustration 57 g01155119
Typical example

(1) Top compression ring

The shape of the top compression ring .. tapered

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

**Note:** When you install a new top compression ring, make sure that the word "TOP" is facing the top of the piston. New top piston rings have a yellow identification mark which must be on the left of the ring end gap when the top piston ring is installed on an upright piston.

(2) Intermediate compression ring

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

Width of intermediate compression ring .... 2.47 to 2.495 mm (0.0972 to 0.0982 inch)

The clearance between a new intermediate compression ring and the groove in a new piston ..... 0.065 to 0.011 mm (0.0026 to 0.0004 inch)

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

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

(3) The oil control ring

Width of oil control ring ..... 2.97 to 2.99 mm (0.1169 to 0.1177 inch)

The clearance between a new oil control ring and the groove in a new piston ..... 0.03 to 0.07 mm (0.0011 to 0.0027 inch)

Ring gap ..... 0.30 to 0.55 mm (0.0118 to 0.0216 inch)

**Note:** The oil control ring is a two-piece ring that is spring loaded. A pin is used in order to hold both ends of the spring of the oil control ring in position. The ends of the spring of the oil control ring must be installed opposite the end gap of the oil control ring.

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

## Piston

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

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

Width of top groove in the piston ..... Tapered

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

REFERENCE ONLY

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

Piston pin

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

## Oversize Piston

Table 13

| Standard piston | |
|---|---|
| 1 Oversize | +0.5 mm (0.0197 inch) piston |
| 2 Oversize | +1.0 mm (0.0394 inch) piston |

i02367100

## Piston Cooling Jet

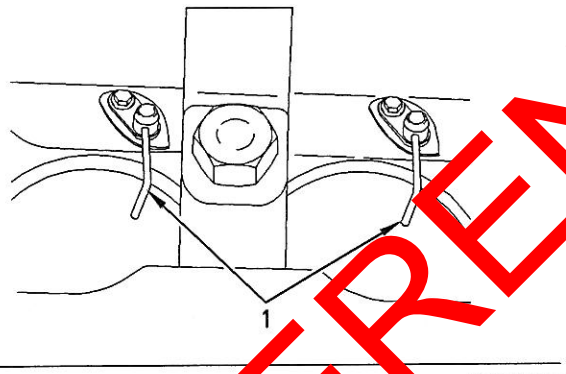



Illustration 58 g00942652

(1) Installed piston cooling jets

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

## Piston Cooling Jet Alignment

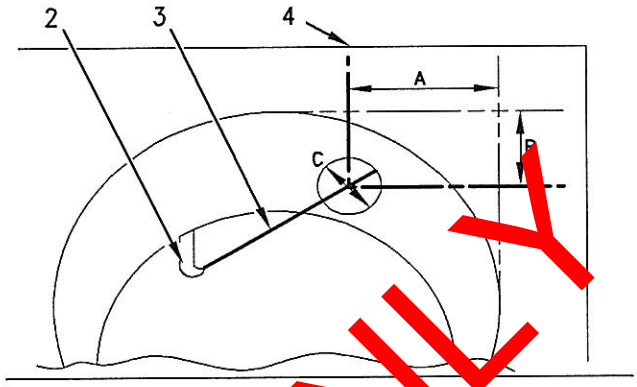



Illustration 59 g01006929

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

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

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

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

3. The position of the rod (3) must be within dimension (C). Dimension (C) is 14 mm (0.5512 inch).

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

i02369751

## 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 )

REFERENCE ONLY

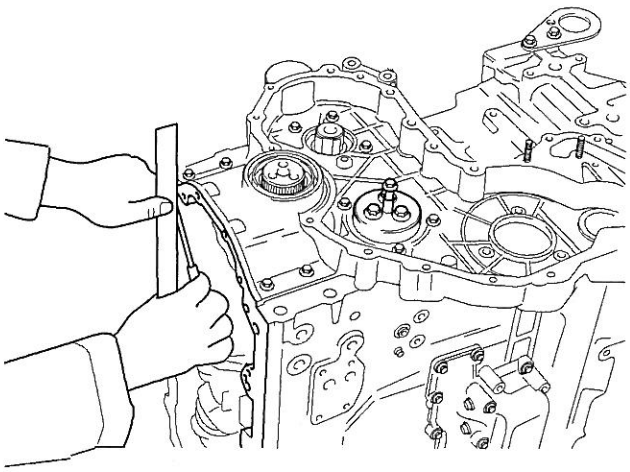


Illustration 60 g00995663
Alignment

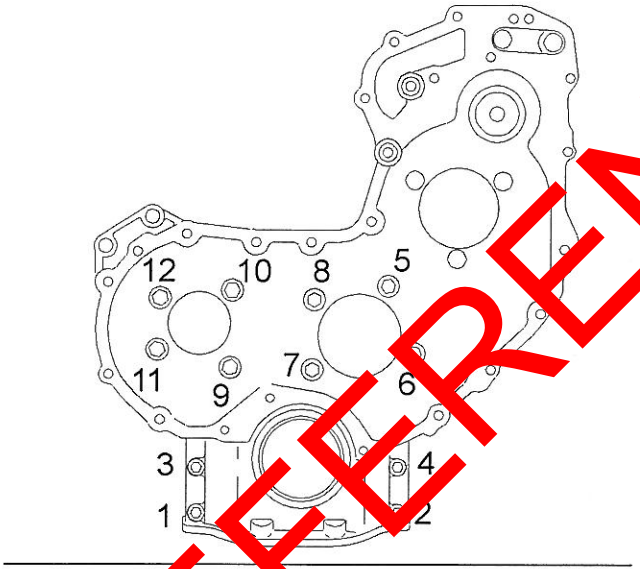



Illustration 61 g01203927
Typical example

Tighten the setscrews to the sequence that is shown in Illustration 61 to the following torque. ..... 28 N·m (20 lb ft)

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

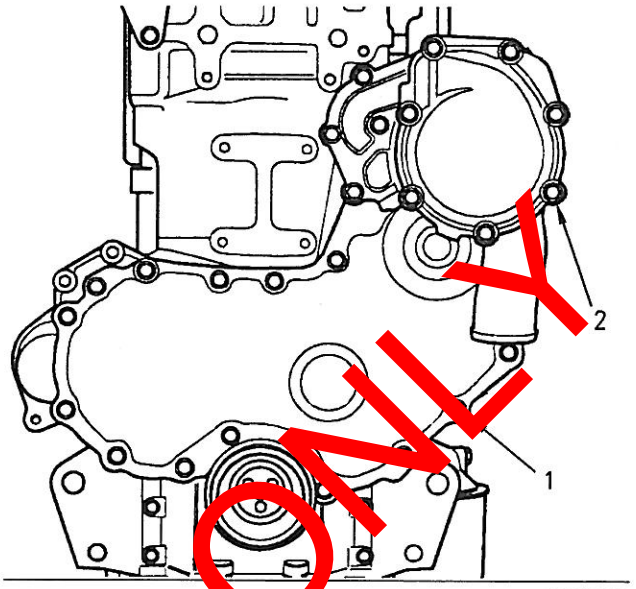



Illustration 62 g00918672
Typical example

(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.

i02504717

## Gear Group (Front)

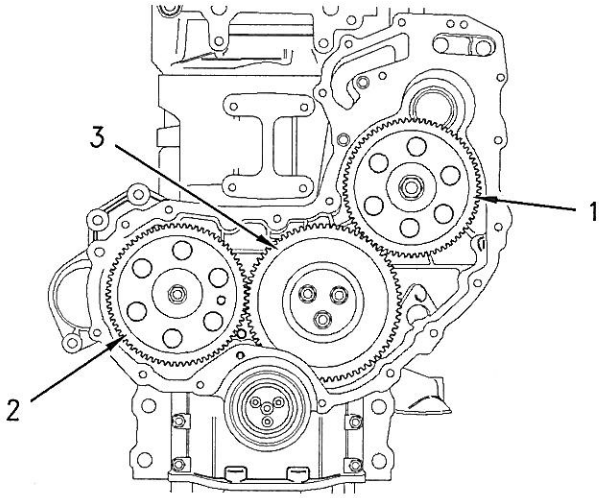



Illustration 63 g00995886
Gear train

REFERENCE ONLY

(1) Fuel injection pump drive gear

Tighten the nut to the following torque. ... 25 N·m (18 lb ft)
Release the lock on the fuel injection pump shaft. Torque the nut to the following torque. .... 90 N·m (66 lb ft)

Number of teeth ..... 68

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

(2) Camshaft gear

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

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)

Width of idler gear and split bearing assembly ..... 30.165 to 30.135 mm (1.1876 to 1.1864 inch)

Inside diameter of idler gear bearings with flanges ..... 50.797 to 50.818 mm (1.9999 to 2.0007 inch)

Outside diameter of idler gear hub ..... 50.716 to 50.737 mm (1.9967 to 1.9975 inch)

Clearance of idler gear bearing on hub .... 0.06 to 0.102 mm (0.0024 to 0.0040 inch)

Idler gear end play ..... 0.13 to 0.205 mm (0.005 to 0.0081 inch)

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

Idler gear end play with roller bearings ..... 0.24 to 0.954 mm (0.0094 to 0.0376 inch)

Number of teeth ..... 73

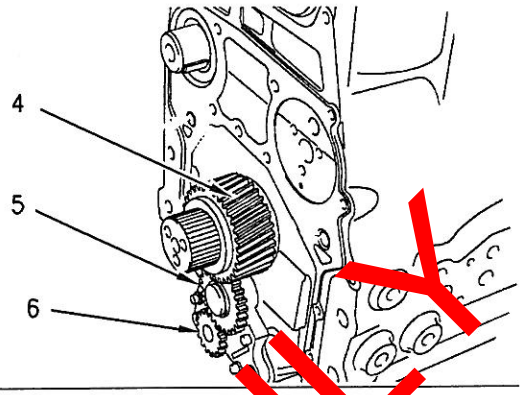



Illustration 64 g00996214

The gear train for the oil pump

(4) Crankshaft gear

Bore diameter of crankshaft gear ..... 51.00 to 51.03 mm (2.0079 to 2.0091 inch)

Outside diameter of crankshaft hub ..... 51.021 to 51.002 mm (2.0087 to 2.0079 inch)

Clearance of gear on crankshaft ..... −0.021 to +0.028 mm (−0.0008 to 0.0011 inch)

Number of teeth ..... 34

(5) Oil pump idler gear

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

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

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

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

(6) Oil pump gear

The number of teeth on the oil pump gear ..... 17

Backlash values

Backlash between the idler gear (5) and the oil pump drive gear (6) ..... 0.05 to 0.14 mm (0.0020 to 0.0055 inch)

Backlash between the oil pump idler gear (5) and the crankshaft gear (4) ..... 0.8 to 0.23 mm (0.0315 to 0.0091 inch)

REFERENCE ONLY

Backlash between the idler gear (3) and the crankshaft gear (4) ..... 0.05 to 0.015 mm (0.0020 to 0.0006 inch)

Backlash between the camshaft gear (2) and the idler gear (3) ..... 0.05 to 0.15 mm (0.0020 to 0.0059 inch)

Backlash between the fuel injection pump gear (1) and the idler gear (3) ..... 0.05 to 0.15 mm (0.0020 to 0.0059 inch)

Backlash between the water pump gear (not shown) and the fuel injection pump gear (1) ..... 0.05 to 0.15 mm (0.0020 to 0.0059 inch)
Backlash between the power take-off drive (if equipped) and the idler gear (3) ..... 0.05 to 0.250 mm (0.0020 to 0.0098 inch)

i02503254

## Flywheel

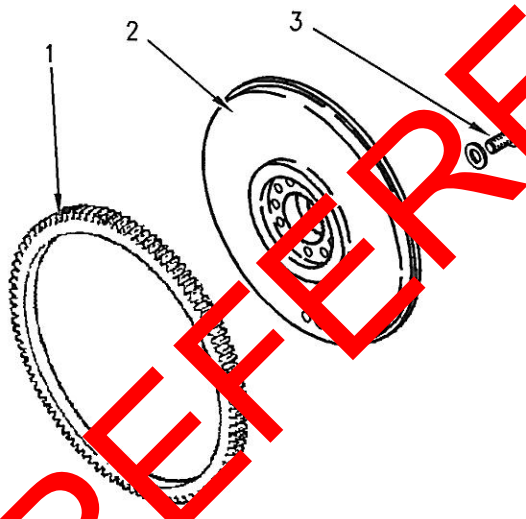



Illustration 65 g00584712
Typical example

(1) Flywheel ring gear

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

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

(2) Flywheel

(3) Bolt

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

i02505674

## Flywheel Housing

Table 14

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 218201[illegible] | POWERPART Thread Lock and Nut Lock | 1 |

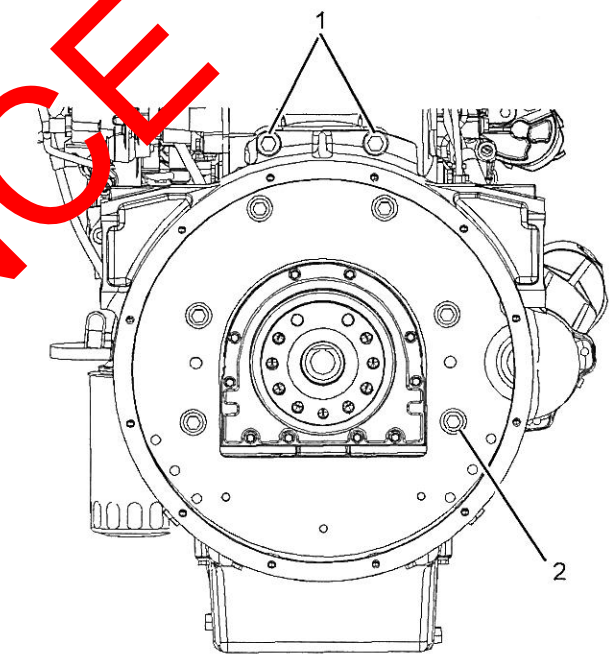



Illustration 66 g01254486
Typical example

Setscrew

(1) Tighten the setscrew to the following torque. ..... 75 N·m (55 lb ft)

Setscrew

(2) Tighten the setscrew to the following torque. ..... 63 N·m (46 lb ft)

REFERENCE ONLY

**Note:** If 12.9 setscrews are installed, apply Tooling (A) to the setscrews. Tighten the 12.9 setscrews to a torque of 70 N·m (52 lb ft).

i02519438

# Belt Tension Chart

Table 15

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

Table 16

| 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.

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

**Note:** A poly v-belt has an automatic belt tensioner. No manual adjustment of the poly v-belt is required.

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

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)

i02504537

# Alternator

## The 12 Volt Denso Alternator

Six types of alternator are available.

Output

Four 12 volt alternators are available. ... 75 Amp, 85 Amp, 100 Amp and 120 Amp
Two 24 volt alternators are available. ..... 55 Amp and 75 Amp

REFERENCE ONLY

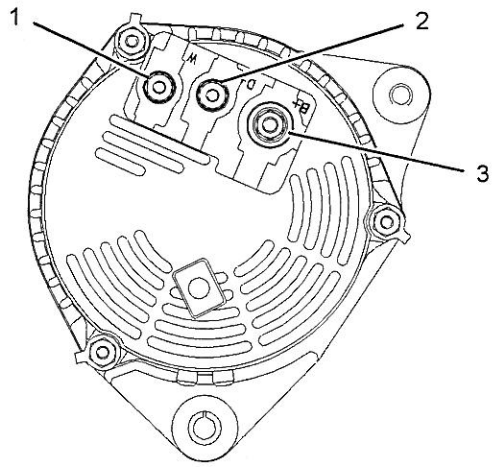



Illustration 67 g01194950
Typical example

(1) Terminal "W"

Tighten the terminal nut to the following torque. ..... 1.5 N·m (13 lb in)

(2) Terminal "D+"

Tighten the terminal nut to the following torque. ..... 1.5 N·m (13 lb in)

(3) Terminal "B+"

Tighten the terminal nut to the following torque. ..... 3.3 N·m (29 lb in)

## The 24 Volt Iskra Alternator

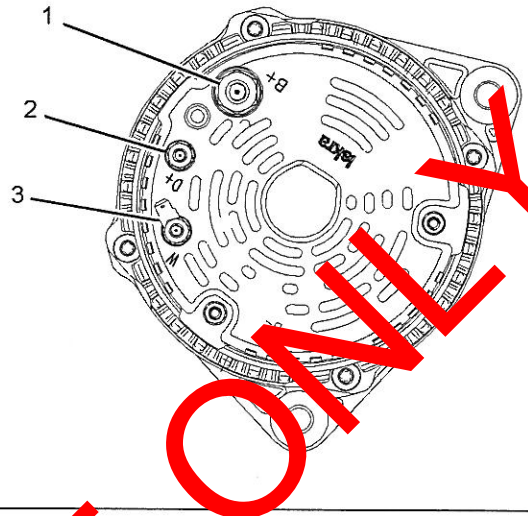



Illustration 68 g01194953
Typical example

(1) Terminal "B+"

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

(2) Terminal "D+"

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

(3) The terminal "W" is spade-type.

24 volt output

The 24 volt alternator ..... 100 Amp

REFERENCE ONLY

i02504538

# Starter Motor

## 24 Volt Starting Motor 4.5 Kw

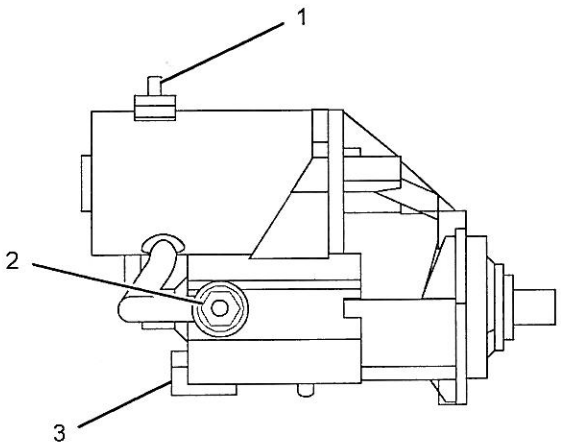



Illustration 69 g012
Typical example

(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

## 12 Volt Starting Motor 3 Kw

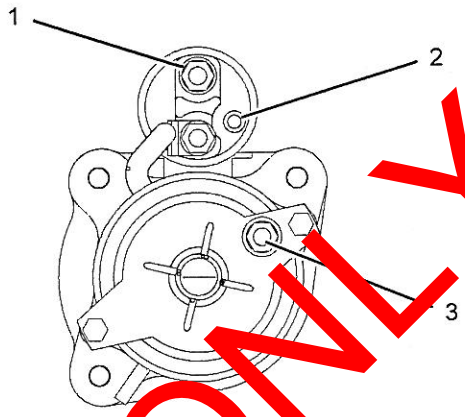



Illustration 70 g01200844
Typical example

(1) Tighten the nut for the positive terminal (terminal 30) to the following torque. ..... 6 N·m (53 lb in )

(2) Tighten the solenoid terminal (terminal 50) to the following torque. ..... 8 N·m ( 70 lb in)

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

Rated voltage ..... 12 volts

Pull in voltage ..... 8 volts

REFERENCE ONLY

i02371978

## Coolant Temperature Sensor

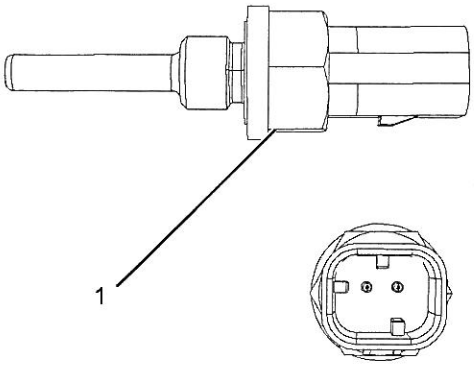



Illustration 71 g01183334
Typical example

(1) Sensor

Tighten the sensor to the following torque. ..... 15 N·m (11 lb ft)

i02378157

## Fuel Pressure Sensor

**WARNING**

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

Refer to the Operation and Maintenance manual, "General Hazard Information and High Pressure Fuel Lines" before adjustments and repairs are performed.

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

Ensure that all adjustments and repairs are performed by personnel that have had the correct training.

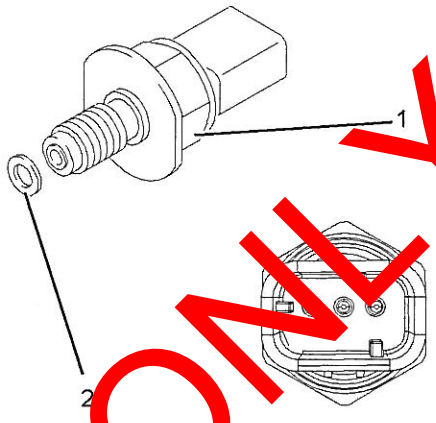



Illustration 72 g01192226
(1) Fuel pressure sensor
(2) Washer

Fuel pressure sensor

Tighten the fuel pressure sensor to the following torque. ..... 34 N·m (25 lb ft)

i02371981

## Engine Oil Pressure Sensor

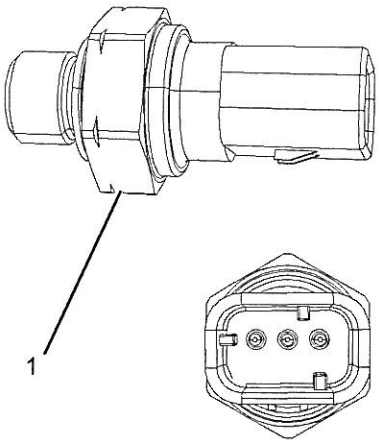



Illustration 73 g01183333
Typical example

REFERENCE ONLY

(1) Sensor

Tighten the sensor to the following torque. ..... 10 N·m (7 lb ft)

i02371977

## Boost Pressure Sensor

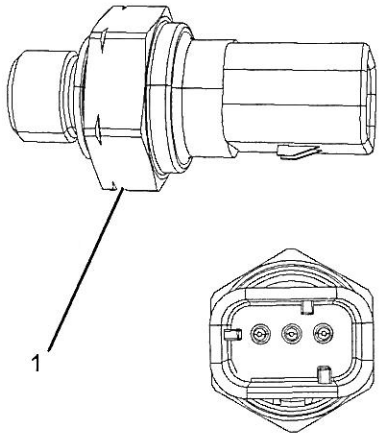



Illustration 74 g011[illegible]333

Typical example

(1) Sensor

Tighten the sensor to the following torque. ..... [illegible] N·m (7 lb ft)

i02493822

## Inlet Manifold Temperature Sensor

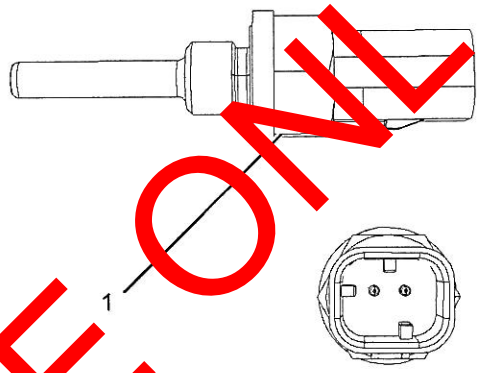



Illustration 75 g01183334

Typical example

(1) Sensor

Tighten the sensor to the following torque. ..... 20 N·m (15 lb ft)

REFERENCE ONLY

i02404840

## Crankshaft Position Sensor

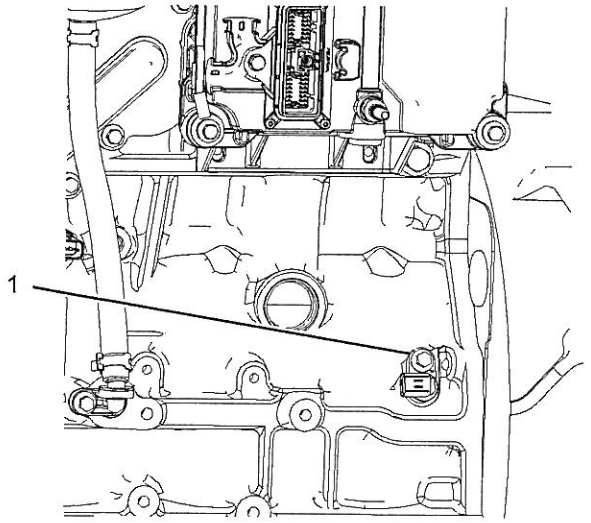



Illustration 76 g01201229

Typical example

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

i02506817

## Electronic Control Module

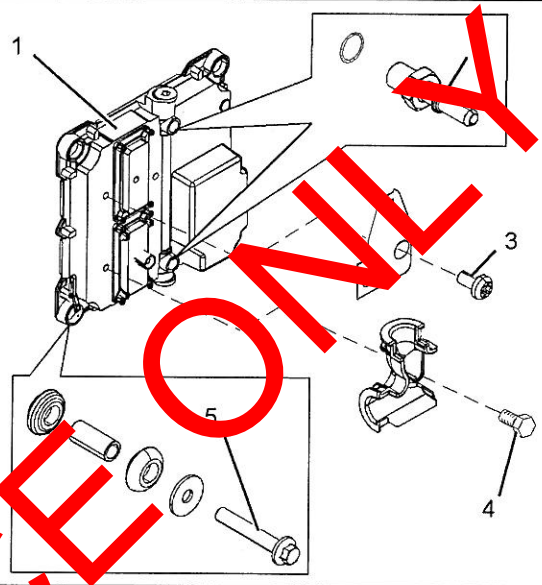



Illustration 77 g01254910

(1) Electronic control module (ECM)
(2) Connectors
(3) Setscrew
(4) Setscrew

(2) Connectors

Tighten the connectors to the following torque. ..... 18.5 N·m (14 lb ft)

(3) Setscrew

Tighten the setscrew to the following torque. ..... 5 N·m (44 lb in)

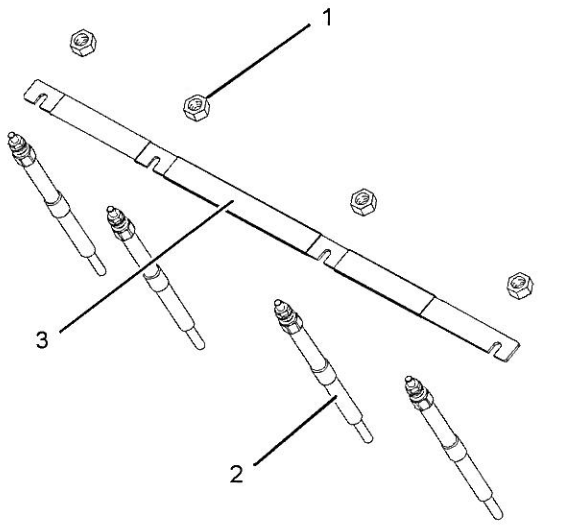
(4) Setscrew

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

REFERENCE ONLY

i02505941

# Glow Plugs




g01254601

Illustration 78
Typical example

Tighten the glow plugs (2) in the cylinder head to the following torque. ..... 15 N·m (11 lb ft)

Tighten the nuts (1) for the bus bar (3) that is installed on top of the glow plugs to the following torque. ..... 2 N·m (18 lb in)

Voltage ..... 12 or 24 volts

REFERENCE ONLY

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RENR9525-01
June 2009

# Disassembly and Assembly

## 1104D Industrial Engine

NH (Engine)
NJ (Engine)

REFERENCE ONLY

# Important Safety Information

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

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

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

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

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

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

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

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

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

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

**⚠ WARNING**

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

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

REFERENCE ONLY

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# Disassembly and Assembly Section

i02933646

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

### Removal Procedure

NOTICE

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

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

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

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

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

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

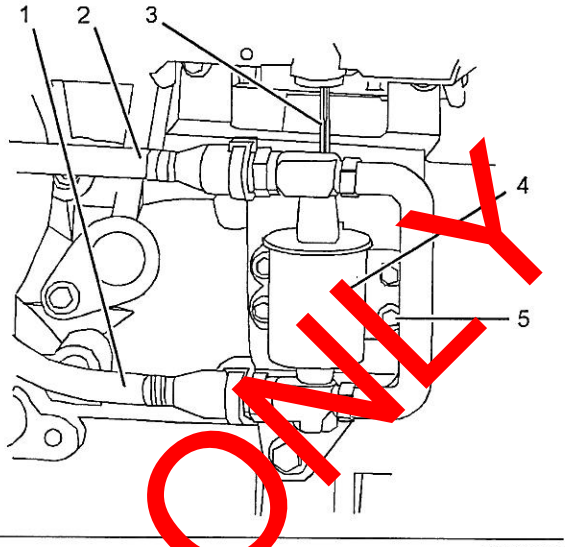



Illustration 1 g01269003
Typical example

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

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

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

### Installation Procedure

NOTICE

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

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

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

REFERENCE ONLY

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

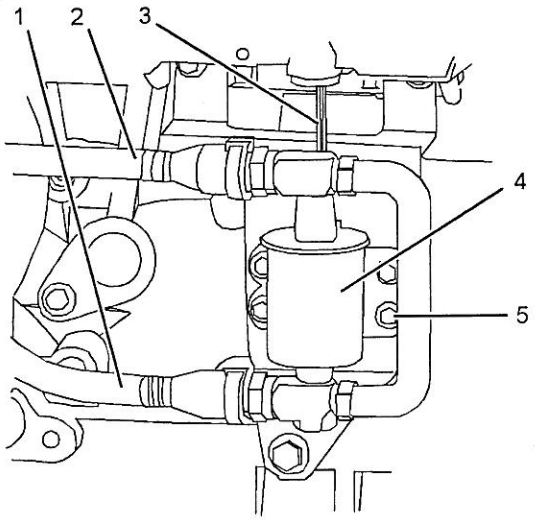



Illustration 2 g01269003
Typical example

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

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

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

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

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

6. Turn the fuel supply to the ON position.

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

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

i02933647

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

## Removal Procedure

NOTICE

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

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

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

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

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

REFERENCE ONLY

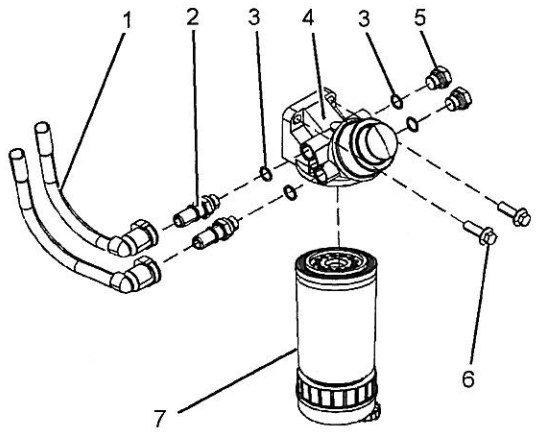



Illustration 3 g01753133

Typical example

1. Turn the fuel supply to the OFF position.

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

3. Disconnect plastic tube assemblies (1).

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

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

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

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

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

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

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

## Installation Procedure

NOTICE

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

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

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

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

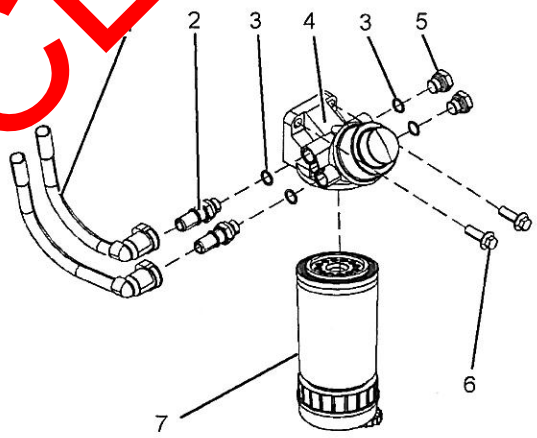



Illustration 4 g01753133

Typical example

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

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

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

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

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

REFERENCE ONLY

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

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

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

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

6. Turn the fuel supply to the ON position.

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

i02933636

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

## Removal Procedure

Table 1

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

NOTICE

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

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

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

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

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

1. Turn the fuel supply to the OFF position.

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

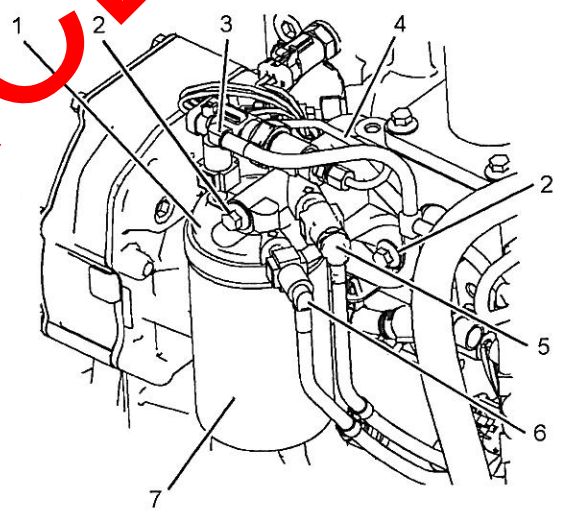



Illustration 5 g01247416
Typical example

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

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

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

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

REFERENCE ONLY

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

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

## Installation Procedure

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

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

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

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

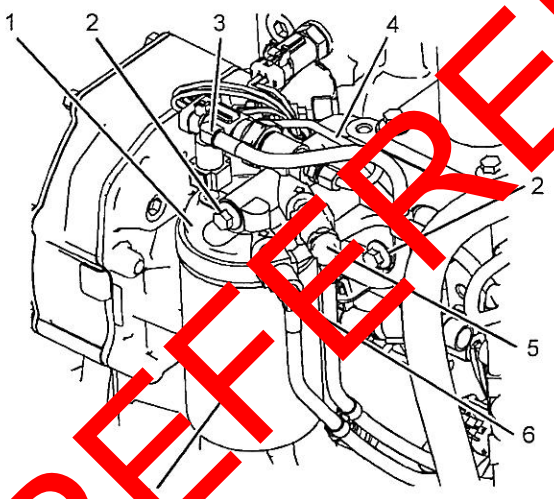



Illustration 6 g01247416
Typical example

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

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

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

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

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

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

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

7. Turn the fuel supply to the ON position.

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

i02933650

# Fuel Transfer Pump - Remove

## Removal Procedure

**Start By:**

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

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

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

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

REFERENCE ONLY

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

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

1. Turn the fuel supply to the OFF position.

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

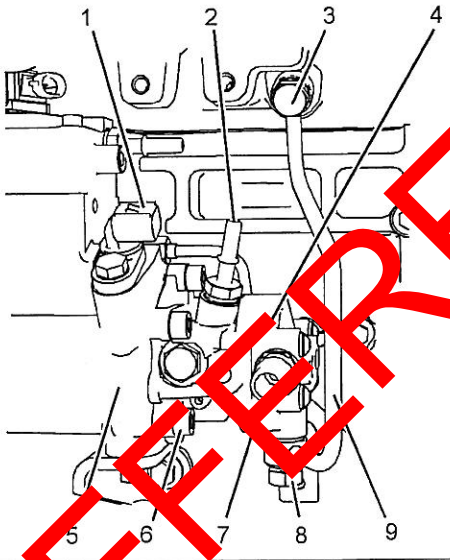



Illustration 7 g01247425
Typical example

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

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

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

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

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

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

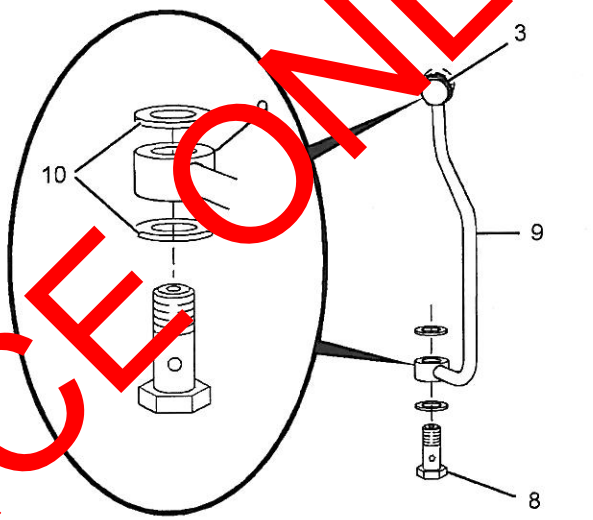



Illustration 8 g01457480

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

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

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

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

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

REFERENCE ONLY

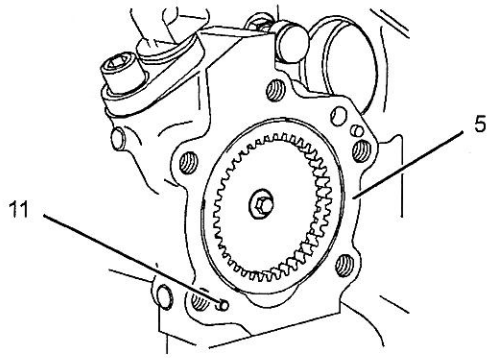



Illustration 9 g01254881

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

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

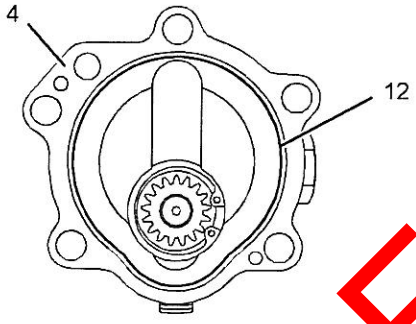



Illustration 10 g01254883

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

i02933648

# Fuel Transfer Pump - Install

## Installation Procedure

NOTICE

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

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

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

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

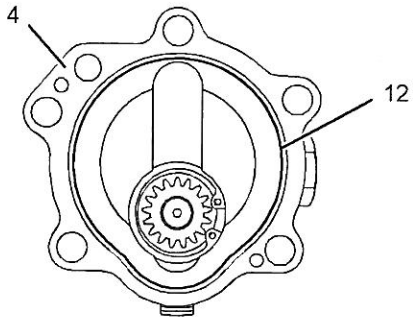



Illustration 11 g01254883

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

REFERENCE ONLY

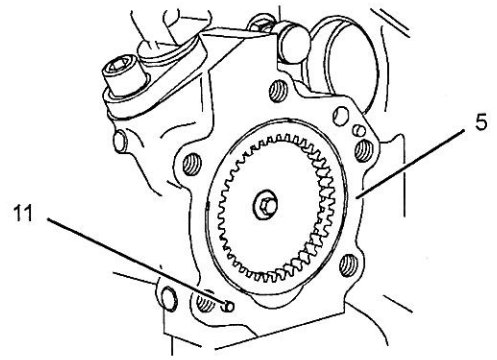



Illustration 12 g01254881

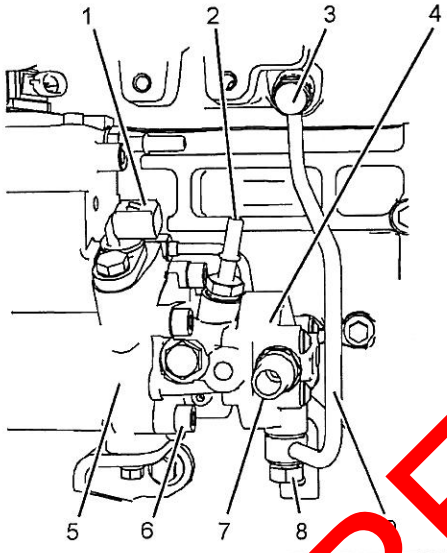



Illustration 13 g01247425

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

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

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

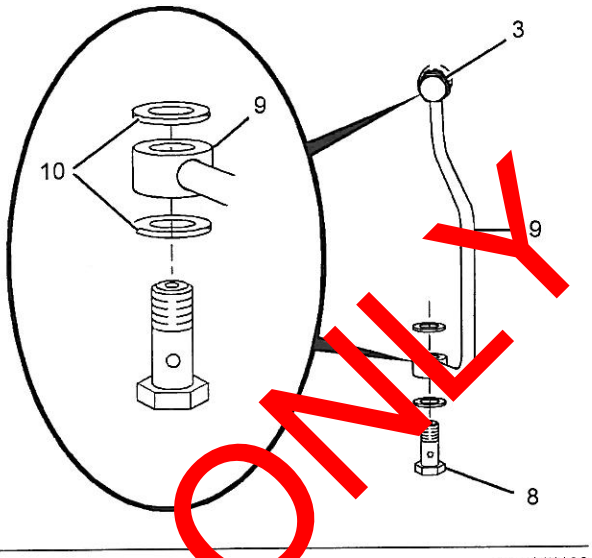



Illustration 14 g01457480

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

7. Install banjo bolt (3) and new sealing washers (10) to tube assembly (9).

8. Install tube assembly (9) to the fuel return to fuel transfer pump (4) and to the cylinder head. Tighten banjo bolt (3) and banjo bolt (8) to a torque of 22 N·m (16 lb ft).

9. If necessary, install a new O-ring seal to inlet connection (7). Install inlet connection (7) to fuel transfer pump (4). Tighten the connection to torque of 15 N·m (11 lb ft).

**Note:** If the tube assembly has quick fit connections, ensure that the connections are clean before the tube assembly is connected.

10. Install the plastic tube assembly to outlet connection (2) on the fuel transfer pump.

11. Install the plastic tube assembly to inlet connection (7) on the fuel transfer pump.

12. If necessary, connect the harness assembly to position sensor (1). Slide the locking tab into the locked position.

13. If necessary, connect the hose for the crankcase breather to the clip that secures the hose to the engine oil pan.

14. Install the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, “ECM Mounting Bracket - Remove and Install”.

REFERENCE ONLY

15. Install the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

16. Turn the fuel supply to the ON position.

17. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933644

# Fuel Manifold (Rail) - Remove and Install

## Removal Procedure

**Start By:**

a. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This will help to prevent fluid loss and this helps to keep contaminants from entering the system.

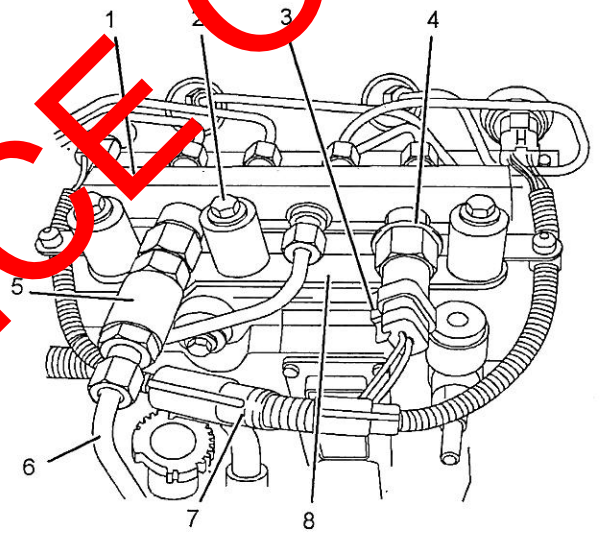



Illustration 15 g01243702

The fuel manifold is shown with fuel injection lines in position.

REFERENCE ONLY

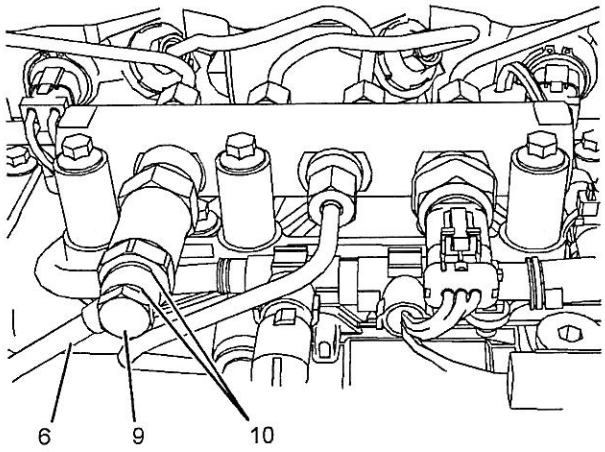



Illustration 16 g01763053

The fuel manifold is shown with fuel injection lines in position.

1. If necessary, remove fuel pressure sensor (4). Refer to Disassembly and Assembly, "Fuel Pressure Sensor - Remove and Install".

2. If fuel pressure sensor (4) does not require removal, slide locking tab (3) into the unlocked position. Disconnect the plug on harness assembly (7) from fuel pressure sensor (4).

3. Disconnect tube assembly (6) from fuel pressure relief valve (5). The tube assembly can be secured with a nut or with a banjo bolt. Immediately cap the open port in the pressure relief valve with a new cap. Immediately plug the open end of the tube assembly with a new plug.

4. If tube assembly (6) is secured with a banjo bolt, remove banjo bolt (9) and sealing washers (10). Refer to Illustration 16.

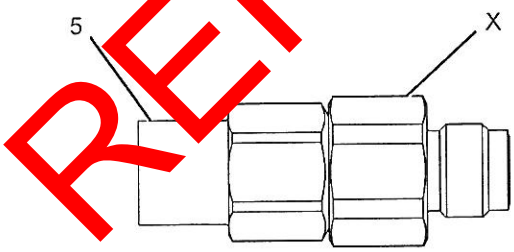



Illustration 17 g01800633

5. If necessary, remove fuel pressure relief valve (5). Use a deep socket in order to remove the fuel pressure relief valve.

**Note:** The fuel pressure relief valve should only be removed at Position (X). The fuel pressure relief valve is a two-piece assembly which should not be disassembled.

6. Remove bolts (2) from fuel manifold (1). Note the position of any brackets that are secured by the bolts.

7. Remove fuel manifold (1) from mounting bracket (8).

8. If necessary, remove the bolts and remove mounting bracket (8).

## Installation Procedure

Table 2

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610294 | Injector Pipe Nut Tool | 1 |

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

1. Ensure that all ports on the fuel manifold are capped. Ensure that the fuel manifold is externally clean and free from damage.

**Note:** Do not install a fuel manifold that has not been capped. All caps must be left in place until the fuel injection lines or the fuel pressure sensor are installed.

REFERENCE ONLY

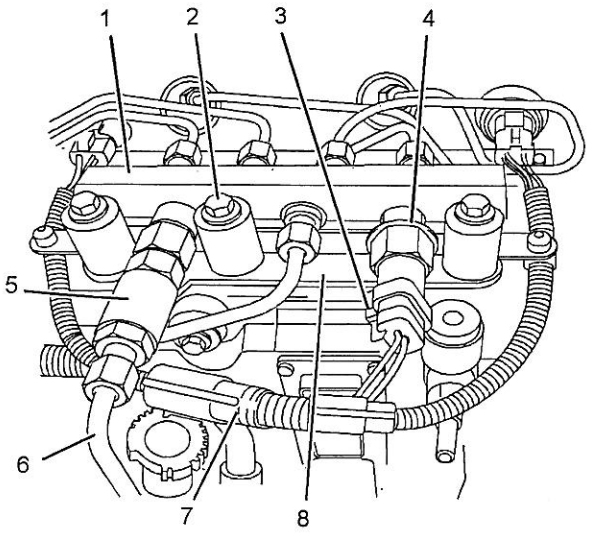



Illustration 18 g01243702

The fuel manifold is shown with fuel injection lines in position.

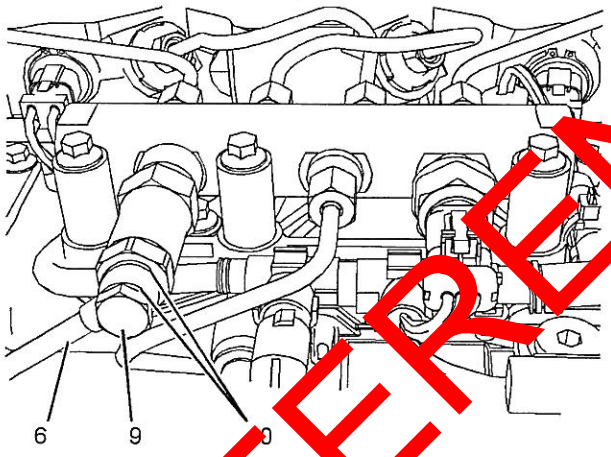



Illustration 19 g01763053

The fuel manifold is shown with fuel injection lines in position.

2. If necessary, install mounting bracket (8) and install the bolts. Tighten the bolts to a torque of 22 N·m (16 lb ft).

3. Position fuel manifold (1) onto mounting bracket (8). Install bolts (2) to the fuel manifold finger tight. Ensure that any brackets that are secured by bolts (2) are installed in the correct position.

4. Loosely install a new set of fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for more information.

5. Tighten bolts (2) to a torque of 22 N·m (16 lb ft).

6. Use Tooling (A) to tighten the nuts on the fuel injection lines to a torque of 30 N·m (22 lb ft). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for more information.

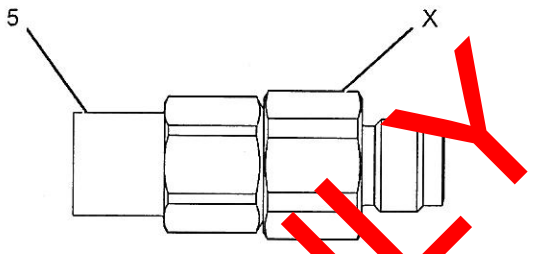



Illustration 20 g01800633

7. If necessary, install a new fuel pressure relief valve (5). Use a deep socket in order to tighten the fuel pressure relief valve. Tighten the fuel pressure relief valve to a torque of 120 N·m (89 lb ft).

**Note:** Fuel pressure relief valve (5) must only be tightened at Position (X). The fuel pressure relief valve is a two-piece assembly which should not be disassembled.

8. Remove the plug from tube assembly (6). Remove the cap from the appropriate port in fuel manifold (1). Connect tube assembly (6) to fuel pressure relief valve (5). If tube assembly (6) is secured with a nut, tighten the nut to a torque of 26 N·m (19 lb ft). Refer to Illustration 18.

9. If tube assembly (6) is secured with a banjo bolt, install new sealing washers (10) and install banjo bolt (9). Tighten the banjo bolt to a torque of 21 N·m (186 lb in).

10. If fuel pressure sensor (4) was removed from fuel manifold (1), install a new sealing washer and install the fuel pressure sensor. Refer to Disassembly and Assembly, "Fuel Pressure Sensor - Remove and Install" for more information.

    If fuel pressure sensor (4) was not removed from fuel manifold (1), connect the plug on harness assembly (7) to fuel pressure sensor (4). Slide locking tab (3) into the locked position.

11. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

REFERENCE ONLY

i02933638

# Fuel Injection Lines - Remove

## Removal Procedure

Table 3

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | U5MK1124 | Cap Kit | 1 |

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

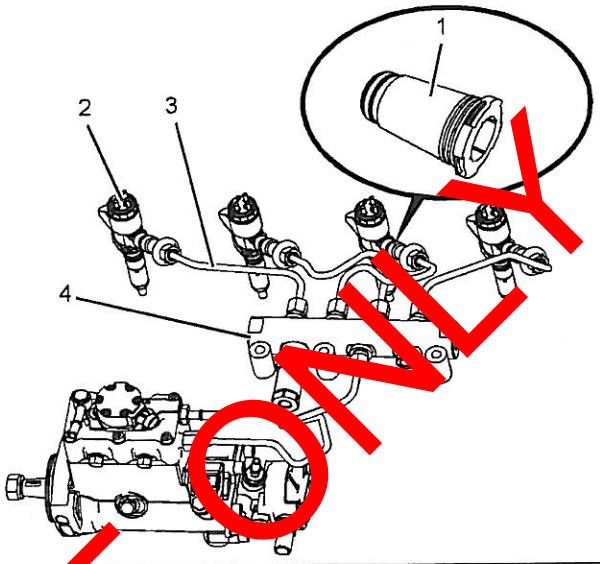



Illustration 21 g01457355
Typical example

3. Disconnect fuel injection line (3) from electronic unit injector (2).
4. Disconnect fuel injection line (3) from fuel manifold (4).
5. Remove fuel injection line (3). Discard the fuel injection line.
6. Plug the open port in fuel manifold (4) immediately. Use Tooling (A) in order to plug the open port.
7. Remove seal (1) from electronic unit injector (2) and from the base of the valve mechanism cover.
8. Use a new plug in order to plug the open port in electronic unit injector (2). Use Tooling (A) in order to plug the open port.
9. Repeat Step 3 through Step 8 in order to remove the remaining fuel injection lines from the electronic unit injectors.
10. If necessary, remove the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".
11. Remove the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

REFERENCE ONLY

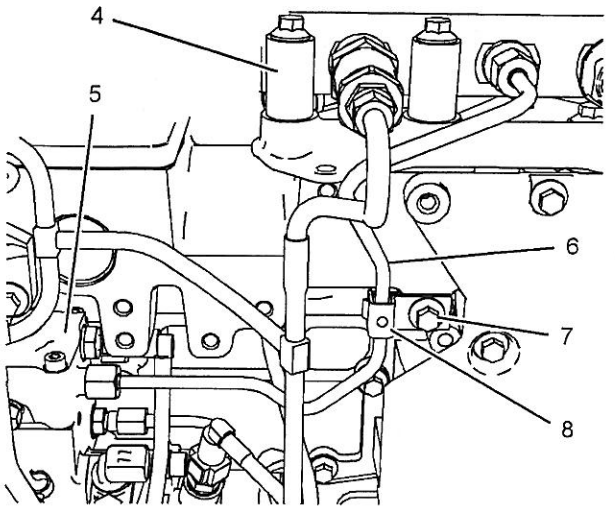



Illustration 22 g01254886
Typical example

12. Remove bolt (7) from clip (8).

13. Disconnect fuel injection line (6) from fuel injection pump (5).

14. Disconnect fuel injection line (6) from fuel manifold (4).

15. Remove fuel injection line (6). Discard the fuel injection line. Plug all open ports immediately. Use Tooling (A) in order to plug the open ports in the fuel manifold and in the fuel injection pump.

i02933637

# Fuel Injection Lines - Install

## Installation Procedure

Table 4

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| | 27610294 | Injector Pipe Nut Tool | 1 |

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

**Note:** The following procedure should be adopted in order to install the fuel injection lines when the electronic unit injectors or the fuel manifold have not been removed. If the electronic unit injectors or the fuel manifold have been removed, refer to Disassembly and Assembly, "Electronic Unit Injector - Install" and Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install" for more information.

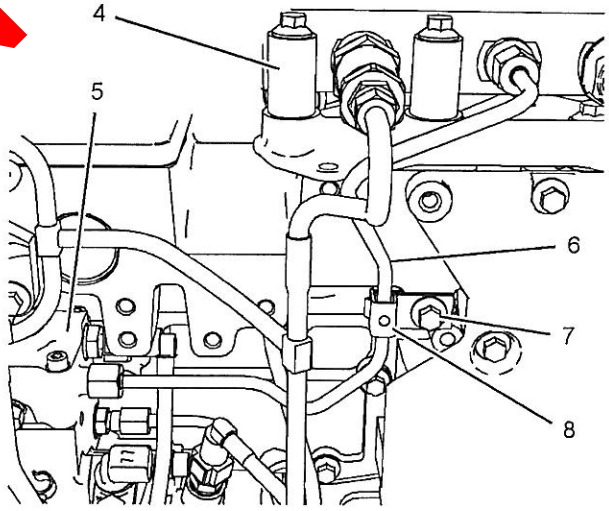



Illustration 23 g01254886
Typical example

1. Remove the caps from the port in fuel injection pump (5) and from the appropriate port in fuel manifold (4). Remove the caps from the new fuel injection line (6).

2. Loosely connect the nuts at both ends of fuel injection line (6), to fuel manifold (4) and to fuel injection pump (5). Ensure that the ends of the fuel injection line are correctly seated in the fuel injection pump and in the fuel manifold.

REFERENCE ONLY

3. Use Tooling (B) to tighten the nuts on fuel injection line (6) to a torque of 30 N·m (22 lb ft).

4. Install bolt (7) to clip (8). Tighten bolt (7) to a torque of 22 N·m (16 lb ft).

   **Ensure that fuel injection line does not contact any other engine component.**

5. Install the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

6. If necessary, install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

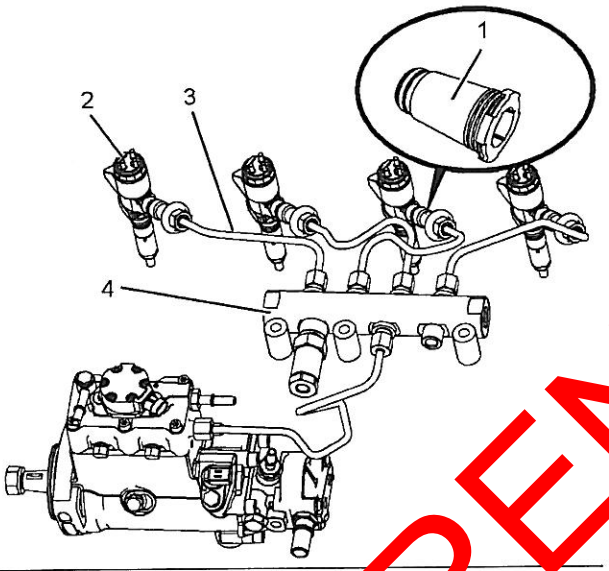



Illustration 24 g01457387
Typical example

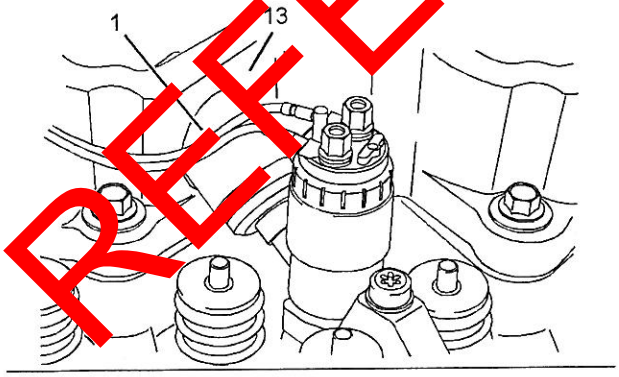



Illustration 25 g01271377
Typical example
The valve mechanism cover is not shown for clarity.

7. Install a new seal (1) to electronic unit injector (2) and to valve mechanism cover base (13).

**Note:** Ensure that the flange on the seal is flush with the valve mechanism cover base.

8. Remove the caps from the new fuel injection line (3).

**Note:** Ensure that a dust seal is installed to the fuel injection line. Install the fuel injection line for number one cylinder first. Install the fuel injection lines in numerical order.

9. Remove the caps from electronic unit injector (2) and from the appropriate port in fuel manifold (4).

10. Loosely connect the nuts at both ends of fuel injection line (3), to electronic unit injector (2) and to the appropriate port in fuel manifold (4). Ensure that the ends of the fuel injection lines are correctly seated in the electronic unit injector and in the fuel manifold.

11. Use Tooling (B) to tighten the nuts on fuel injection line (3) to a torque of 30 N·m (22 lb ft). Ensure that the dust seal is seated correctly against seal (1).

12. Follow Step 7 through Step 11 in order to install the remaining fuel injection lines.

**Note:** Ensure that fuel injection lines do not contact any other engine component.

13. Turn the fuel supply to the ON position.

14. Turn the battery disconnect switch to the ON position.

15. Remove the air from the fuel system. Refer to Operations and Maintenance Manual, "Fuel System - Prime".

i03458261

# Fuel Injection Pump - Remove

## Removal Procedure

Table 5

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |
| D | U5MK1124 | Cap Kit | 1 |

(1) Install Tooling to the front pulley.
(2) Install Tooling into the aperture for the electric starting motor.

REFERENCE ONLY

**Start By:**

a. Remove the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

b. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Note: Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.

2. Turn the battery disconnect switch to the OFF position.

3. If necessary, remove the fuel filter base. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install".

4. If necessary, remove the fuel priming pump. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

5. If necessary, remove the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

6. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No. 1 Piston".

7. Use Tooling (B) in order to lock the camshaft in the correct position. Use Tooling (C) in order to lock the crankshaft in the correct position. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install" for the correct procedure.

8. Remove the backlash from the fuel pump gear. Lock the fuel injection pump in the correct position and remove the fuel pump gear. Refer to Disassembly and Assembly, "Fuel Pump Gear - Remove" for the correct procedure.

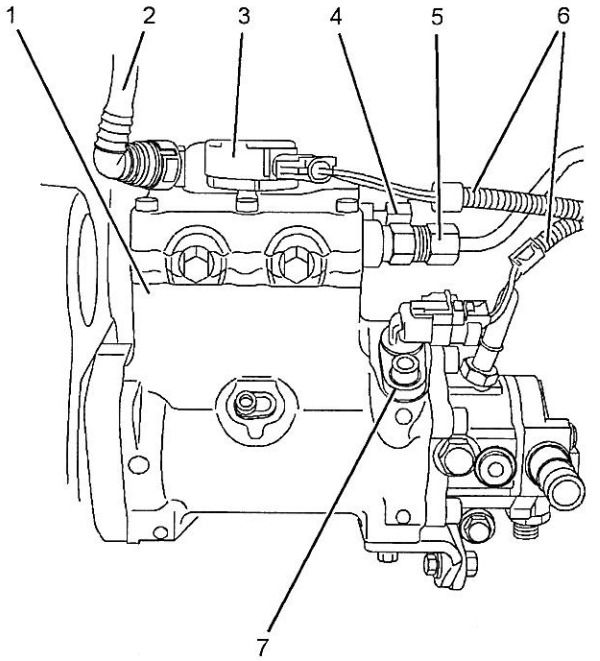
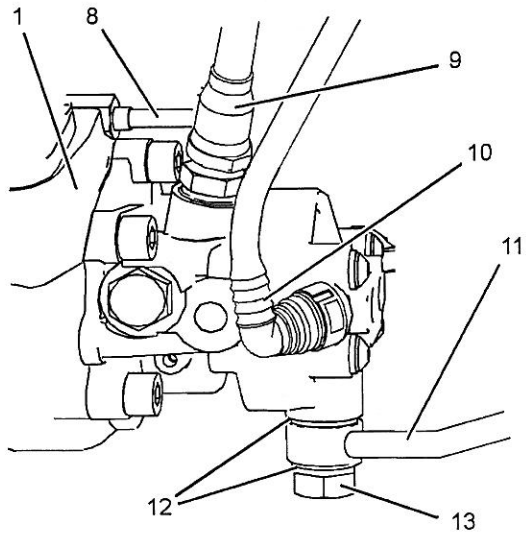



Illustration 26 g01563275
Typical example

REFERENCE ONLY




g01563276

Illustration 27

Typical example

**9.** Disconnect plastic tube assembly (2) from fuel injection pump (1).

**10.** Disconnect harness assembly (6) from solenoid (3). Slide the locking tab into the unlocked position and disconnect harness assembly (6) from position sensor (7).

**Note:** The harness assembly should be positioned in order to avoid an obstruction to the fuel injection pump.

**11.** Disconnect plastic tube assembly (12) from fuel injection pump (1).

**12.** Disconnect plastic tube assembly (11) from fuel injection pump (1).

**13.** Disconnect plastic tube assembly (4) from fuel injection pump (1).

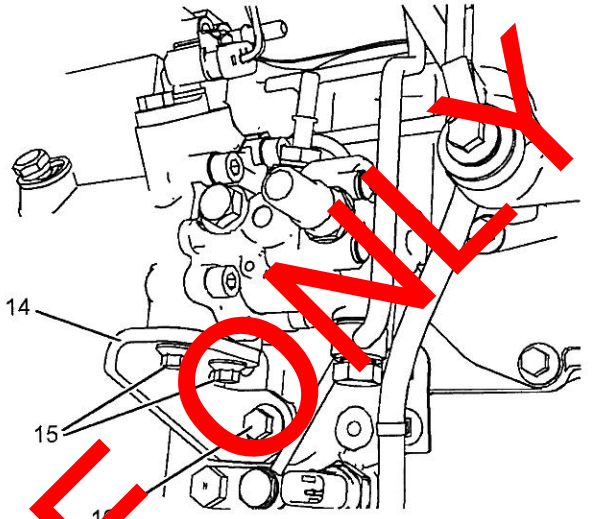
**14.** Remove banjo bolt (13) and remove sealing washers (14).

**15.** Plug or cap all open ports and tube assemblies immediately with new plugs or caps.

**Note:** Ensure that quick fit connections are clean before the tube assemblies are plugged.

**16.** Remove fuel injection line (5). Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove". Use Tooling (D) in order to plug the open ports in the fuel injection pump and in the fuel manifold. Discard the fuel injection line.

**17.** Remove tube assembly (8) for the engine oil supply to the fuel injection pump. Remove the banjo bolt and the sealing washers from the tube assembly.

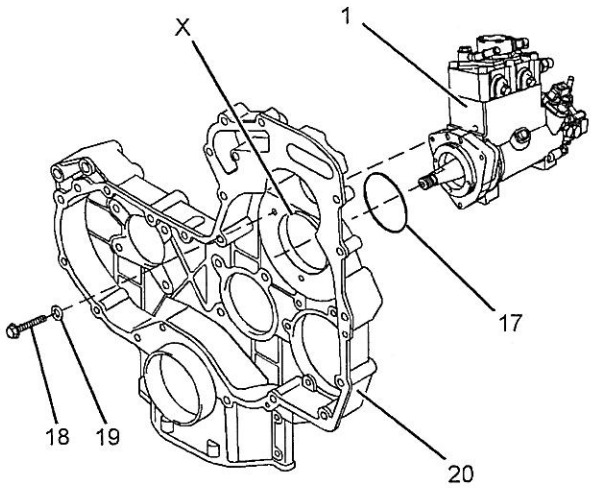



g01566973

Illustration 28

Typical example

**18.** Remove bolts (15) and remove bolt (16). Remove support bracket (14).




g01801934

Illustration 29

Typical example

**19.** Remove bolts (18) and remove sealing washers (19).

**Note:** The fuel injection pump should be supported by hand as the bolts are removed.

REFERENCE ONLY

**20.** Carefully remove fuel injection pump (1) from front housing (20). Ensure that bore (X) in the front housing is not damaged as the fuel injection pump is removed.

**21.** Remove O-ring seal (17) from fuel injection pump (1).

i03401825

# Fuel Injection Pump - Install

## Installation Procedure

Table 6

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |
| E | 27610352 | Fuel Injection Pump Timing Tool | 1 |
| F | 21820221 | POWERPART Rubber Grease | - |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

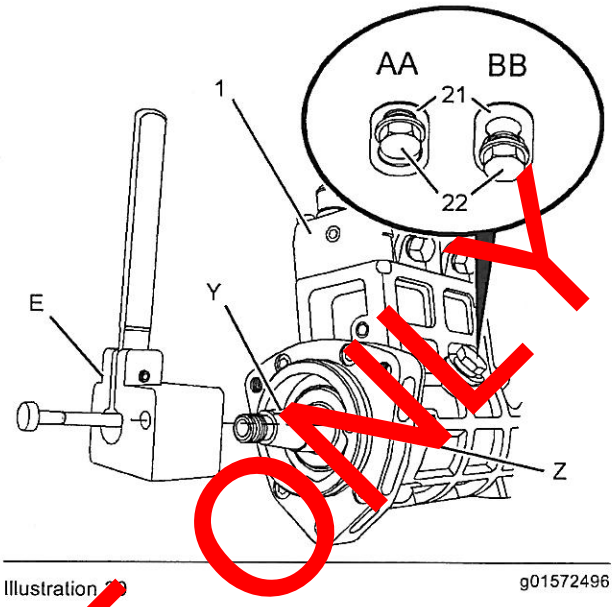



Illustration 19 g01572496
Typical example

**Note: A new fuel injection pump is supplied, locked in the correct position. Do not unlock the fuel injection pump before installation.**

1. If the fuel injection pump timing has been lost, it is possible to reset the fuel injection pump timing. Follow Step 1.a through Step 1.e in order to reset the fuel injection pump timing.

   **a.** Loosen locking screw (22) and slide spacer (21) to Position (AA). Tighten locking screw (22) to a torque of 9 N·m (80 lb in). This will prevent the locking screw from tightening against the shaft of the fuel injection pump.

   The fuel injection pump is now unlocked.

   **b.** Position Tooling (E) onto the shaft of fuel injection pump (1). Align the lever of Tooling (E) with Keyway (Y) and engage the lever into the keyway.

**Note:** The lever of Tooling (E) should be a close fit in the keyway. If the lever is a loose fit in the keyway, it is not possible to reset the fuel injection pump timing.

   **c.** Rotate the shaft of the fuel injection pump and engage the pin of Tooling (E) into Hole (Z).

   The fuel injection pump timing is now set in the correct position.

   **d.** Loosen locking screw (22) and slide spacer (21) to Position (BB). Tighten locking screw (22) to a torque of 9 N·m (80 lb in). The locking screw is now tightened against the shaft of the fuel injection pump.

   The fuel injection pump is now locked.

REFERENCE ONLY

**e.** Remove Tooling (E).

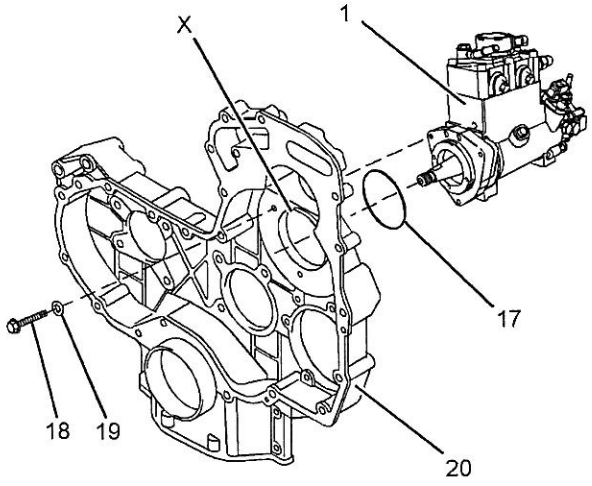



Illustration 31 g01801934
Typical example

**2.** Inspect Bore (X) in front housing (20) for damage. If the bore is damaged, replace the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove" and Disassembly and Assembly, "Housing (Front) - Install".

**3.** Use Tooling (F) to lubricate a new O-ring seal (17). Install the O-ring seal onto fuel injection pump (1).

**4.** Align fuel injection pump (1) with front housing (20). Carefully install the fuel injection pump to the front housing.

**Note:** The fuel injection pump should be supported by hand until the bolts are installed.

**5.** Install bolts (18) and new sealing washers (19). Tighten the bolts to a torque of 25 N·m (18 lb ft).

**6.** If necessary, use Tooling (A) in order to rotate the crankshaft so that number one piston is at top dead center on the compression stroke. Refer to System Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

**7.** Use Tooling (B) in order to lock the camshaft in the correct position. Use Tooling (C) in order to lock the crankshaft in the correct position. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install" for the correct procedure.

**8.** Install the fuel injection pump gear to the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install" and refer to Disassembly and Assembly, "Gear Group (Front) - Install".

**Note:** Ensure that the fuel injection pump is unlocked after the installation of fuel injection pump gear is completed.

**9.** Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

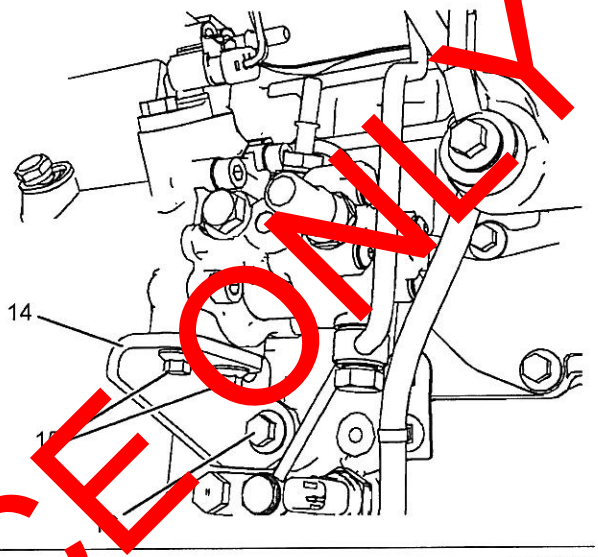



Illustration 32 g01566973
Typical example

**10.** Position support bracket (14) and install bolts (15) finger tight. Install bolt (16) finger tight.

**11.** Tighten bolt (16) to a torque of 44 N·m (32 lb ft). Tighten bolts (15) to a torque of 22 N·m (16 lb ft).

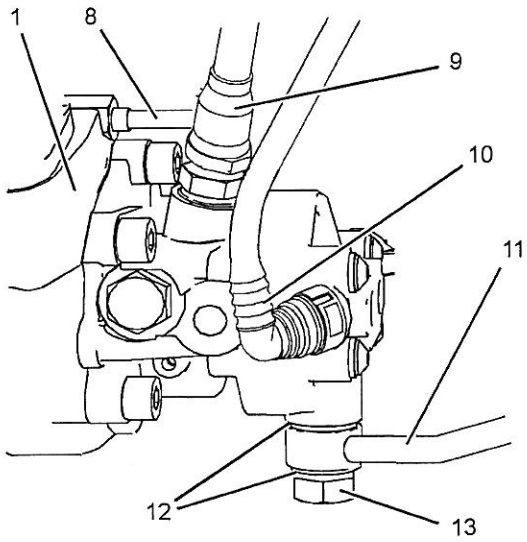



Illustration 33 g01563276
Typical example

REFERENCE ONLY

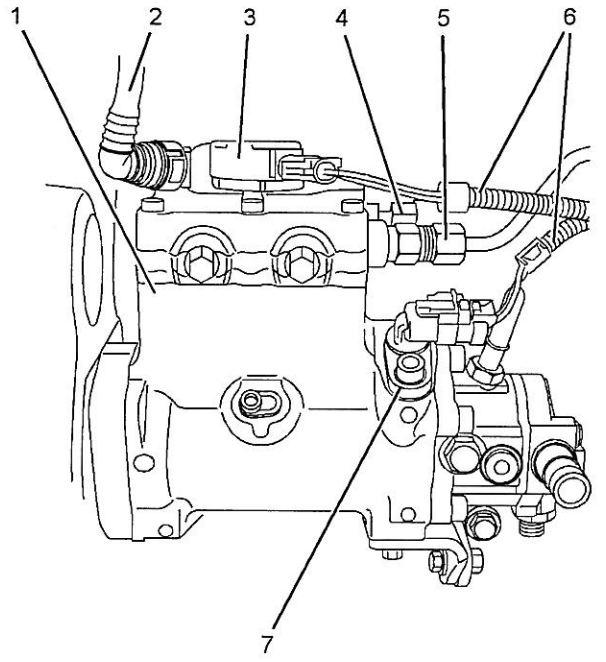



Illustration 34 g01563275
Typical example

**12.** Install the banjo bolt and new sealing washers to tube assembly (8). Install tube assembly (8) for the oil feed to the fuel injection pump. Tighten the banjo bolt and the nut to a torque of 15 N·m (11 lb ft).

**13.** Install a new fuel injection line (5). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

**14.** Install new sealing washers (12) and banjo bolt (13) to tube assembly (11). Tighten the banjo bolt to a torque of 24 N·m (15 lb ft).

**15.** Connect plastic tube assembly (4) to fuel injection pump (1).

**16.** Connect plastic tube assembly (9) to fuel injection pump (1).

**17.** Connect plastic tube assembly (10) to fuel injection pump (1).

**18.** Connect harness assembly (6) to solenoid (3). Connect harness assembly (6) to position sensor (7). Slide the locking tab into the locked position.

**19.** Connect plastic tube assembly (2) to fuel injection pump (1).

**20.** If necessary, install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

**21.** If necessary, install the fuel priming pump. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

**22.** If necessary, install the fuel filter base. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install".

**23.** Turn the battery disconnect switch to the ON position.

**24.** Turn the fuel supply to the ON position.

**25.** Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

i02933643

# Fuel Injection Pump Gear - Remove

## Removal Procedure

Table 7

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Descriptions** | **Qty** |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |
| D | - | Puller (Three Leg) | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

**a.** Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

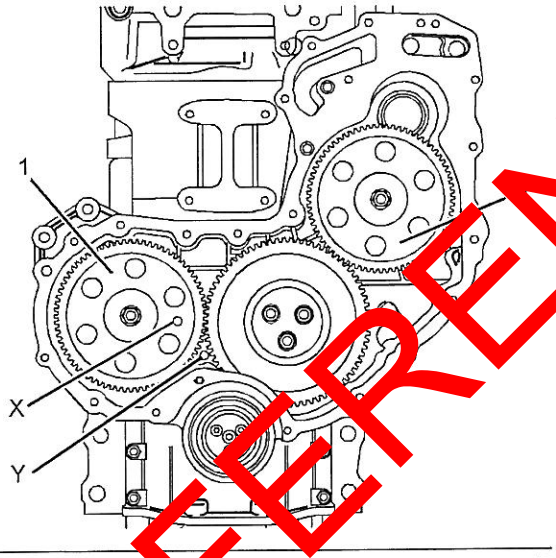



Illustration 35 g01459155
Typical example

2. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position.

3. Install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

**Note:** Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

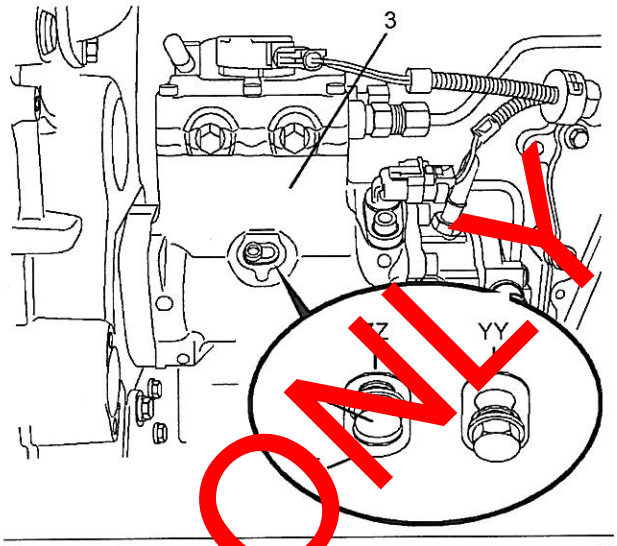



Illustration 36 g01459153
Typical example

4. Apply sufficient pressure to fuel injection pump gear (2) in the counterclockwise direction in order to remove the backlash. Lock fuel injection pump (3) in this position.

In order to lock fuel injection pump (3), loosen locking screw (4) in the fuel injection pump. Slide spacer (5) into Position (YY). Tighten locking screw (4) against the shaft of the fuel injection pump to a torque of 9 N·m (80 lb in).

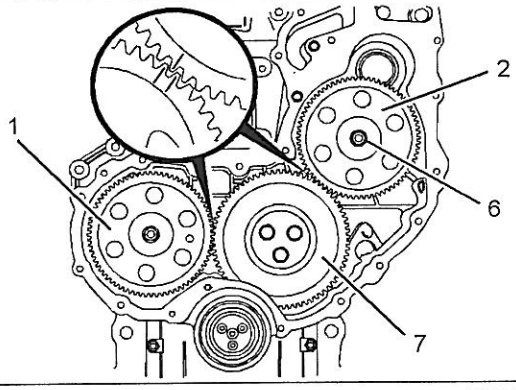



Illustration 37 g01765133
Alignment of timing marks

5. Mark gear (1), gear (2) and gear (7) in order to show alignment. Refer to Illustration 37.

**Note:** Identification will ensure that the gears can be installed in the original alignment.

6. Loosen nut (6) on fuel pump gear (2).

REFERENCE ONLY

7. Install Tooling (D) through three holes in fuel pump gear (2). Tighten Tooling (D) until the fuel pump gear is released.

8. Remove Tooling (D) from fuel pump gear (2).

9. Remove nut (6) and the washer from fuel pump gear (2). Remove the fuel pump gear.

i02933642

# Fuel Injection Pump Gear - Install

## Installation Procedure

Table 8

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |
| E | 21825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The fuel injection pump must remain locked until the procedure instructs you to unlock the fuel injection pump.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

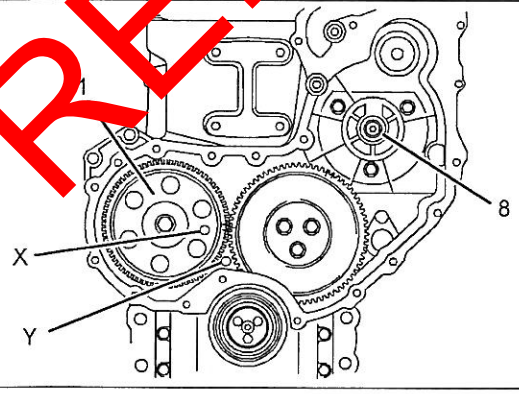



Illustration 38 g01765193
Typical example

2. Ensure that Tooling (C) is installed in Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

3. Ensure that Tooling (B) is installed into Hole (X) in camshaft gear (1).

4. Ensure that shaft (8) on the fuel injection pump is clean, dry and free from damage.

5. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

6. Ensure that the fuel pump gear is clean, dry and free from wear or damage. If necessary, replace the fuel pump gear.

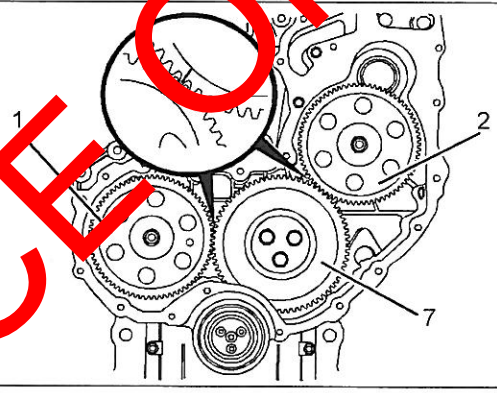



Illustration 39 g01769115
Alignment of timing marks

7. Install fuel pump gear (2) to shaft (8) of the fuel injection pump. Ensure that the timing marks on gears (2) and (7) are in alignment and that the mesh of the gears is correct.

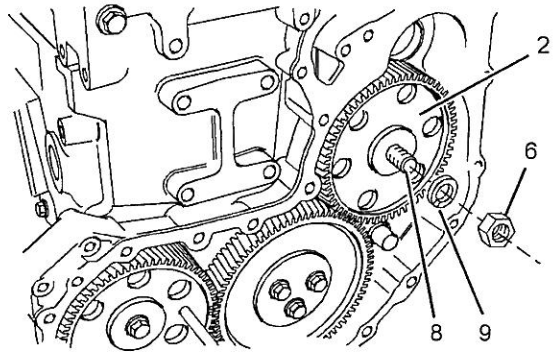
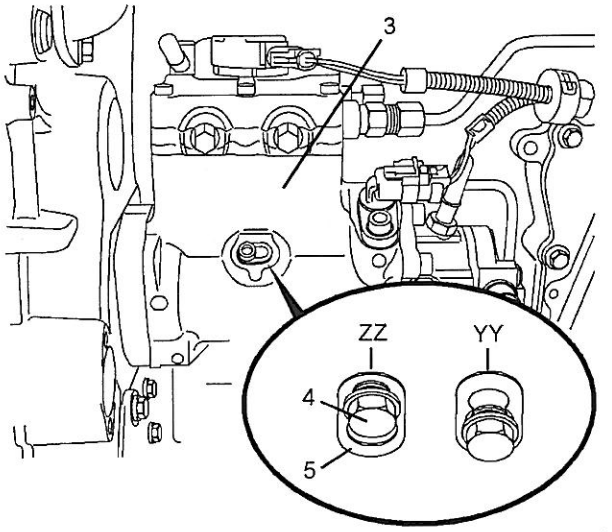



Illustration 40 g01769133
Typical example

REFERENCE ONLY




g01459724

Illustration 41

Typical example

8. Install a new spring washer (9) and install nut (6) to shaft (8) of the fuel injection pump. Apply sufficient pressure to fuel injection pump gear (2) in a counterclockwise direction in order to remove the backlash. Tighten nut (6) to a torque of 25 N·m (18 lb ft). Unlock fuel injection pump (3).

   In order to unlock the fuel injection pump, loosen locking screw (4) on the fuel injection pump. Slide spacer (5) into Position (ZZ). Tighten the locking screw against the spacer to a torque of 9 N·m (80 lb in). This will prevent the locking screw from tightening against the shaft of the fuel injection pump.

9. Remove Tooling (B) and Tooling (C).

10. Tighten nut (6) to a torque of 90 N·m (66.4 lb ft).

11. Use Tooling (E) to measure the backlash of gears (2) and (7). Ensure that the backlash for the gears is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

12. Lubricate the teeth of the gears with clean engine oil.

**End By:**

a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

i02933618

# Electronic Unit Injector - Remove

## Removal Procedure

Table 9

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Bearing Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610317 | T40 Torx Socket | 1 |
| C | 27610281 | Pry Bar | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This tool is used in the aperture for the electric starting motor.

**Start By:**

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

REFERENCE ONLY

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

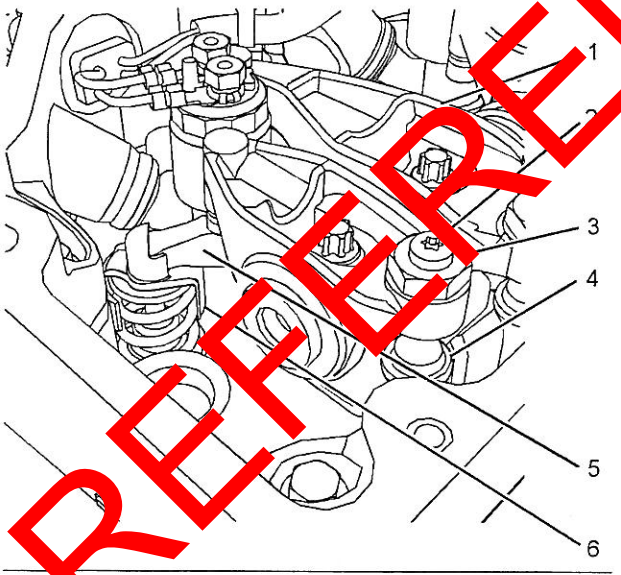



Illustration 42 g01772534
Typical example

3. Use Tooling (A) in order to rotate the crankshaft until rocker arms (1) for the appropriate cylinder are in the correct position in order to adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".
4. Follow Step 4.a through Step 4.d in order to gain access to the electronic unit injector.
   a. Make a temporary mark on valve bridges (5) in order to show the location and orientation.

**Note:** Identification will ensure that the valve bridges can be reinstalled in the original location and the original orientation.

   b. Loosen nuts (3) for the appropriate cylinder. Unscrew adjusters (2) for the appropriate cylinder until pushrods (4) can be withdrawn from the balls of the adjusters.
   c. Withdraw the cups of pushrods (4) from the balls of adjusters (2).
   d. Remove valve bridges (5) from the cylinder head. If the valve bridges are equipped with shrouds (6), ensure that the shrouds are removed from the cylinder head.

**Note:** Do not interchange the location or the orientation of used valve bridges.

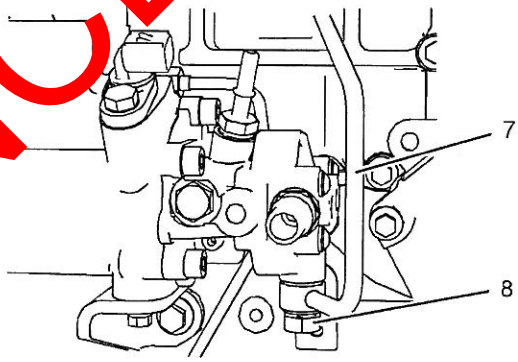



Illustration 43 g01769493
Typical example

5. Loosen banjo bolt (8) on the fuel transfer pump sufficiently in order to allow the fuel to drain from tube assembly (7).

REFERENCE ONLY

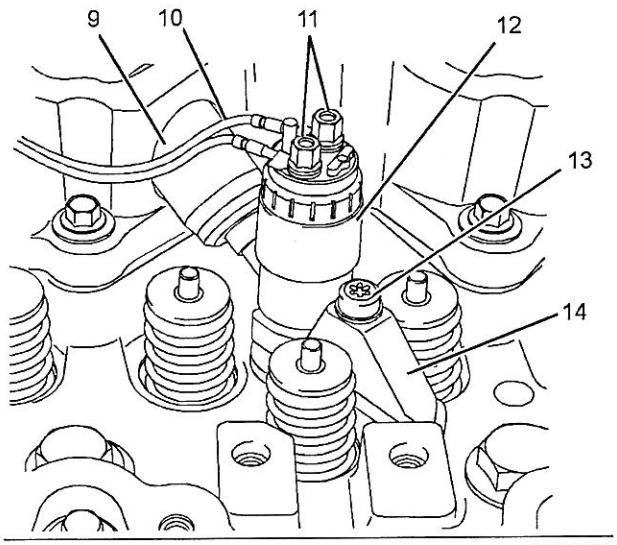



Illustration 44 g01769513

The rocker shaft is not shown for clarity.

6. Remove the fuel injection line and remove seal (9) from the appropriate electronic unit injector (12). Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

**Note:** Cap all open ports immediately with new caps.

7. Use a deep socket to remove connections (11) from electronic unit injector (12).

8. Slide rocker arms (1) to one side in order to gain access to torx screw (13). Use Tooling (B) in order to remove the torx screw from clamp (14). Discard the torx screw.

**Note: Tooling (B) must be used to ensure no damage to the rocker arms.**

9. Place a temporary identification mark on the original electronic unit injector. The electronic unit injector must be reinstalled in the original location in the cylinder head.

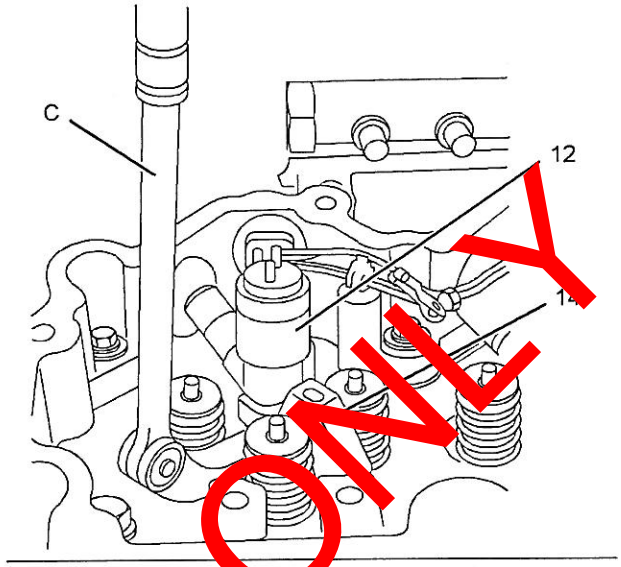



Illustration 45 g01769553

The rocker shaft is not shown for clarity.

10. Use Tooling (C) to pry beneath clamp (14) and free electronic unit injector (12) from the cylinder head.

11. Remove electronic unit injector (12) and clamp (14) from the cylinder head.

**Note:** Always handle electronic unit injectors with care.

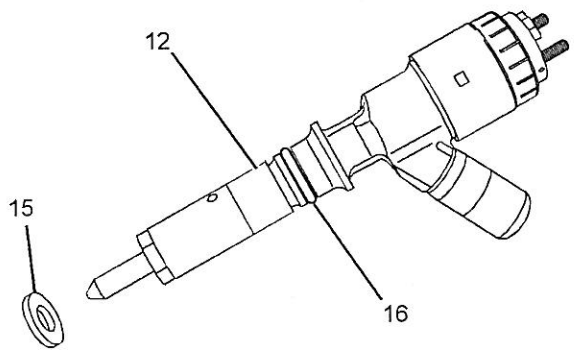



Illustration 46 g01769574

Typical example

12. Remove sealing washer (15). Ensure that the sealing washer is removed from the cylinder head. Remove O-ring seal (16) from the electronic unit injector.

REFERENCE ONLY

## Alternative Removal Procedure

Table 10

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| B | 27610307 | T40 Torx Socket | 1 |
| C | 27610288 | Pry Bar | 1 |

**Start By:**

**a.** Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

**b.** Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

**Note:** This is an optional procedure to remove the electronic unit injectors. The method should ONLY be used when all electronic unit injectors are removed and when the engine is removed from the application.

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

**1.** Turn the fuel supply to the OFF position.

**2.** Turn the battery disconnect switch to the OFF position.

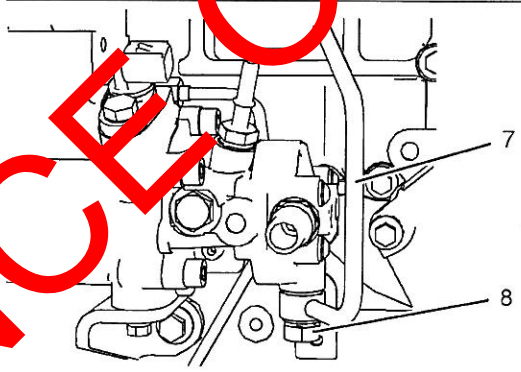



Illustration 47 g01769493

Typical example

**3.** Loosen banjo bolt (8) on the fuel transfer pump sufficiently in order to allow the fuel to drain from tube assembly (7).

REFERENCE ONLY

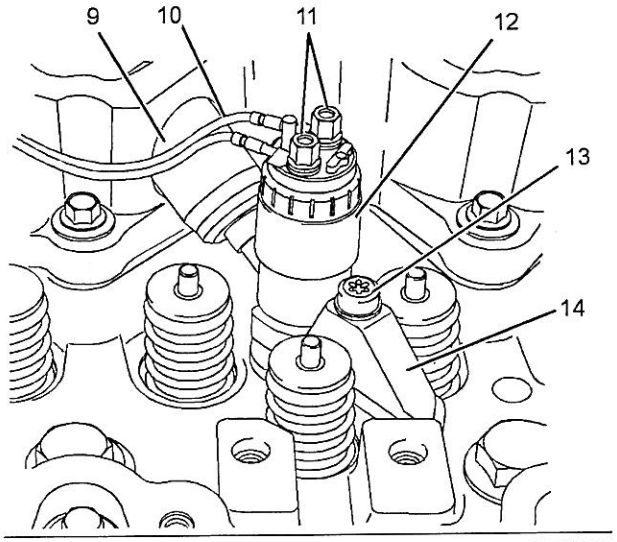



Illustration 48 g01769513
Typical example

4. Place a temporary identification mark on connections (11) for harness assembly (10).

5. Use a deep socket to remove connections (11) from electronic unit injector (12).

6. Use Tooling (B) in order to remove torx screw (13) from clamp (14). Discard the torx screw.

7. Place a temporary identification mark on the original electronic unit injector. The electronic unit injector must be reinstalled in the original location in the cylinder head.

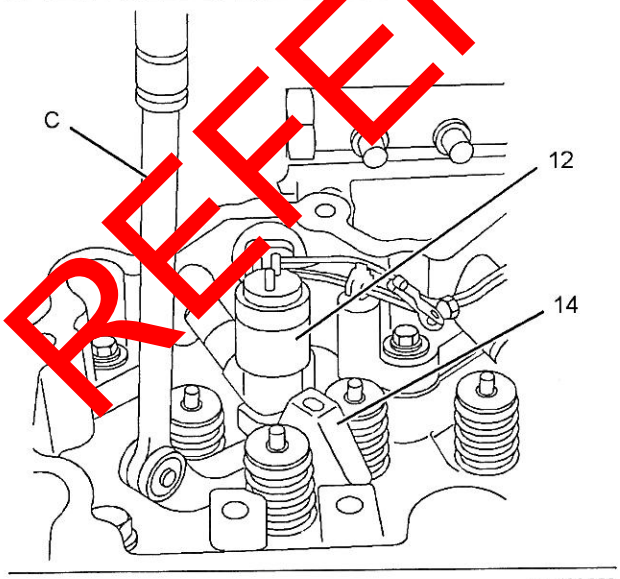



Illustration 49 g01769553
Typical example

8. Use Tooling (C) to pry beneath clamp (14) and free electronic unit injector (12) from the cylinder head.

9. Remove electronic unit injector (12) and clamp (14) from the cylinder head.

**Note:** Always handle electronic unit injectors with care.

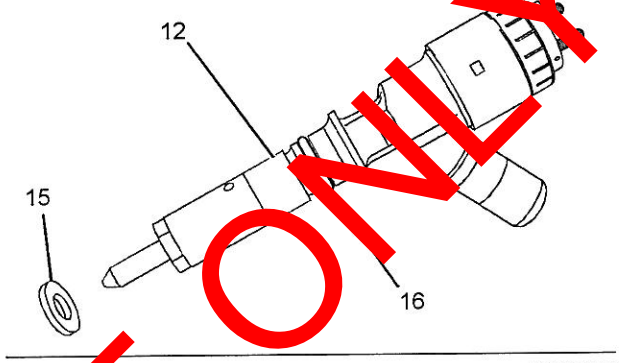



Illustration 50 g01769574
Typical example

10. Remove sealing washer (15). Ensure that the sealing washer is removed from the cylinder head. Remove O-ring seal (16) from the electronic unit injector.

11. Repeat Step 4 through Step 11 in order to remove the remaining electronic unit injectors.

i02933617

# Electronic Unit Injector - Install

## Installation Procedure

Table 11

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 27610307 | T40 Torx Socket | 1 |
| D | GE50028 | Vacuum Pump | 1 |
| | GE50030 | Tube<br>7.9 mm (0.31 inch)<br>Outside Diameter | 1 |
| E | 27610294 | Injector Pipe Nut Tool | 1 |
| F | 27610296 | Torque Wrench | 1 |

REFERENCE ONLY

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to install the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

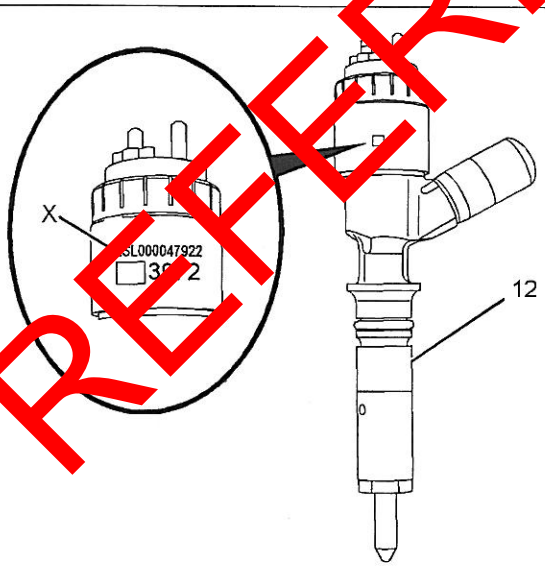



Illustration 51 g01772353

Typical calibration code

1. If a replacement electronic unit injector is installed, the correct trim file for the injector must be programmed into the electronic control module. Refer to Troubleshooting, "Injector Trim File" for more information. The code that is required to obtain the trim file for the injector is located at Position (X).

**Note:** Record Code (X) before the electronic unit injector is installed.

2. Use Tooling (D) in order to remove any fuel from the cylinder.

**Note:** Evacuate as much fuel as possible from the cylinder before installing the electronic unit injector.

3. Ensure that the fuel inlet port of the electronic unit injector is capped. Ensure that the electronic unit injector is clean.

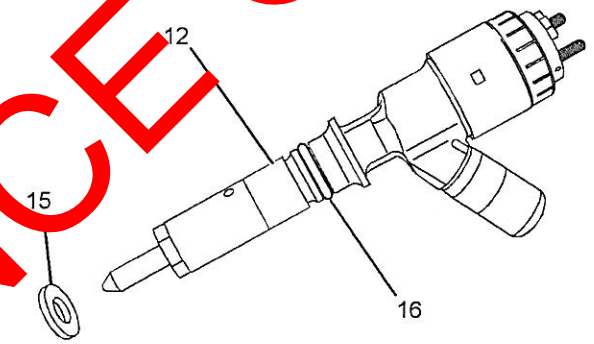



Illustration 52 g01769574

Typical example

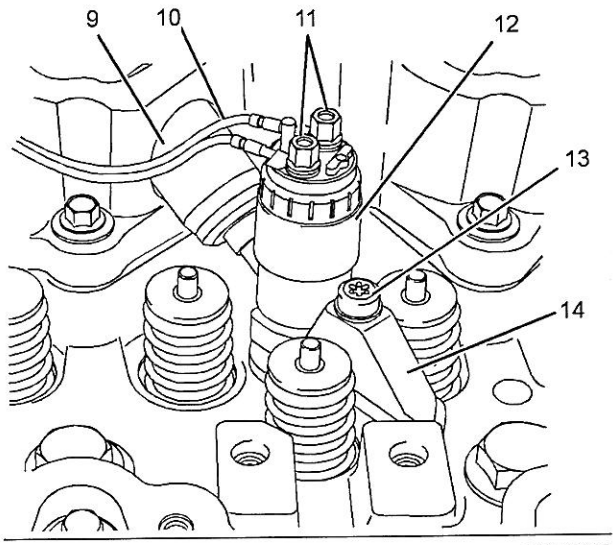
4. On installing an original electronic unit injector, install a new O-ring seal (16) and sealing washer (15) to electronic unit injector (12).

   Ensure that O-ring seal (16) and sealing washer (15) on a new electronic unit injector are not damaged and in place.

**Note:** Do not lubricate the O-ring seal.

5. Ensure that the seat for the electronic unit injector in the cylinder head is clean and free from damage. Ensure that the old sealing washer has been removed from the cylinder head.

REFERENCE ONLY




g01769513

Illustration 53

The rocker shaft is not shown for clarity.

6. Position clamp (14) between the rocker arm and the valve springs. Align electronic unit injector (12) to the bore for the electronic unit injector in the cylinder head. Install the clamp to the electronic unit injector. Ensure that the electronic unit injector is pushed firmly against the seat in the cylinder head.

7. Install a new torx screw (13) to clamp (14). Tighten the torx screw finger tight.

8. Remove the cap from electronic unit injector (12). Install a new seal (9) to electronic unit injector (12) and to the valve mechanism cover base. Ensure that the flange on the seal is flush with the valve mechanism cover base.

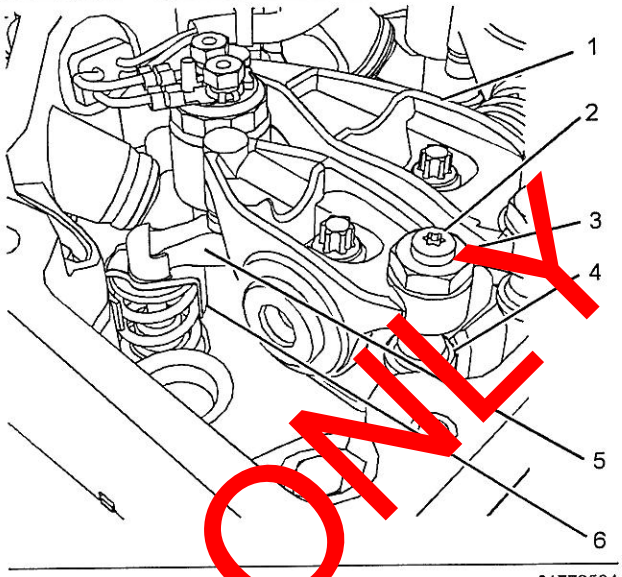
9. Remove the plug from the new fuel injection line. Loosely install the fuel injection line. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

**Note:** Ensure that the ends of the fuel injection line are seated in the electronic unit injector and the fuel manifold. Tighten the nuts finger tight.

10. Use Tooling (B) to tighten torx screw (12) to a torque of 27 N·m (20 lb ft).

**Note: Tooling (B) must be used to ensure no damage to the rocker arms.**

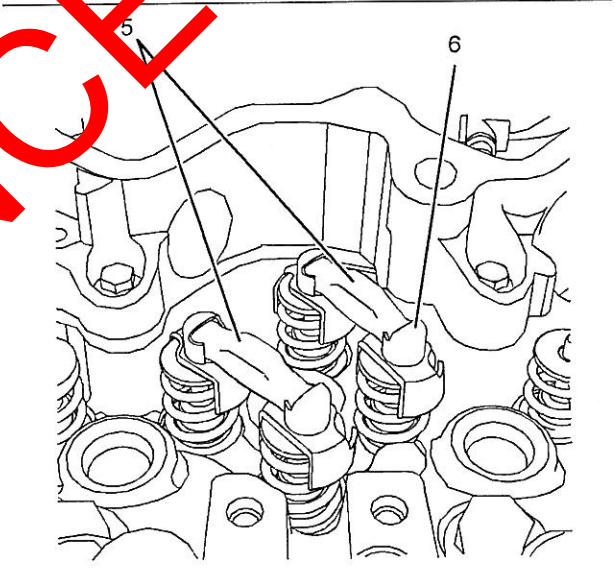
11. Use Tooling (E) to tighten the fuel injection line to a torque of 30 N·m (22 lb ft). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".




g01772534

Illustration 54

Typical example




g01774093

Illustration 55

Typical example

The electronic unit injector is not shown for clarity.

NOTICE

Failure to ensure that ALL valve bridges are correctly seated onto the valve stems will cause interference between the pistons and the valves, resulting in damage to the engine.

12. Install valve bridges (5) to the cylinder head. If valve bridges (5) are equipped with shrouds (6), ensure that the shrouds are located correctly.

REFERENCE ONLY

**Note:** Ensure that used valve bridges are reinstalled in the original location and the original orientation. Do not interchange the location or the orientation of used valve bridges.

13. Ensure that the bottoms of the pushrods are seated in the cups of the valve lifters. Locate the balls of adjusters (2) into the cups of pushrods (4). Adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

14. Use a deep socket to install harness assembly (10) to electronic unit injector (12). Use Tooling (F) to tighten connections (11) to a torque of 2.4 N·m (21 lb in).

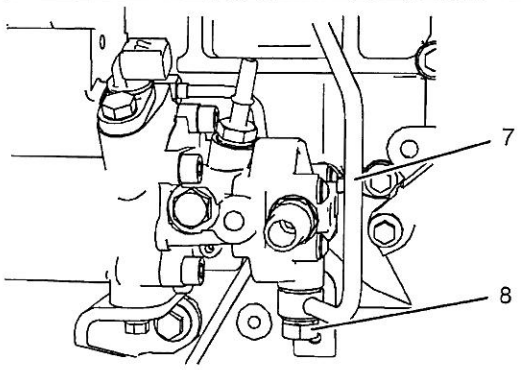



Illustration 56 g017[illegible]

Typical example

15. Tighten banjo bolt (8) on the fuel transfer pump for tube assembly (7). Tighten the banjo bolt to a torque of 21 N·m (15 lb ft).

16. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

17. Turn the fuel supply to the ON position.

18. Turn the battery disconnect switch to the ON position.

19. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System Prime" for more information.

## Alternative Installation Procedure

Table 12

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 27610307 | T40 Torx Socket | 1 |
| D | GE50028 | Vacuum Pump | 1 |
| | GE50030 | Tube 7.9 mm (0.31 inch) Outside Diameter | 1 |
| E | 27610294 | Injector Pipe Nut Tool | 1 |
| F | 27610296 | Torque Wrench | 1 |

**Note:** This is an optional procedure to install the electronic unit injectors. The method should ONLY be used when all electronic unit injectors are installed and when the engine is removed from the application.

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE

Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

REFERENCE ONLY

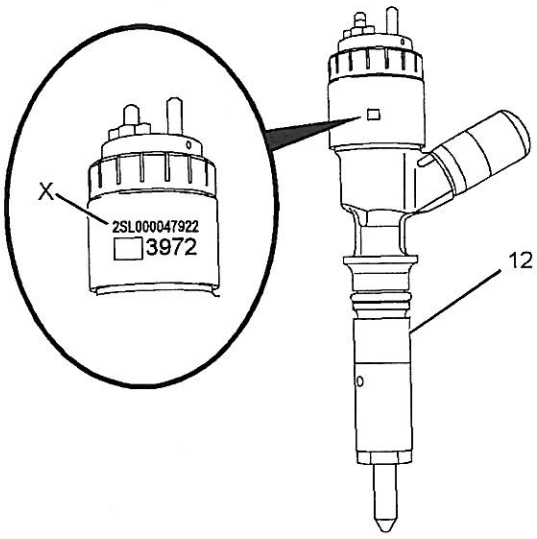



Illustration 57 g01772353
Typical calibration code

1. If a replacement electronic unit injector is installed, the correct trim file for the injector must be programmed into the electronic control module. Refer to Troubleshooting, "Injector Trim File" for more information. The code that is required to obtain the trim file for the injector is located at Position (X).

**Note:** Record Code (X) before the electronic unit injector is installed.

2. Use Tooling (D) to remove any fuel from the cylinder.

**Note:** Evacuate as much fuel as possible from the cylinder before installing the electronic unit injector.

3. Ensure that the fuel inlet port of the electronic unit injector is capped. Ensure that the electronic unit injector is clean.

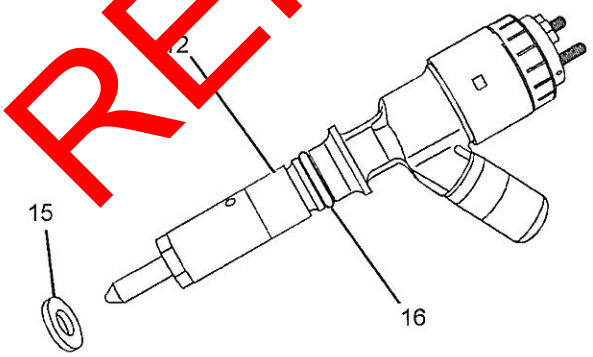



Illustration 58 g01769574
Typical example

4. On installing an original electronic unit injector, install a new O-ring seal (16) and sealing washer (15) to electronic unit injector (12).

   Ensure that O-ring seal (16) and sealing washer (15) on a new electronic unit injector are not damaged and in place.

**Note:** Do not lubricate the O-ring seal.

5. Ensure that the seat for the electronic unit injector in the cylinder head is clean and free from damage. Ensure that the old sealing washer has been removed from the cylinder head.

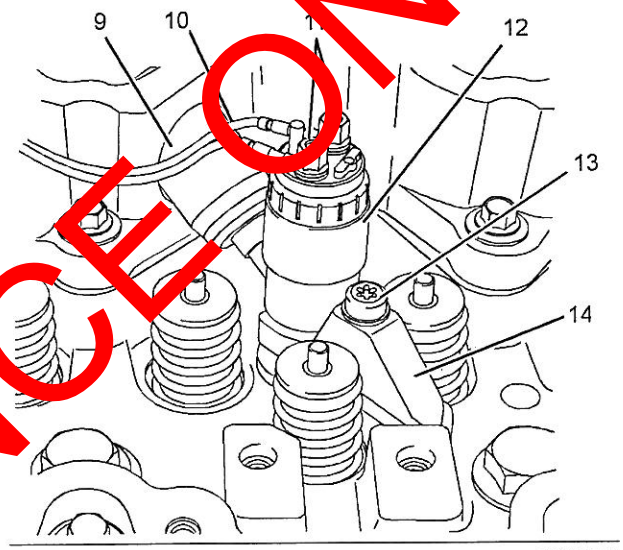



Illustration 59 g01769513
Typical example

6. Install clamp (14) to electronic unit injector (12). Install the electronic unit injector assembly into the original location in the cylinder head.

**Note:** Ensure that the electronic unit injector is pushed firmly against the seat in the cylinder head. Install the electronic unit injector for number one cylinder first. Install the electronic unit injectors in numerical order.

7. Install a new torx screw (13) to clamp (14). Tighten the torx screw finger tight.

8. Remove the cap from electronic unit injector (12). Install a new seal (9) to electronic unit injector (12) and to the valve mechanism cover base. Ensure that the flange on the seal is flush with the valve mechanism cover base.

9. Remove the plugs from the new fuel injection line. Loosely install the fuel injection line. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

REFERENCE ONLY

**Note:** Ensure that the ends of the fuel injection line are seated in the electronic unit injector and the fuel manifold. Tighten the nuts finger tight.

**10.** Use Tooling (B) to tighten torx screw (12) to a torque of 27 N·m (20 lb ft).

**11.** Use Tooling (E) to tighten the fuel injection line to a torque of 30 N·m (22 lb ft). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

**12.** Repeat Step 2 through Step 11 in order to install the remaining electronic unit injectors.

**13.** Use a deep socket to install harness assemblies (10) to electronic unit injectors (12). Use Tooling (F) to tighten connections (11) to a torque of 2.4 N·m (21 lb in).

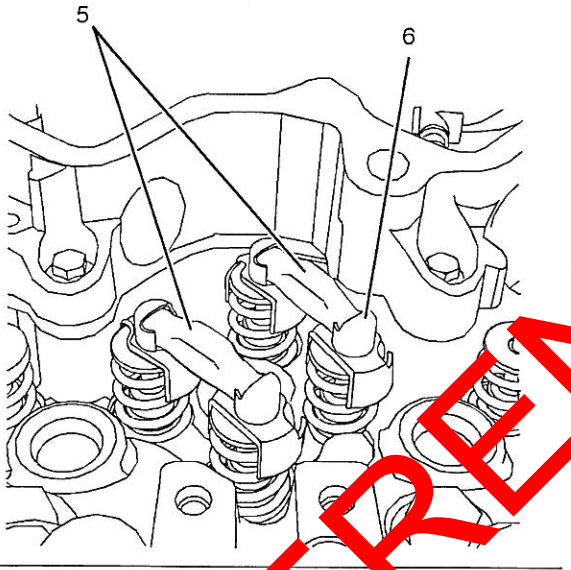



Illustration 60 g01774093
Typical example
The electronic unit injector is not shown for clarity.

NOTICE
Failure to ensure that all valve bridges are correctly seated onto the valve stems will cause interference between the pistons and the valves, resulting in damage to the engine.

**14.** Install valve bridges (5) to the cylinder head. If valve bridges (5) are equipped with shrouds (6), ensure that the shrouds are located correctly.

**15.** Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods - Install".

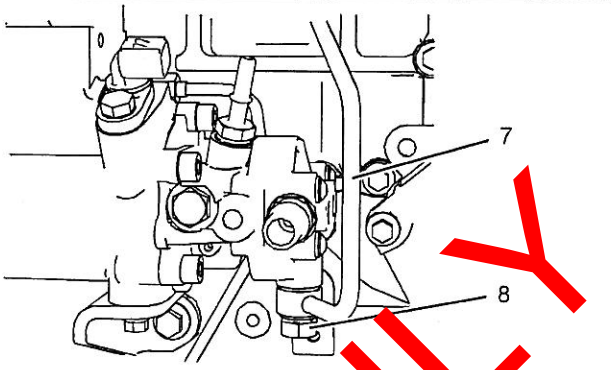



Illustration 61 g01769493
Typical example

**16.** Tighten banjo bolt (8) on the fuel transfer pump for tube assembly (7). Tighten the banjo bolt to a torque of 21 N·m (15 lb ft).

**17.** Turn the fuel supply to the ON position.

**18.** Turn the battery disconnect switch to the ON position.

**19.** Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System Prime" for more information.

i03428965

# Turbocharger - Remove (Top Mounted Turbocharger )

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Plug and cap all open ports and tube assemblies.

REFERENCE ONLY

1. Disconnect the air hose for the turbocharger inlet and for the turbocharger outlet.

2. If the turbocharger has a remote wastegate solenoid, disconnect the hose from the actuator on the turbocharger. Disconnect the hose assembly for the wastegate solenoid from the tube assembly for the oil feed on the turbocharger. The hose assembly is secured with clips.

3. Disconnect the exhaust pipe.

4. If the turbocharger has an exhaust elbow, remove the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

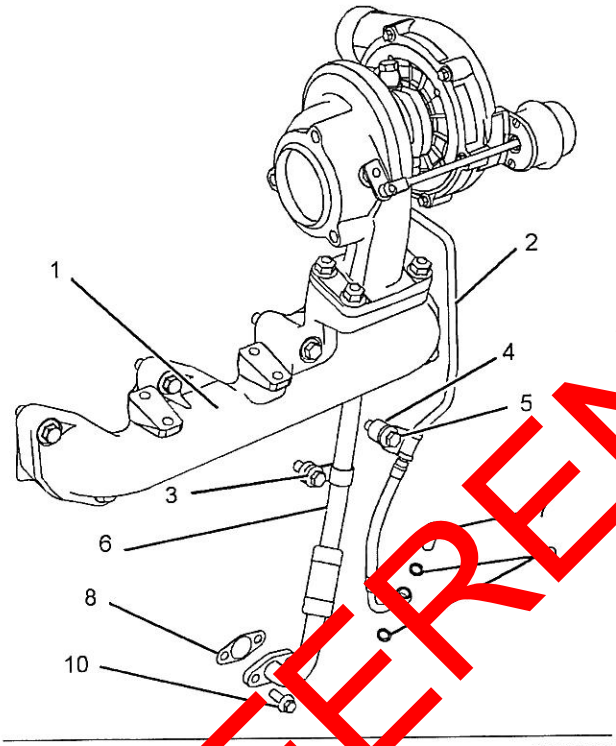



Illustration 62 g01780893

5. Remove bolts (10) in order to disconnect tube assembly (6) from the cylinder block. Remove gasket (

6. Remove bolt (7) in order to disconnect tube assembly (2) from the cylinder block. Remove sealing washers (9).

7. Remove bolt (3) for the tube clip.

8. Remove bolt (5) and spacer (4) for the tube clip.

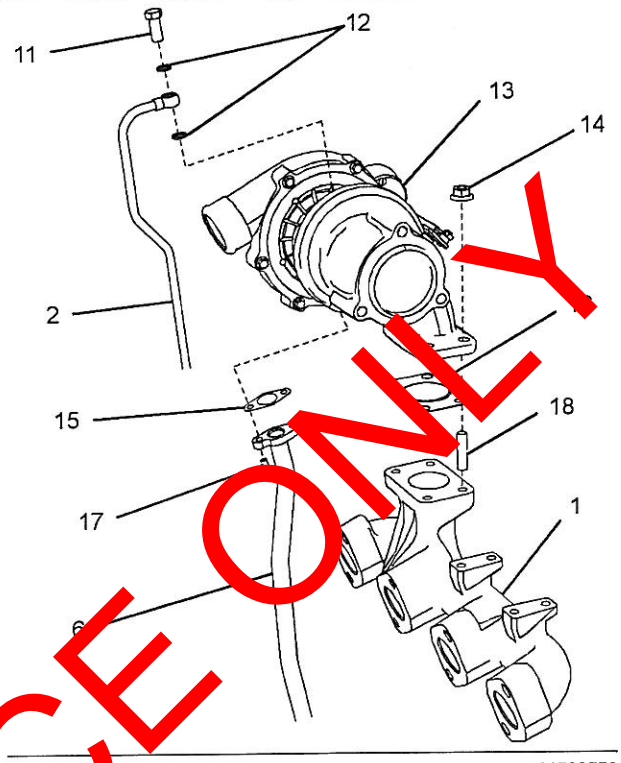



Illustration 63 g01782773

9. Loosen nuts (14).

10. Remove banjo bolt (11) and remove tube assembly (2) for the oil feed from turbocharger (13). Remove sealing washers (12).

11. Remove exhaust manifold (1) and the assembly of the turbocharger from the cylinder head. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install" for the correct procedure.

12. Remove bolts (17) and remove tube assembly (6) for the oil drain from turbocharger (11).

13. Remove gasket (15).

14. Remove nuts (14) and remove turbocharger (13) from exhaust manifold (1).

**Note:** Ensure that the exhaust manifold and the turbocharger are adequately supported during the removal of the turbocharger.

15. Remove gasket (16) from exhaust manifold (1).

16. If necessary, remove studs (18) from exhaust manifold (1).

REFERENCE ONLY

i02933674

# Turbocharger - Remove (Side Mounted Turbochargers)

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Plug and cap all open ports and tube assemblies.

1. Disconnect the air hose for the turbocharger inlet and for the turbocharger outlet (not shown).

2. If the turbocharger is equipped with an exhaust elbow, remove the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

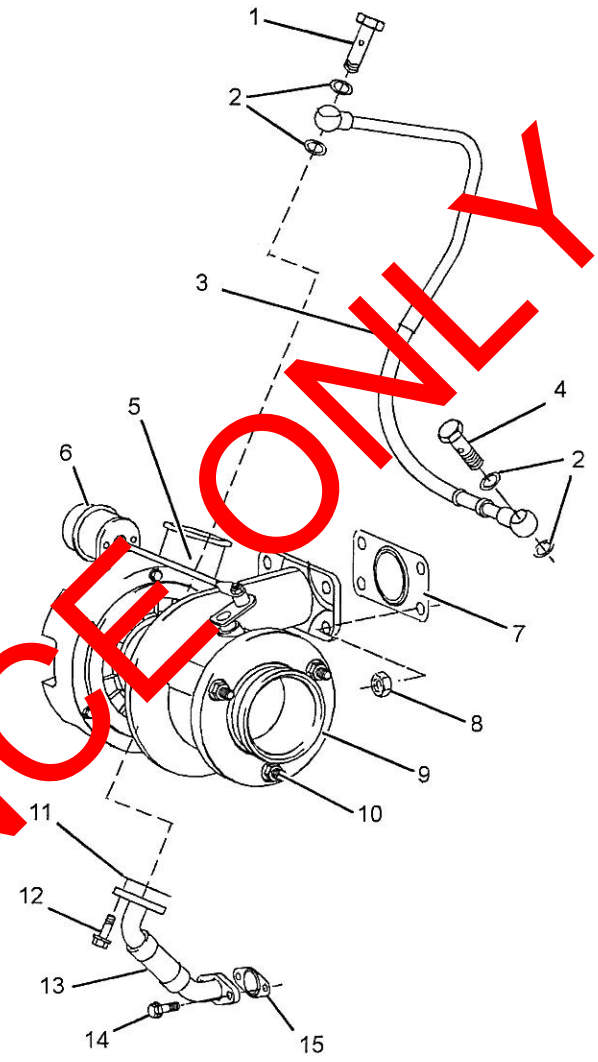



Illustration 64 g01264131
Typical example

3. If the turbocharger is equipped with an adapter (9), Remove nuts (10) and remove adapter (9) from turbocharger (5).

4. Remove banjo bolt (1) and disconnect tube assembly (3) from turbocharger (5). Remove sealing washers (2) from tube assembly (3).

   If necessary, remove tube assembly (3) from the tube assembly for actuator (6). Tube assembly (3) is secured to the tube assembly for the actuator by clips.

5. Disconnect the hose from actuator (6).

6. Remove banjo bolt (4) and remove tube assembly (3) from the cylinder block. Remove sealing washers (2) from tube assembly (3).

REFERENCE ONLY

7. Remove bolts (12). Disconnect tube assembly (13) from turbocharger (5). Remove gasket (11).

   If necessary, remove bolts (14) and remove tube assembly (13) from the cylinder block. Remove gasket (15).

8. Remove nuts (8) and remove turbocharger (5).

**Note:** Do not use the actuator rod to lift the turbocharger.

9. Remove gasket (7).

10. If necessary, remove the studs from the exhaust manifold.

i03431780

# Turbocharger - Install (Top Mounted Turbocharger )

## Installation Procedure

Table 13

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21820117 | POWERPART Threadlock and Nutlock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

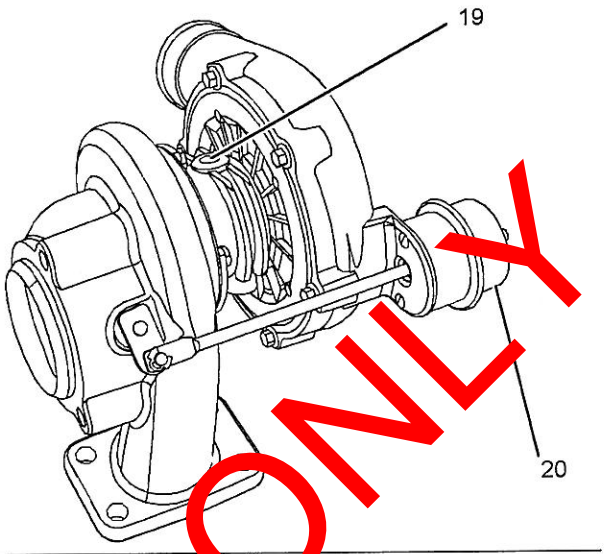



Illustration 65 g01784893
Typical example

1. Ensure that the turbocharger is clean and free from damage. Inspect the turbocharger for wear. Refer to System Operation, Testing and Adjusting, "Turbocharger Inspect" for more information. If the turbocharger is worn, the complete turbocharger must be replaced.

2. Test wastegate actuator (20) for correct operation. Refer to System Operation, Testing and Adjusting, "Turbocharger Inspect". If the wastegate actuator is damaged or the wastegate actuator does not operate within the specified limits, the complete turbocharger must be replaced.

REFERENCE ONLY

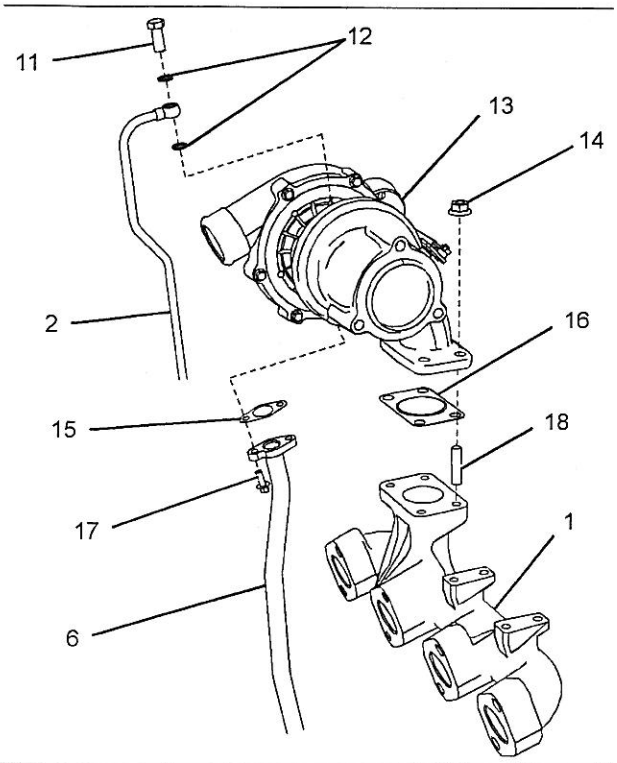



Illustration 66 g01782773

3. Clean the gasket surfaces of the exhaust manifold (1). If necessary, install studs (18) to the exhaust manifold. Tighten the studs to a torque of 18 N·m (13 lb ft).

**Note:** Support the exhaust manifold during installation of the turbocharger.

4. Install a new gasket (16) to exhaust manifold (1).

5. Position turbocharger (13) on exhaust manifold (1).

6. Install nuts (14). Tighten the nuts to a torque of 44 N·m (32 lb ft).

7. Ensure that tube assembly (6) is clean and free from damage. Replace any damaged components.

8. Position a new gasket (15) and bolts (17) onto tube assembly (6).

9. Install tube assembly (6) to turbocharger (13). Tighten bolts (17) finger tight.

10. Install exhaust manifold (1) and the assembly of the turbocharger to the cylinder head. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install" for the correct procedure.

11. Remove the plug from oil inlet port (19). Refer to Illustration 65. Lubricate the turbocharger bearings with clean engine oil through the oil inlet port. Rotate the wheel of the compressor several times in order to lubricate the bearings.

12. Ensure that tube assembly (2) is clean and free from damage. Replace any damaged components.

13. Install banjo bolt (11) and new sealing washers (12) to tube assembly (2).

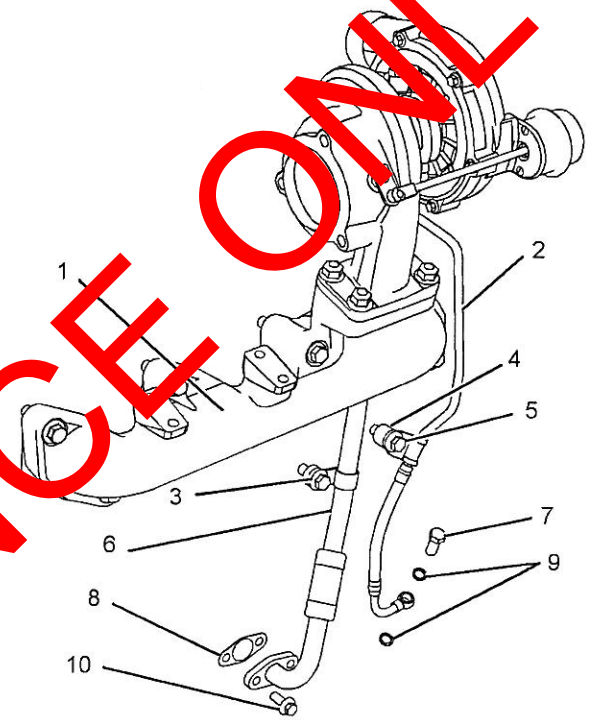



Illustration 67 g01780893

14. Install banjo bolt (7) and new sealing washers (9) to tube assembly (2).

15. Install tube assembly (2) to turbocharger (13). Tighten banjo bolt (11) finger tight. Refer to Illustration 66.

16. Tighten banjo bolt (7) to the cylinder block finger tight.

17. Position a new gasket (8) between the flange of tube assembly (6) and the cylinder block. Install bolts (10) finger tight.

18. Tighten banjo bolt (7) to a torque of 20 N·m (14 lb ft). Tighten bolts (10) to a torque of 22 N·m (16 lb ft).

19. Tighten banjo bolt (11) to a torque of 20 N·m (14 lb ft). Tighten bolts (17) to a torque of 9 N·m (80 lb in). Refer to Illustration 66.

REFERENCE ONLY

**20.** Install bolt (3) for the tube clip to the cylinder block. Tighten bolt (3) to a torque of 44 N·m (32 lb ft).

**21.** Install bolt (5) and spacer (4) for the tube clip to the cylinder block. Tighten bolt (5) to a torque of 44 N·m (32 lb ft).

**22.** If the turbocharger has an exhaust elbow, install the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

**23.** Connect the exhaust pipe.

**24.** If the turbocharger has a remote wastegate solenoid, connect the hose to the actuator on the turbocharger. Connect the hose assembly for the wastegate solenoid to the tube assembly for the oil feed on the turbocharger. The hose assembly is secured with clips.

**25.** Connect the air outlet hose to turbocharger (13).

If the engine has an air pipe, install the air pipe and install the gasket to the cylinder head. Apply Tooling (A) to the fasteners for the air pipe. Tighten the fasteners to a torque of 22 N·m (16 lb ft).

Tighten the hose clamps to a torque of 5 N·m (44 lb in).

**Note:** If the air outlet hose has a reflective heat shield, ensure that the reflective heat shield is installed toward the engine.

**26.** Connect the air inlet hose to turbocharger (13).

u02933673

# Turbocharger - Install (Side Mounted Turbochargers)

## Installation Procedure

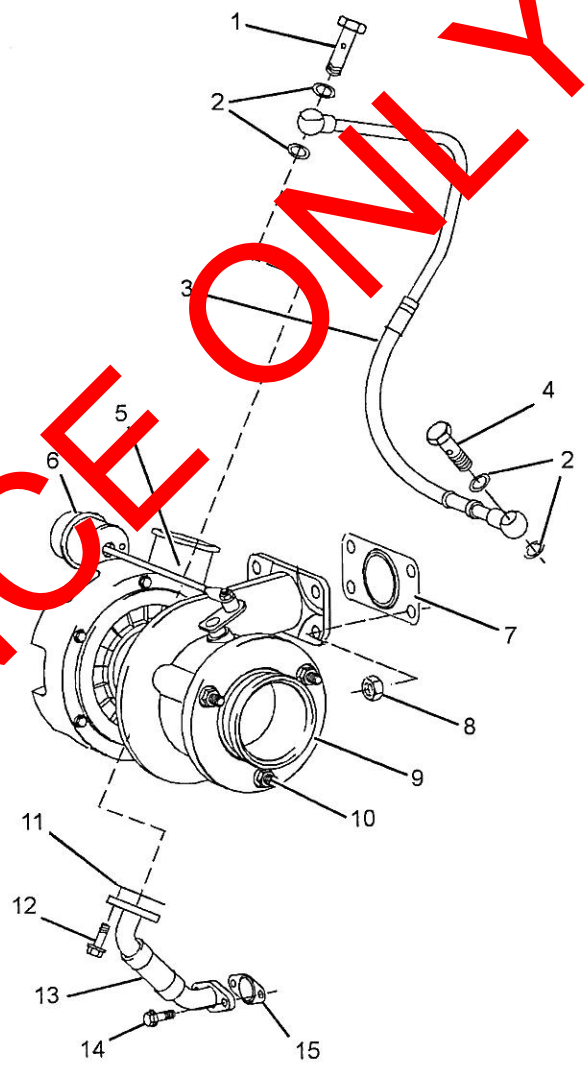
Table 14

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21820117 | POWERPART Threadlock and Nutlock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**1.** Ensure that the turbocharger is clean and free from damage. Inspect the turbocharger for wear. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for more information. If the turbocharger is worn, the complete turbocharger must be replaced.




g01264131
Illustration 68
Typical example

**2.** Test actuator (6) for correct operation. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect". If the actuator is damaged or the actuator does not operate within the specified limits, the complete turbocharger must be replaced.

**3.** Clean the gasket surfaces of the exhaust manifold. If necessary, install the studs to the exhaust manifold. Tighten the studs to a torque of 18 N·m (13 lb ft).

**4.** Install a new gasket (7) to the exhaust manifold.

REFERENCE ONLY

5. Position turbocharger (5) onto the exhaust manifold and install nuts (8). Tighten the nuts to a torque of 44 N·m (32 lb ft).

**Note:** Do not use the actuator rod to lift the turbocharger.

6. Position a new gasket (11) and tube assembly (13) onto turbocharger (5). Install bolts (12) finger tight.

7. Position a new gasket (15) onto the cylinder block. Install bolts (14) finger tight.

8. Tighten bolts (12) to a torque of 9 N·m (80 lb in). Tighten bolts (14) to a torque of 22 N·m (16 lb ft).

9. Lubricate the bearings of turbocharger (5) with clean engine oil through the oil inlet port. Rotate the shaft of the turbocharger in order to distribute the lubricant.

10. Position tube assembly (3) onto turbocharger (5). Install new washers (2) and banjo bolt (1) to tube assembly (3). Tighten the banjo bolt finger tight.

11. Install new washers (2) and banjo bolt (4) onto tube assembly (3). Connect the tube assembly to the cylinder block. Tighten the banjo bolt finger tight.

12. Tighten banjo bolts (1) and (4) to a torque of 18 N·m (13 lb ft).

**Note:** Ensure that the tube assembly does not come into contact with any other engine components.

13. Connect the hose to actuator (6). If necessary, secure tube assembly (3) to the tube assembly for actuator (6). Tube assembly (3) is secured to the tube assembly for the actuator by clips.

14. If the turbocharger has an exhaust elbow, install the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

15. If the turbocharger has an adapter (9), position the adapter onto the turbocharger. Tighten three nuts (10) progressively. Tighten the nuts to a torque of 25 N·m (18 lb ft).

**Note:** Ensure that the adapter is square with the face of the turbocharger.

16. Connect the air outlet hose to turbocharger (5).

    If the engine has an air pipe, install the air pipe and install the gasket to the cylinder head. Apply Tooling (A) to the bolts for the air pipe. Tighten the bolts to a torque of 22 N·m (16 lb ft).

    Tighten the hose clamps to a torque of 5 N·m (44 lb in).

**Note:** If the air outlet hose has a reflective heat shield, ensure that the reflective heat shield is installed toward the engine.

17. Connect the air inlet hose to turbocharger (5).

i02933679

# Wastegate Solenoid - Remove and Install

## Removal Procedure

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to keep contaminants from entering the system.

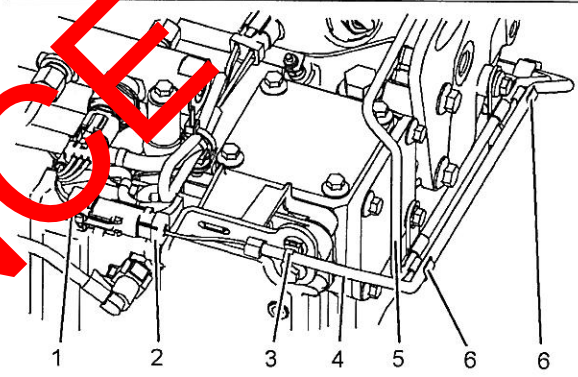



Illustration 69 g01247498

Typical example

1. Follow Step 1.a through Step 1.d in order to disconnect the harness assembly for the wastegate solenoid.

   a. Slide locking tab (1) into the unlocked position.

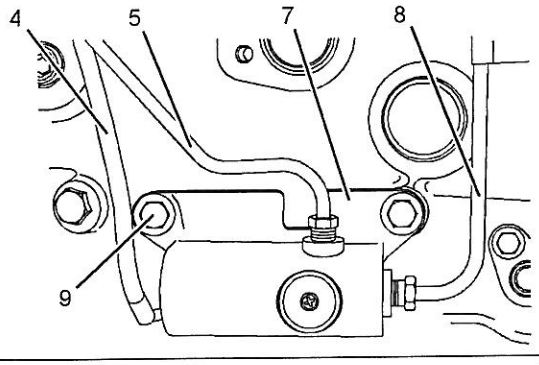
   b. Disconnect plug (2) from the engine wiring harness.

   c. Cut cable straps (3).

**Note:** Identify the position of all cable straps for installation purposes.

   d. Remove harness assembly (4) from tube assembly (5). The harness assembly is secured to the tube assembly by plastic clips (6).

REFERENCE ONLY




g01247569

Illustration 70

Typical example

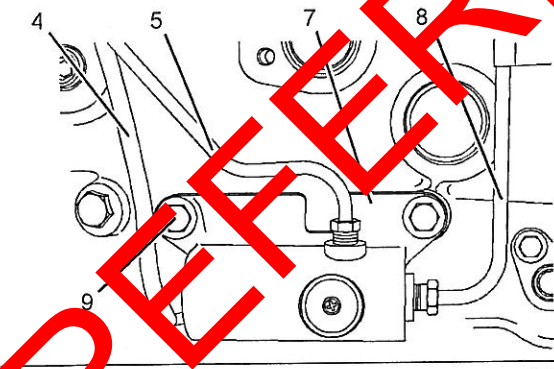
2. Disconnect tube assembly (5) from wastegate solenoid (7).

3. Disconnect tube assembly (8) from wastegate solenoid (7). Remove tube assembly (8) from the tube assembly for the oil feed for the turbocharger. Tube assembly (8) is secured to the tube assembly for the oil feed for the turbocharger by spring clips.

**Note:** Tube assembly (8) must be loose in order to release the tube assembly from the wastegate solenoid.

4. Remove bolts (9) and remove wastegate solenoid (7) from the cylinder block.

## Installation Procedure




g01247569

Illustration 71

Typical example

1. Loosely install wastegate solenoid (7) to tube assembly (5).

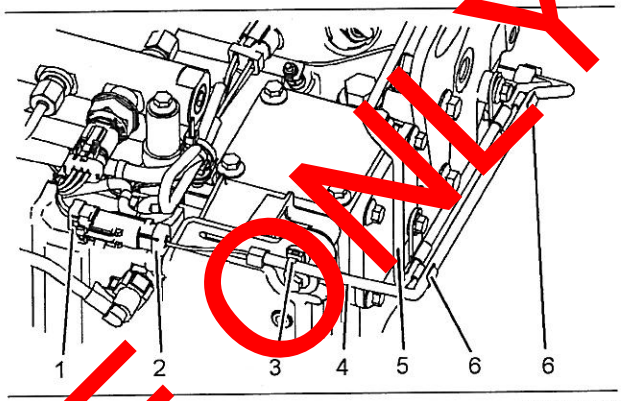
2. Loosely install tube assembly (8) to wastegate solenoid (7).

3. Install bolts (9). Tighten bolts (9) to a torque of 44 N·m (32 lb ft).

4. Tighten tube assembly (5) and tube assembly (8) to a torque of 18 N·m (13 lb ft).

5. Secure tube assembly (8) to the tube assembly for the oil feed for the turbocharger. Tube assembly (8) is secured by spring clips.

**Note:** Ensure that the tube assemblies do not contact any other engine component.




g01247498

Illustration 72

Typical example

6. Follow Step 6 through Step 6.d in order to connect the wire lead for the wastegate solenoid.

   a. Install harness assembly (4) to tube assembly (5). The harness assembly is secured to the tube assembly by plastic clips (6).

   b. Connect plug (2) to the engine harness assembly.

   c. Slide locking tab (1) into the locked position.

   d. Install new cable straps (3) to the previously identified positions.

i02933629

# Exhaust Manifold - Remove and Install (Top Mounted Exhaust Manifold)

## Removal Procedure

1. Disconnect all hoses, tube assemblies and wire leads from the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" for more information.

REFERENCE ONLY

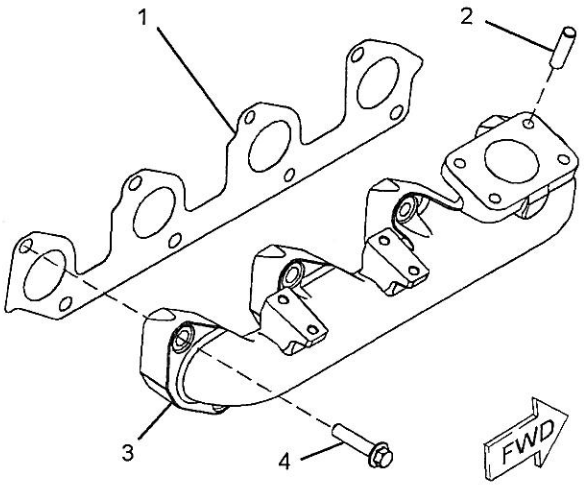



Illustration 73 g01245092
Typical example

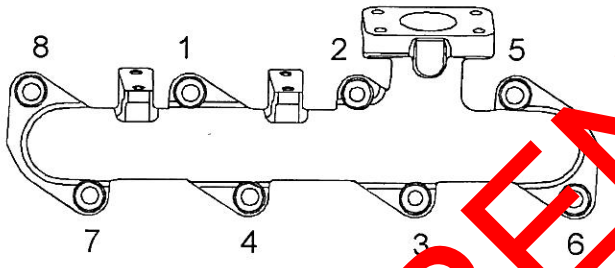



Illustration 74 g01789673
Tightening sequence for the exhaust manifold

2. Loosen bolts (4) in reverse numerical order to the sequence that is shown in Illustration 74.

**Note:** This will help prevent distortion of the exhaust manifold.

3. Remove bolts (4) from exhaust manifold (3).

**Note:** Support the manifold as the bolts are removed.

4. Remove the assembly of exhaust manifold (3) and the turbocharger.

5. Remove exhaust manifold gasket (1).

6. Remove the turbocharger from exhaust manifold (3). Refer to Disassembly and Assembly, "Turbocharger - Remove" for more information.

7. If necessary, remove studs (2) from exhaust manifold (3).

## Installation Procedure (Top Mounted Exhaust Manifold)

Table 15

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Stud M10 by 100 mm | 2 |

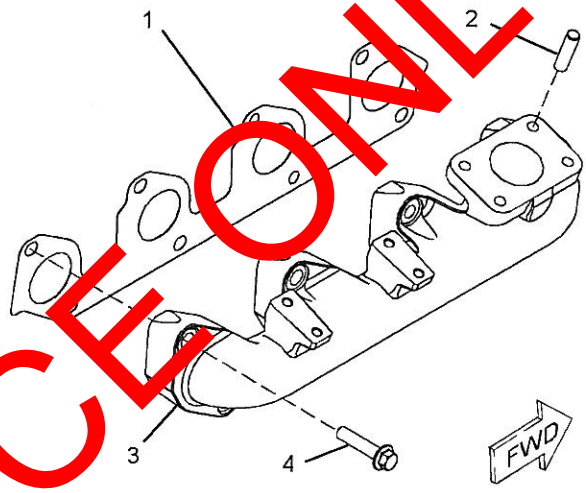



Illustration 75 g01245092
Typical example

1. Ensure that the exhaust manifold is clean and free from damage. If necessary, replace the exhaust manifold. Clean the gasket surface of the cylinder head.

2. If necessary, install studs (2) to exhaust manifold (3). Tighten the studs to a torque of 18 N·m (13 lb ft).

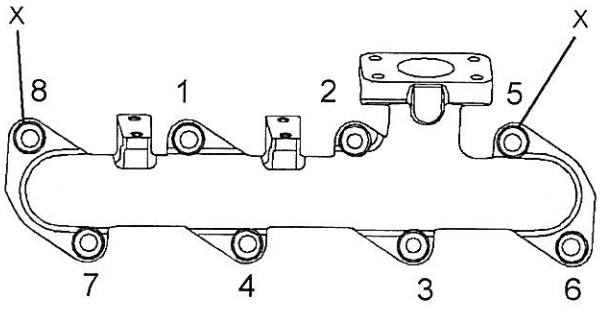



Illustration 76 g01789677
Tightening sequence for the exhaust manifold

3. Install Tooling (A) to the cylinder head in Positions (X). Refer to Illustration 76.

REFERENCE ONLY

4. Position a new exhaust manifold gasket (1) onto Tooling (A).

**Note:** Ensure that the exhaust manifold gasket is correctly oriented.

5. Install the tube assembly for the oil drain from the turbocharger to the cylinder block. Refer to Disassembly and Assembly, "Turbocharger - Install" for more information.

6. Align exhaust manifold (3) with Tooling (A). Install the exhaust manifold to the cylinder head.

7. Install new bolts (4) finger tight.

8. Remove Tooling (A). Install remaining bolts (4) finger tight.

9. Tighten bolts (4) to a torque of 40 N·m (30 lb ft) in the sequence that is shown in Illustration 76.

**End By:**

a. Install the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Install".

i03440266

# Exhaust Manifold - Remove and Install (Side Mounted Exhaust Manifold)

## Removal Procedure

**Start By:**

a. Remove the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove".

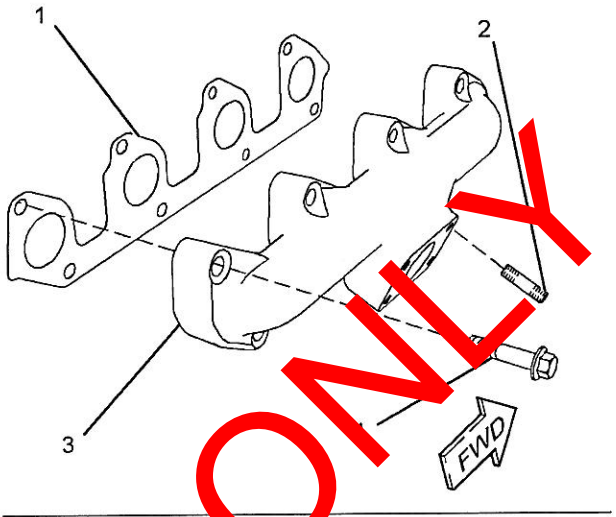



Illustration 77 g01789922
Typical example

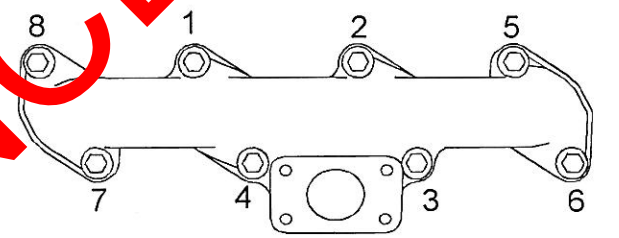



Illustration 78 g01789982
Tightening sequence for the exhaust manifold

1. Loosen bolts (4) in reverse numerical order. Refer to Illustration 78.

**Note:** This will help prevent distortion of the exhaust manifold.

2. Remove bolts (4) from exhaust manifold (3).

**Note:** Support the manifold as the bolts are removed.

3. Remove exhaust manifold (3).

4. Remove exhaust manifold gasket (1).

5. If necessary, remove studs (2) from exhaust manifold (3).

REFERENCE ONLY

## Installation Procedure (Side Mounted Exhaust Manifold)

Table 16

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Stud M10 by 100 mm | 4 |

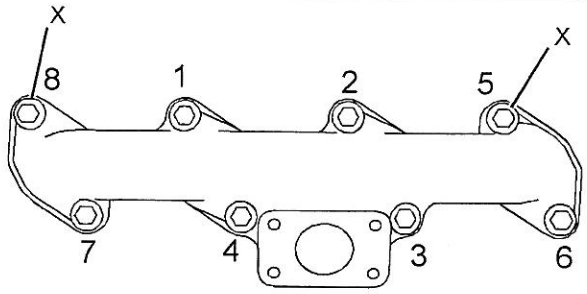



Illustration 79 g01790878

Tightening sequence for the exhaust manifold

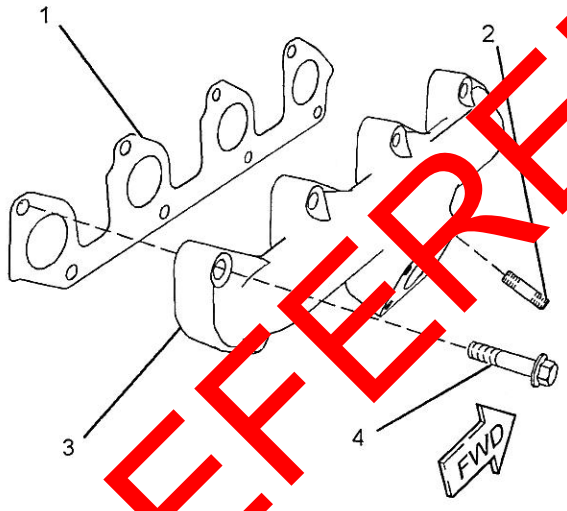



Illustration 80 g01789922

Typical example

1. Ensure that the exhaust manifold is clean and free from damage. If necessary, replace the exhaust manifold. Clean the gasket surface of the cylinder head.

2. If necessary, install studs (2) to exhaust manifold (3). Tighten the studs to a torque of 18 N·m (13 lb ft).

3. Install Tooling (A) to the cylinder head in Positions (X). Refer to Illustration 79.

4. Position a new exhaust manifold gasket (1) onto Tooling (A).

**Note:** Ensure that the exhaust manifold gasket is correctly oriented.

5. Align exhaust manifold (3) with Tooling (A). Install the exhaust manifold to the cylinder head.

6. Install new bolts (4) finger tight.

7. Remove Tooling (A). Install remaining bolts (4) finger tight.

8. Tighten bolts (4) to a torque of 40 N·m (30 lb ft). Tighten the bolts in the sequence that is shown in Illustration 79.

**End By:**

a. Install the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Install".

i02933628

## Exhaust Elbow - Remove and Install

### Removal Procedure

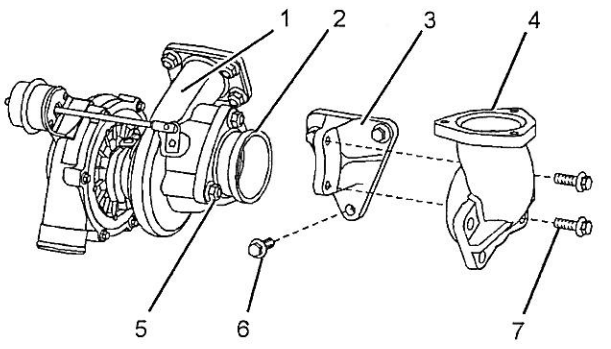



Illustration 81 g01798993

Typical example

1. Remove bolts (7) and remove exhaust elbow (4) from turbocharger (1). Note the orientation of the exhaust elbow.

2. Remove nuts (5) and remove adapter (2).

3. If necessary, remove bolts (6) and remove support bracket (3) from the cylinder block.

REFERENCE ONLY

## Installation Procedure

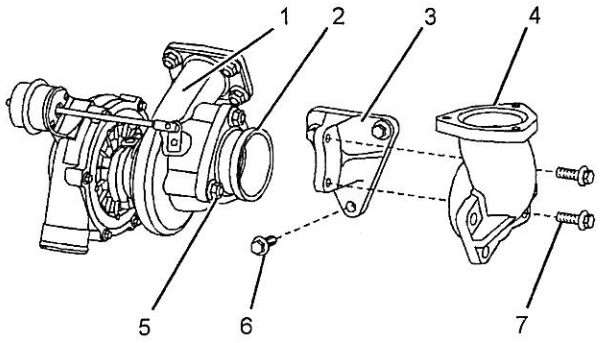



Illustration 82 g01798993

Typical example

1. Ensure that the exhaust elbow, the adapter and the outlet of the turbocharger are free from damage. Replace any components that are damaged.
2. Install adapter (2) to turbocharger (1).
3. Install nuts (5). Tighten the nuts progressively. Tighten nuts (5) to a torque of 25 N·m (18 lb ft).
4. If necessary, install support bracket (3) to the cylinder block and install bolts (6). Tighten the bolts to a torque of 44 N·m (32 lb ft).
5. Install bolts (7) finger tight.
6. Ensure that the gap between the turbocharger and the exhaust elbow is evenly spaced.
7. Tighten bolts (7) to a torque of 44 N·m (32 lb ft).

i02933660

# Inlet and Exhaust Valve Springs - Remove and Install

## Removal Procedure

Table 17

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Circlip Plier | 1 |
| B | 21825739 | Valve Spring Compressor | 1 |
| | 27610235 | Adapter | 1 |
| | 27610295 | Head | 1 |
| C(1) | 21825577 | Crankshaft Turning Tool | 1 |
| C(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

a. Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

**Note:** Either Tooling (C) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The following procedure should be adopted in order to remove the valve springs when the cylinder head is installed to the engine. Refer to Disassembly and Assembly, "Inlet and Exhaust Valves - Remove and Install" for the procedure to remove the valve springs from a cylinder head that has been removed from the engine.

**Note:** Ensure that the appropriate piston is at the top center position before the valve spring is removed. Failure to ensure that the piston is at the top center position may allow the valve to drop into the cylinder bore.

NOTICE
Plug the apertures for the push rods in the cylinder head in order to prevent the entry of loose parts into the engine.

REFERENCE ONLY

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

1. Turn the battery disconnect switch to the OFF position.

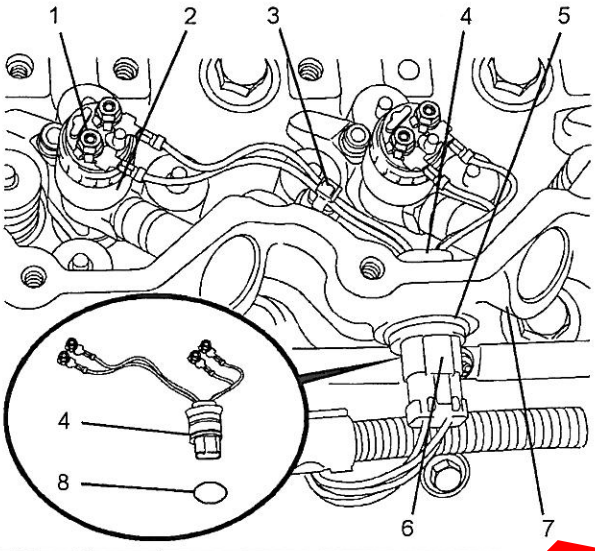



Illustration 83 g0146[illegible]91
Typical example

2. Follow Step 2.a through Step 2.h in order to remove the harness assemblies for the electronic unit injectors.

   a. Place a temporary identification mark on connections (1).

   b. Use a deep socket to remove connections (1) from electronic unit injectors (2).

   c. Cut cable straps (3).

   d. Disconnect plug (6) from harness assembly (4).

   e. Use Tooling (A) to remove circlip (5).

   f. From the outside of valve mechanism cover base (7), push harness assembly (4) inward. Withdraw the harness assembly from the valve mechanism cover base.

   g. Remove O-ring seal (8) from harness assembly (4).

   h. Repeat Step 2.a through Step 2.g in order to remove the remaining harness assembly.

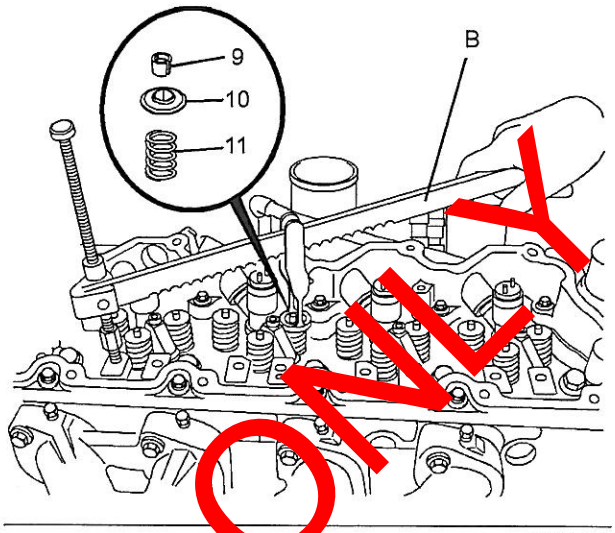



Illustration [illegible] g01469792
Typical example

**WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

NOTICE
Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

3. Follow Step 3.a through Step 3.d in order to position the appropriate piston at top dead center.

   a. Install Tooling (B) in position on the cylinder head in order to compress a valve spring for the appropriate piston.

   b. Use Tooling (B) in order to compress valve spring (11) and open the valve slightly.

**Note:** Do not compress the spring so that valve spring retainer (10) touches the valve stem seal.

   c. Use Tooling (C) in order to rotate the crankshaft carefully, until the piston touches the valve.

**Note:** Do not use excessive force to turn the crankshaft. The use of force can result in bent valve stems.

REFERENCE ONLY

d. Continue to rotate the crankshaft and gradually release the pressure on Tooling (B) until the piston is at the top center position. The valve is now held in a position that allows the valve spring to be safely removed.

**Note:** Valve springs must be replaced in pairs for the inlet valve or the exhaust valve of each cylinder. If all valve springs require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. Ensure that all of the valve springs are installed before changing from one pair of cylinders to another pair of cylinders.

NOTICE
Do not turn the crankshaft while the valve springs are removed.

4. Apply sufficient pressure to Tooling (B) in order to allow removal of valve keepers (9).

**Note:** Do not compress the spring so that valve spring retainer (10) touches the valve stem seal .

Remove valve keepers (9).

5. Slowly release the pressure on Tooling (B).

6. Remove valve spring retainer (10) and remove valve spring (11).

7. If necessary, remove the valve stem seals.

8. Repeat Step 4 through Step 7 in order to remove the remaining valve springs from the appropriate cylinder.

9. Remove Tooling (B).

## Installation Procedure

Table 18

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | Circlip Pliers | 1 |
| B | 21825739 | Valve Spring Compressor | 1 |
| | 27610235 | Adapter | 1 |
| | 27610295 | Head | 1 |
| C(1) | 21825576 | Crankshaft Turning Tool | 1 |
| C(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| D | 21820221 | POWERPART Rubber Grease | 1 |
| E | 2761029[illegible] | Torque Wrench | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (C) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Do not turn the crankshaft while the valve springs are removed.

NOTICE
Plug the apertures for the push rods in the cylinder head in order to prevent the entry of loose parts into the engine.

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

1. Inspect the valve springs for the correct length. Refer to Specifications, “Cylinder Head Valves ”.

2. If necessary, install a new valve stem seal onto the valve guide.

**Note:** The outer face of the valve guide must be clean and dry before installing the valve stem seal.

REFERENCE ONLY

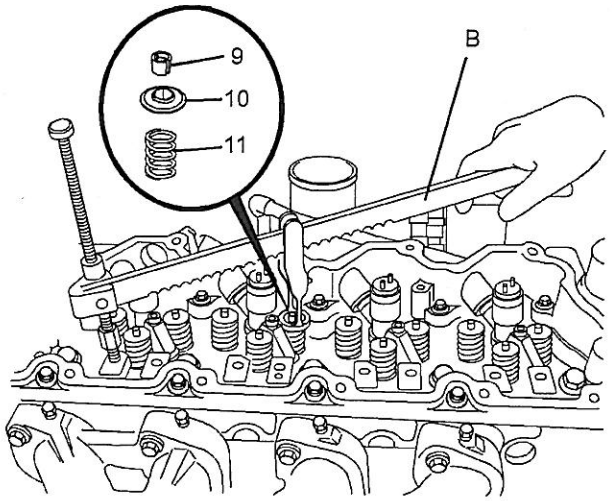



Illustration 85 g01469792
Typical example

3. Install valve spring (11) onto the cylinder head. Position valve spring retainer (10) onto valve spring (11).

**⚠ WARNING**

**Improper assembly of parts that are spring loaded can cause bodily injury.**

**To prevent possible injury, follow the established assembly procedure and wear protective equipment.**

NOTICE
Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

4. Install Tooling (B) in the appropriate position on the cylinder head in order to compress the valve spring.

5. Apply sufficient pressure to Tooling (B) in order to install valve keepers (9).

**Note:** Do not compress the spring so that valve spring retainer (10) touches the valve stem seal .

Install the valve spring keepers.

6. Carefully release the pressure on Tooling (B).

**Note:** Ensure that the valve keepers are correctly seated.

7. Repeat Step 2 through Step 6 for the remaining valves.

**⚠ WARNING**

**The valve spring keepers can be thrown from the valve when the valve spring compressor is released. Ensure that the valve spring keepers are properly installed on the valve stem. To help prevent personal injury, keep away from the front of the valve spring keepers and valve springs during the installation of the valves.**

8. Remove Tooling (B).

**Note:** Valve springs must be replaced in pairs for the inlet valve or the exhaust valve of each cylinder. If all valve springs require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. Ensure that all of the valve springs are installed before changing from one pair of cylinders to another pair of cylinders.

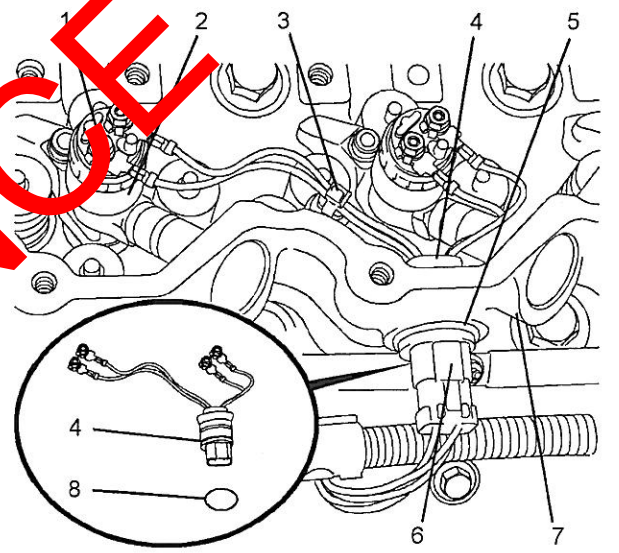



Illustration 86 g01469791
Typical example

9. Follow Step 9.a through Step 9.g in order to install the harness assemblies for the electronic unit injectors.

   a. Ensure that harness assembly (4) and the bore in the valve mechanism cover base (7) are clean and free from damage.

   b. Use Tooling (D) to lubricate a new O-ring seal. Install new O-ring seal (8) onto harness assembly (4).

   c. From the inside of valve mechanism cover base (7), push harness assembly (4) into the valve mechanism cover base.

   d. Use Tooling (A) to install circlip (5).

REFERENCE ONLY

e. Connect plug (6) to harness assembly (4).

f. Use a deep socket to install connections (1) to electronic unit injectors (2). Use Tooling (E) to tighten the connections to a torque of 2.5 N·m (22 lb in).

g. Install a new cable strap (3).

**Note:** Ensure that the cable straps conform to the Perkins specification.

h. Repeat Step 9.a through Step 9.g in order to install the remaining harness assembly.

10. Turn the battery disconnect switch to the ON position.

**End By:**

a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods - Install".

i02933661

# Inlet and Exhaust Valves - Remove and Install

## Removal Procedure

Table 19

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21825666 | Valve Spring Compressor | 1 |
| | 27610235 | Adapter | 1 |
| | 27610295 | Head | 1 |

**Start By:**

a. Remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the bottom face of the cylinder head. Check the depth of the valves below the face of the cylinder head before the valve springs are removed. Refer to Specifications, "Cylinder Head Valves" for the correct dimensions.

2. Place a temporary identification mark on the heads of the valves in order to identify the correct position. Inlet valves have a recess in the center of the head.

**Note:** Do not stamp the heads of the valve. Stamping or punching the heads of the valves could cause the valves to fracture.

3. Use a suitable lifting device to position the cylinder head with the valve springs upward. The weight of the cylinder head is approximately 56 kg (125 lb).

**Note:** Ensure that the cylinder head is kept on a clean, soft surface in order to prevent damage to the machined face.

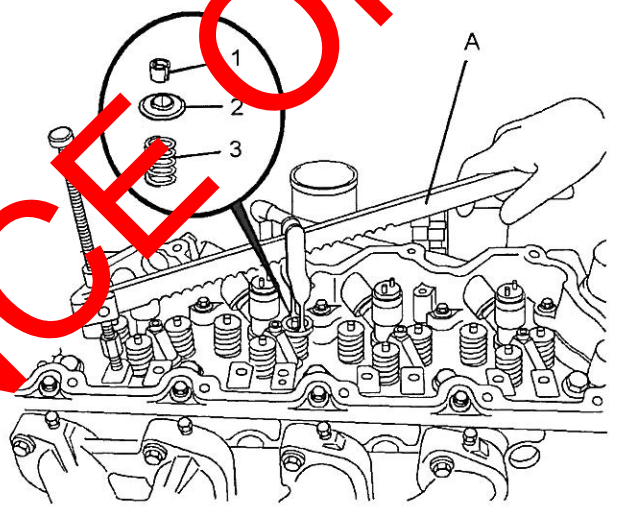



Illustration 87 g01469809
Typical example

**WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

4. Install Tooling (A) in position on the cylinder head in order to compress the appropriate valve spring.

NOTICE
Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

REFERENCE ONLY

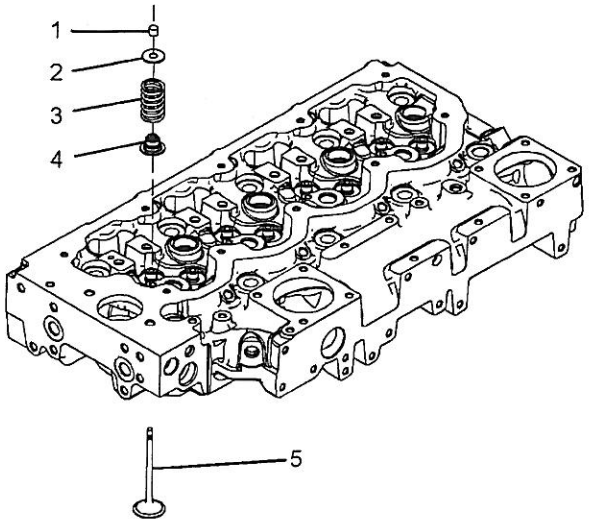



Illustration 88 g01245105

5. Apply sufficient pressure to Tooling (A) in order to remove valve keepers (1).

**Note:** Do not compress the spring so that valve spring retainer (2) touches valve stem seal (4).

6. Slowly release the pressure on Tooling (A).

7. Remove valve spring retainer (2). Remove valve spring (3).

8. Repeat Step 4 through Step 7 for the remaining valves.

9. Remove Tooling (A).

10. Remove valve stem seals (4).

11. Use a suitable lifting device to carefully turn over the cylinder head.

12. Remove valves (5).

## Installation Procedure

Table 20

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825666 | Valve Spring Compressor | 1 |
| | 27610235 | Adapter | 1 |
| | 27610295 | Head | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean all components of the cylinder head assembly. Ensure that all ports, all coolant passages and all lubrication passages in the cylinder head are free from debris. Follow Step 1.a through Step 1.e in order to inspect the components of the cylinder head assembly. Replace any components that are worn or damaged.

   a. Inspect the cylinder head for wear and for damage. Refer to Systems Operation, Testing and Adjusting, "Cylinder Head Inspect".

   b. Inspect the valve seats for wear and for damage. Refer to Specifications, "Cylinder Head Valves" for further information.

   c. Inspect the valve guides for wear and for damage. Refer to Specifications, "Cylinder Head Valves" and Systems Operation, Testing and Adjusting, "Valve Guide - Inspect" for further information.

   d. Inspect the valves for wear and for damage. Refer to Specifications, "Cylinder Head Valves".

   e. Inspect the valve springs for damage and for the correct length. Refer to Specifications, "Cylinder Head Valves".

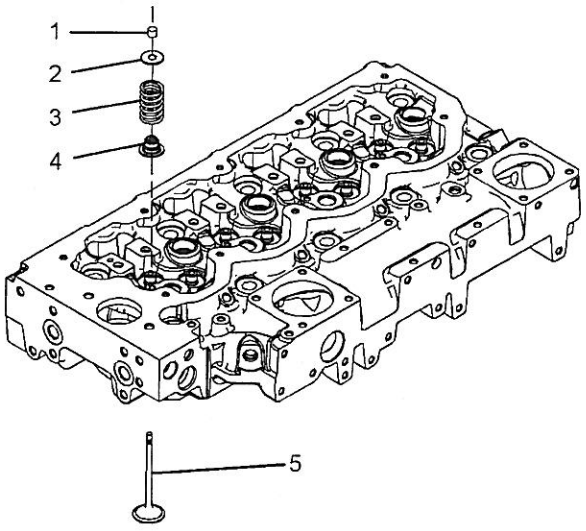



Illustration 89 g01245105

REFERENCE ONLY

2. Lubricate the stems of valves (5) with clean engine oil. Install valves (5) in the appropriate positions in the cylinder head. Check the depth of the valves below the face of the cylinder head. Refer to Systems Operation, Testing and Adjusting, "Valve Depth - Inspect" for more information.

3. Use a suitable lifting device to carefully turn over the cylinder head. The weight of the cylinder head is approximately 56 kg (125 lb).

**Note:** Ensure that all of the valves remain in place.

4. Install new valve stem seals (4) onto each of the valve guides.

**Note:** The outer face of the valve guides must be clean and dry before installing the valve stem seals.

5. Install valve spring (3) onto the cylinder head. Position valve spring retainer (2) onto valve spring (3).

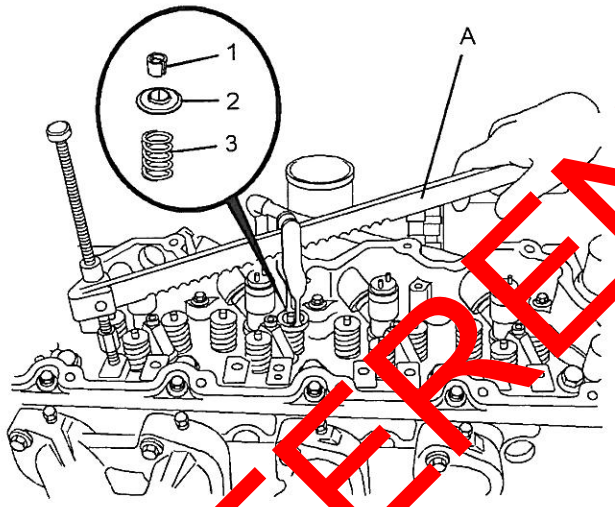



Illustration 90 g01469809
Typical exam

**WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

6. Install Tooling (A) in the appropriate position on the cylinder head in order to compress valve spring (3).

NOTICE
Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

7. Apply sufficient pressure to Tooling (A) in order to install valve keepers (1).

**Note:** Do not compress the spring so that valve spring retainer (2) touches valve stem seal (4).

**WARNING**

**The valve spring keepers can be thrown from the valve when the valve spring compressor is released. Ensure that the valve spring keepers are properly installed on the valve stem. To help prevent personal injury, keep away from the front of the valve spring keepers and valve springs during the installation of the valves.**

8. Carefully release the pressure on Tooling (A).

9. Repeat Step 6 through Step 8 for the remaining valves.

10. Remove Tooling (A) from the cylinder head.

11. Use a suitable lifting device to position the cylinder head on a support. Ensure that the heads of the valves are not obstructed.

**End By:**

a. Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

i02933621

# Engine Oil Filter Base - Remove and Install

## Removal Procedure

Table 21

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | Strap Wrench | 1 |

**Note:** The oil filter may be installed vertically or the oil filter may be installed horizontally.

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

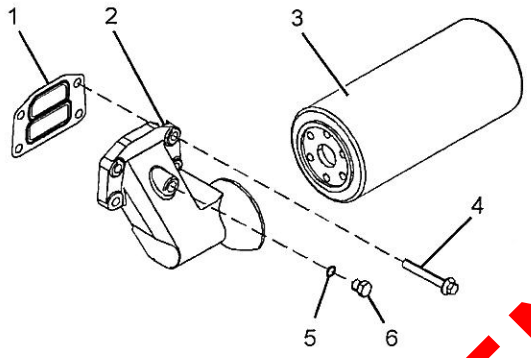



Illustration 91 g01251186
Typical example

1. Use Tooling (A) to remove engine oil filter (3). Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

2. If the engine oil pressure sensor is located in the engine oil filter base, remove the engine oil pressure sensor. Refer to Disassembly and Assembly, "Engine Oil Pressure Sensor - Remove and Install".

3. Remove bolts (4) and remove engine oil filter base (2).

4. Remove gasket (1).

5. If the engine oil filter base has a spacer plate, remove the spacer plate and remove the gasket.

**Note:** Mark the orientation of the spacer plate.

6. If necessary, remove plug (6) from engine oil filter base (2). Remove O-ring seal (5) from the plug.

## Installation Procedure

Table 22

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 21820117 | POWERPART Threadlock and Nutlock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

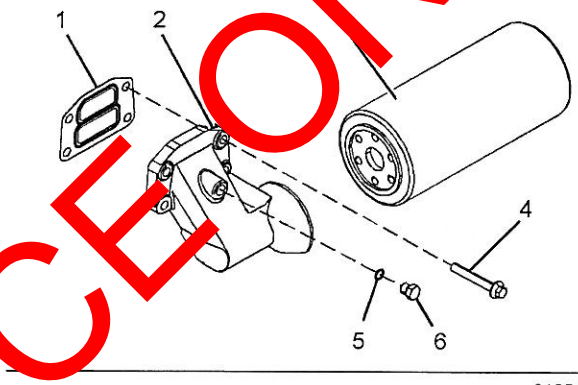



Illustration 92 g01254186
Typical example

1. Ensure that the engine oil filter base is clean. Clean the gasket surface of the cylinder block.

2. If necessary, install a new O-ring seal (5) to plug (6). Install plug (6) to engine oil filter base (2). Tighten the plug to a torque of 12 N·m (106 lb in).

3. Install bolts (4) to engine oil filter base (2).

4. Install a new gasket (1) onto bolts (4). If the engine oil filter base has a spacer plate, install the spacer plate and a new gasket onto the bolts.

**Note:** Ensure the correct orientation of spacer plate.

5. Apply Tooling (B) to the threads of the bolts. Install the assembly of the engine oil filter base to the cylinder block.

6. Tighten bolts (4) to a torque of 22 N·m (16 lb ft).

7. If the engine oil pressure sensor is located in the engine oil filter base, Install the engine oil pressure sensor. Refer to Disassembly and Assembly, "Engine Oil Pressure Sensor - Remove and Install".

REFERENCE ONLY

8. Install a new engine oil filter (3). If necessary, fill the engine oil pan to the correct level that is indicated on the oil level gauge. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

i02933620

# Engine Oil Cooler - Remove

## Removal Procedure

**Start By:**

a. Remove the bracket for the Electronic Control Module. Refer to Disassembly and Assembly, "ECM Mounting Bracket - Remove and Install".

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system into a suitable container. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

2. Drain the engine lubricating oil into a suitable container. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

3. If necessary, remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

4. Position the engine wiring harness away from the assembly of oil cooler (1). If necessary, cut the cable strap.

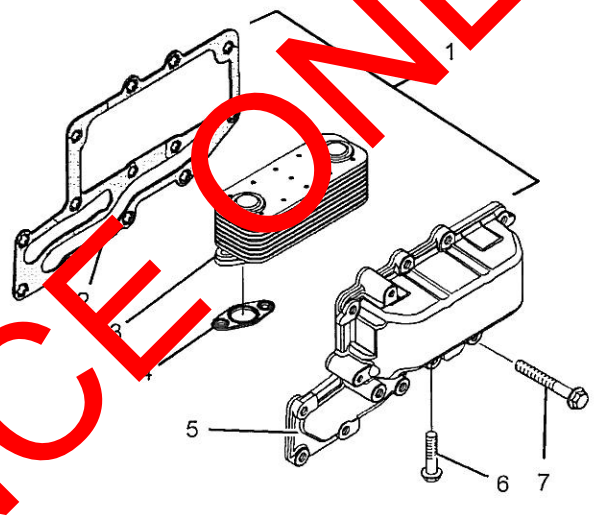



Illustration 93 g01254472
Typical example

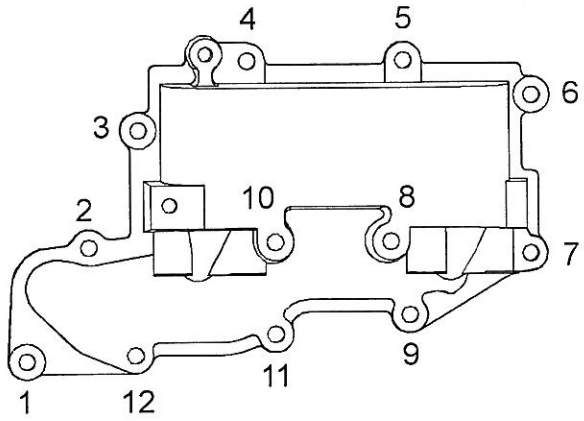



Illustration 94 g01254473
Tightening sequence for the engine oil cooler

REFERENCE ONLY

5. Loosen bolts (7) in reverse numerical order to the sequence that is shown in Illustration 94. Remove bolts (7). Support the assembly of engine oil cooler (1) as the bolts are removed.

**Note:** Bolts of different lengths are installed. Note the correct position of the bolts. Note the position of any brackets that are secured by the bolts. Do not remove bolts (6) at this time.

6. Remove the assembly of oil cooler (1) from the cylinder block.

7. Remove gasket (2).

8. Follow Step 8.a through Step 8.c in order to disassemble the engine oil cooler.

   a. Remove bolts (6).

   b. Remove cooler matrix (3) from housing (5).

   c. Remove gaskets (4).

i02933619

# Engine Oil Cooler - Install

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

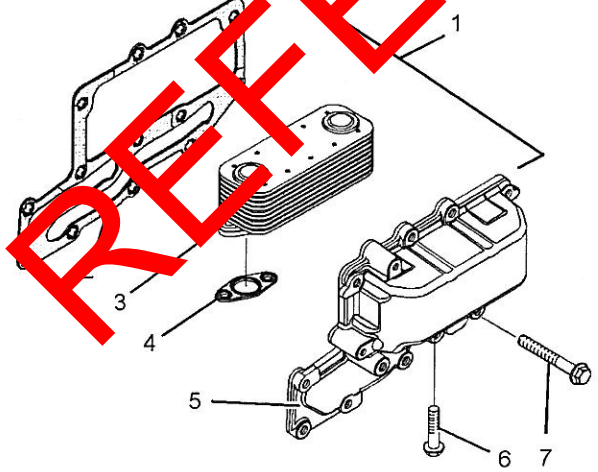



Illustration 95 g01254472
Typical example

1. Follow Step 1.a through Step 1.c in order to assemble the engine oil cooler.

   a. Ensure that cooler matrix (3) is clean and free from damage. Ensure that housing (5) is clean and free from damage. Replace any damaged components.

   b. Position new gasket (4) onto housing (5). Install cooler matrix (3).

   c. Install bolts (6) finger tight.

2. Clean the gasket surface of the cylinder block.

3. Install bolts (7) to the engine oil cooler.

**Note:** The bolts are different lengths. Ensure that the different bolts are installed in the correct location. Ensure that any brackets that are secured by the bolts are installed in the correct location.

4. Install a new gasket (2) to the assembly of oil cooler (1). Push bolts (7) through the holes in the gasket.

**Note:** The holes in the gasket have serrations that hold the bolts captive.

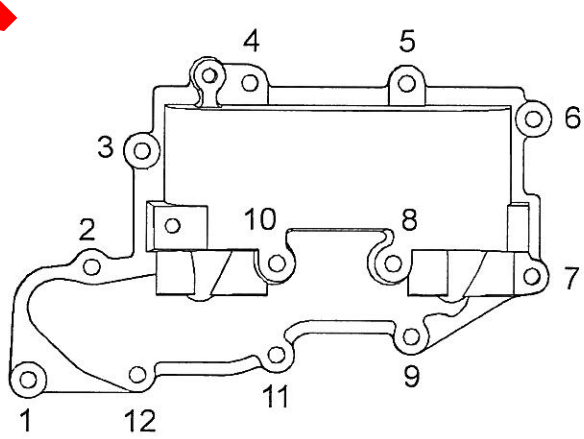



Illustration 96 g01254473
Tightening sequence for the engine oil cooler

5. Install the assembly of oil cooler (1) to the cylinder block. Tighten bolts (7) to a torque of 22 N·m (16 lb ft). Tighten the bolts in the sequence that is shown in Illustration 96.

   Tighten bolts (6) to a torque of 22 N·m (16 lb ft). Refer to Illustration 95.

6. Place the engine wiring harness in the correct position. If necessary, install a new cable strap.

REFERENCE ONLY

7. If necessary, Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

8. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

9. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

**End By:**

a. Install the bracket for the Electronic Control Module. Refer to Disassembly and Assembly, "ECM Bracket - Remove and Install".

i02933626

# Engine Oil Relief Valve - Remove and Install (Engines with a Balancer Unit)

## Removal Procedure

Table 23

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Descriptio | Qty |
| A | - | Telescopic M | 1 |

**Start By:**

a. Remove the engine oil pan. Refer to Disassembly and Assembly , "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

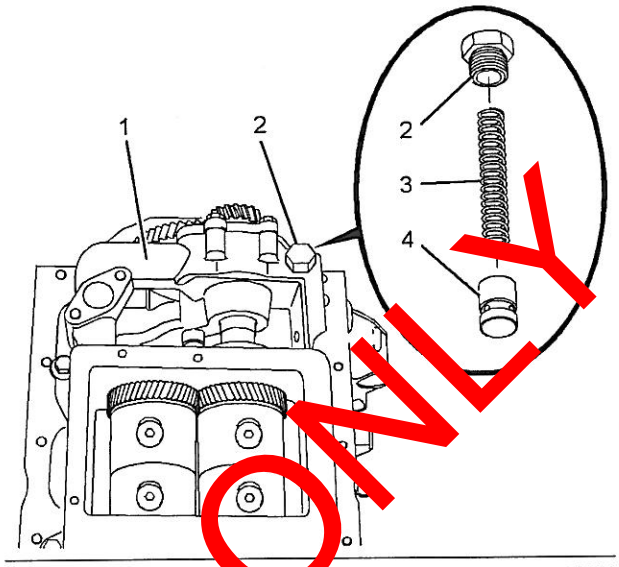



Illustration 9
Typical example
g01470291

**WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

1. Loosen cap (2). Carefully remove the cap from balancer (1).

**Note:** The spring force will be released when the cap is removed.

2. Remove spring (3) from the bore for the relief valve in balancer (1).

3. Use Tooling (A) in order to remove plunger (4) from the bore for the relief valve in balancer (1).

## Installation Procedure

Table 24

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Telescopic Magnet | 1 |
| B | 21820117 | POWERPART Threadlock and Nutlock | 1 |

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

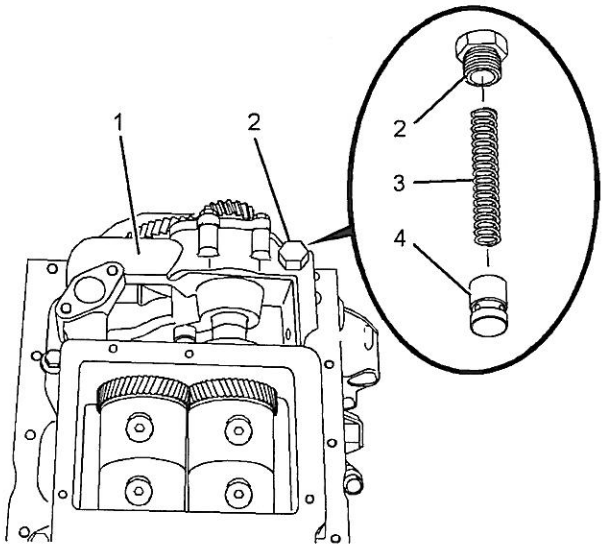



Illustration 98 g01470291
Typical example

**⚠ WARNING**

**Improper assembly of parts that are spring loaded can cause bodily injury.**

**To prevent possible injury, follow the established assembly procedure and wear protective equipment.**

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged. If the bore for the relief valve in balancer (1) is worn or damaged, the complete assembly of the balancer must be replaced.
2. Lubricate plunger (4) with clean engine oil. Install plunger (4) and spring (3) into the bore for the relief valve in balancer (1).

**Note:** The plunger must slide freely in the bore for the relief valve.

3. Apply Tooling (B) to the threads of cap (2). Install cap (2) to balancer (1). Tighten the cap to a torque of 21 N·m (15 lb ft).

**Note:** Ensure that the spring is properly located inside the plunger and the cap. Ensure that Tooling (B) does not contaminate the bore for the relief valve in balancer (1).

**End By:**

a. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

i02933627

# Engine Oil Relief Valve - Remove and Install (Engines Without a Balancer Unit)

## Removal Procedure

Table 25

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Telescoping Magnet | 1 |

**Start By:**

a. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

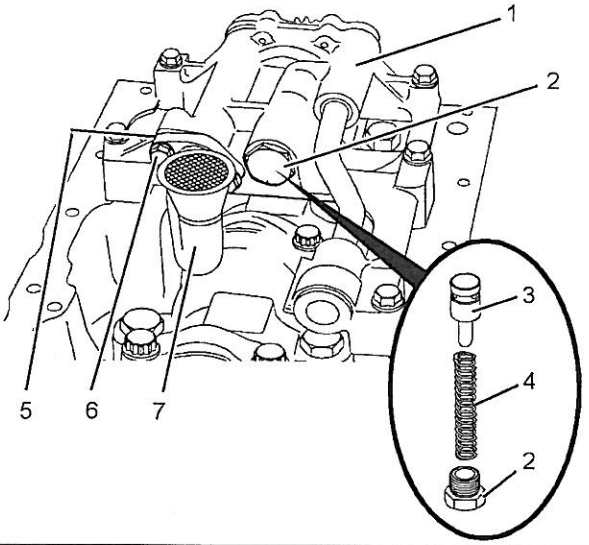



Illustration 99 g01470289
Typical example

REFERENCE ONLY

**⚠ WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

1. Remove bolts (6) and suction pipe (7).
2. Remove gasket (5) (not shown) from the suction pipe .
3. Loosen cap (2). Carefully remove cap (2) from the housing of engine oil pump (1).

**Note:** The spring force will be released when the cap is removed.

4. Remove spring (4) from the bore for the relief valve in the housing of engine oil pump (1).
5. Use Tooling (A) to remove plunger (3) from the bore for the relief valve in the housing of engine oil pump (1).

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

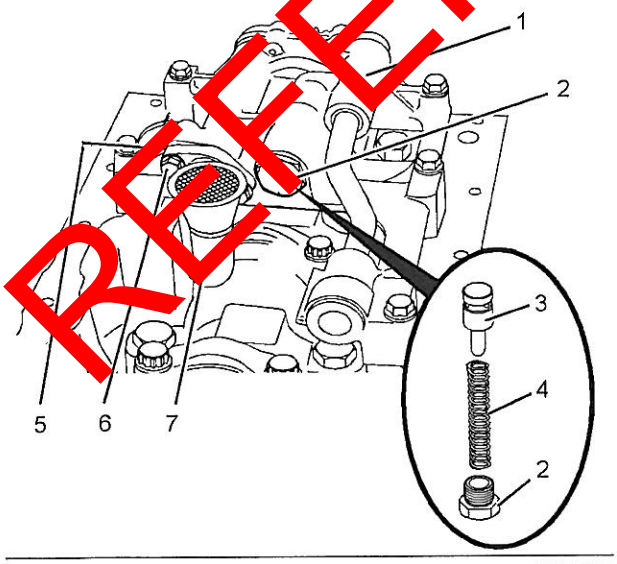



Illustration 100
Typical example
g01470289

**⚠ WARNING**

**Improper assembly of parts that are spring loaded can cause bodily injury.**

**To prevent possible injury, follow the established assembly procedure and wear protective equipment.**

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged. If the bore for the relief valve in the housing of engine oil pump (1) is worn or damaged, the complete assembly of the engine oil pump must be replaced.
2. Lubricate plunger (3) with clean engine oil. Use long nose pliers to install plunger (3) and spring (4) into the bore for the relief valve in the housing of engine oil pump (1).

**Note:** The plunger must slide freely in the bore for the relief valve.

3. Install cap (2) to engine oil pump (1). Tighten the cap to a torque of 45 N·m (33 lb ft).

**Note:** Ensure that the spring is properly located between the plunger and the cap.

4. Install suction pipe (7) and a new gasket (5) (not shown) to the assembly of the engine oil pump.
5. Install bolts (6). Tighten the bolts to a torque to 22 N·m (16 lb ft).

**End By:**

a. Install the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install”.

i02933625

# Engine Oil Pump - Remove and Install (Engines Without a Balancer Unit)

## Removal Procedure

**Start By:**

a. Remove the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install”.

REFERENCE ONLY

**Note:** This procedure is for the removal of the engine oil pump on engines that are not equipped with a balancer. Refer to Disassembly and Assembly, "Balancer - Remove" for information on the removal of the engine oil pump for engines that are equipped with a balancer.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

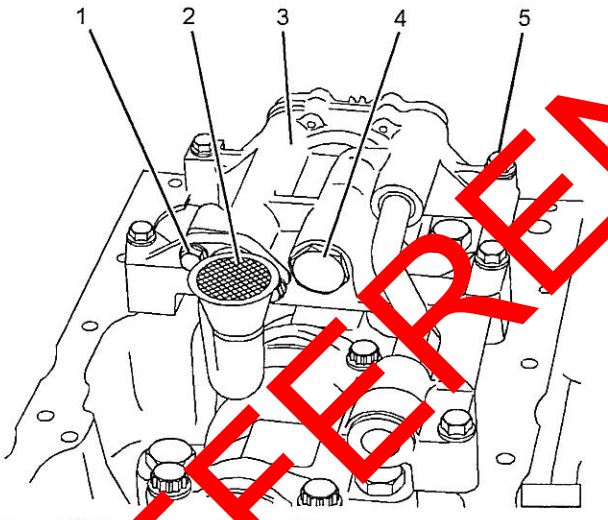



Illustration 1 g01255703
Typical example

1. Remove bolts (1) and suction pipe (2).
2. Remove the gasket from the suction pipe.
3. Remove bolts (5). Remove the assembly of the engine oil pump (3) from the cylinder block.
4. If necessary, remove pressure relief valve (4) from the housing of engine oil pump (3). Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install".

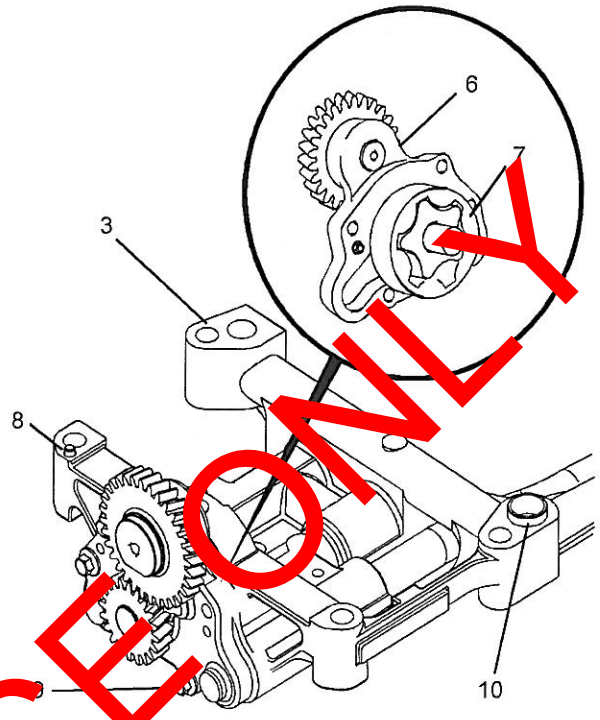



Illustration 102 g01470295
Typical example

5. If necessary, remove bolts (9) and front cover assembly (6). Remove outer rotor (7) from the housing of engine oil pump (3).

**Note:** Do not remove dowels (8) and (10) from the housing of the engine oil pump unless the dowels are damaged.

## Installation Procedure

Table 26

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |

**Note:** This procedure is for the installation of the engine oil pump on engines that are not equipped with a balancer. Refer to Disassembly and Assembly, "Balancer - Install" for information on the installation of the engine oil pump for engines that are equipped with a balancer.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

NOTICE
If any of the parts on the engine oil pump are worn or damaged, the entire pump must be replaced.

1. Ensure that all components of the engine oil pump are clean and free from wear or damage. Check the clearance between the outer rotor of the oil pump and the oil pump body. Check the clearance between the outer rotor and the inner rotor. Check the end play of the rotor. Refer to Systems Operation, Testing and Adjusting, "Engine Oil Pump - Inspect". Replace the complete assembly of the engine oil pump if any of the components are worn or damaged.

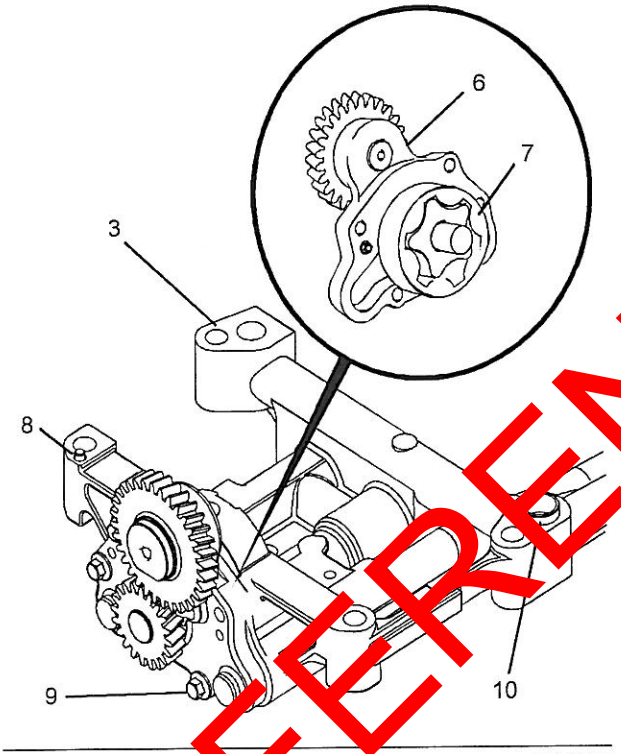



Illustration 103 g01470295
Typical example

2. If necessary, lubricate the internal components of the assembly of the engine oil pump with clean engine oil. Install outer rotor (7) and front cover (6) to the housing of engine oil pump (3). Install bolts (9). Tighten the bolts to a torque of 9.5 N·m (84 in).

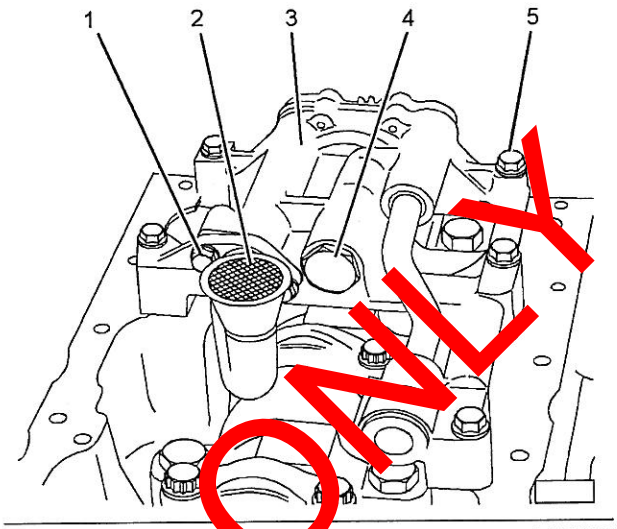



Illustration 104 g01255703
Typical example

3. If necessary, install pressure relief valve (4). Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install" for further information.

4. Ensure that dowel (8) and dowel (10) are correctly located in the housing of engine oil pump (3). Position the assembly of the engine oil pump onto the cylinder block.

**Note:** Ensure that the dowels in the housing of the engine oil pump are aligned with the holes in the cylinder block.

5. Install bolts (5). Tighten the bolts to a torque of 44 N·m (32 lb ft).

6. Install suction pipe (2) and a new gasket to the assembly of the engine oil pump.

7. Install bolts (1). Tighten the bolts to a torque to 22 N·m (16 lb ft).

8. Use Tooling (A) in order to check the backlash between the idler gear of the oil pump and the crankshaft gear. Refer to Specifications, "Gear Group - Front" for further information.

**End By:**

a. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

REFERENCE ONLY

i02933681

# Water Pump - Remove

## Removal Procedure

**Start By:**

**a.** Remove the fan and the fan pulley. Refer to Disassembly and Assembly, "Fan - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**1.** Drain the coolant from the cooling system into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

**2.** Loosen the hose clamps and remove the hose from the water pump inlet.

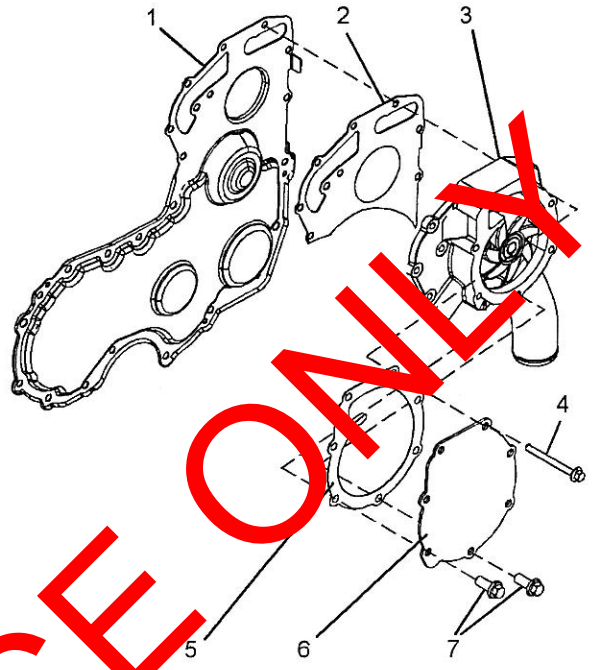



Illustration 105 g01263054
Typical example

**3.** Remove bolts (4). The bolts are different lengths. Note the positions of the different bolts.

**Note:** Do not remove bolts (7) at this time.

**4.** Remove water pump (3) from front cover (1).

**Note:** If necessary, tap the water pump with a soft hammer in order to loosen the water pump.

**5.** Remove gasket (2).

**6.** If necessary, remove cover (6) from the water pump. Follow Step 6.a through Step 6.c in order to remove the cover.

**a.** Remove bolts (7).

**b.** Remove cover (6).

**c.** Remove gasket (5).

REFERENCE ONLY

i02933680

# Water Pump - Install

## Installation Procedure

Table 27

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Stud M8 by 80 mm | 2 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the water pump is clean and free from wear or damage. If necessary, replace the water pump.

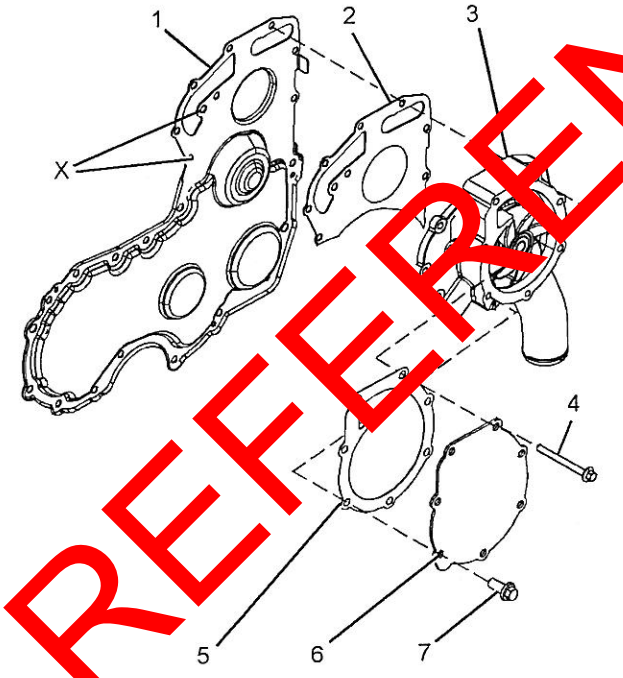



Illustration 106 g01269391
Typical example

2. If necessary, install cover (6) to water pump (3). Follow Step 2.a through Step 2.d in order to install the cover.

   a. Clean the gasket surface of cover (6).

   b. Position a new gasket (5) onto water pump (3).

   c. Install cover (6) to water pump (3).

   d. Install bolts (7) to cover (6). Tighten the bolts finger tight.

3. Clean the gasket surface of front cover (1).

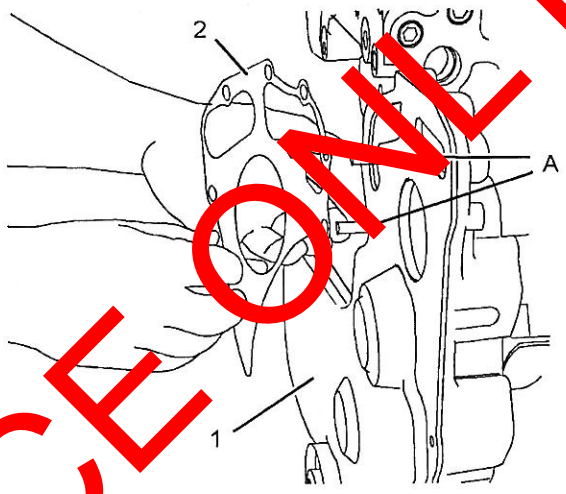



Illustration 107 g01269392

4. Install Tooling (A) in Position (X).

5. Use Tooling (A) in order to align a new gasket (2) to front cover (1). Install the gasket to the front cover.

6. Align water pump (3) with Tooling (A). Install the water pump to front cover (1).

**Note:** Ensure that the gear of the water pump and the gear of the fuel injection pump mesh.

7. Install bolts (4). Refer to Illustration 106. Tighten the bolts finger tight.

**Note:** Ensure that bolts of different lengths are installed in the correct positions.

8. Remove Tooling (A) and install remaining bolts (4) finger tight.

REFERENCE ONLY

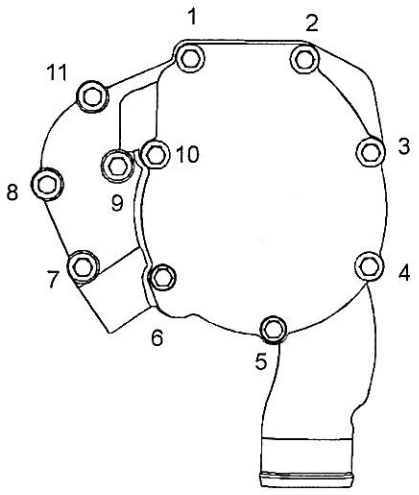



Illustration 108 g01269393

Tightening sequence for the water pump

9. Tighten bolts (4) and bolts (7) to a torque of 22 N·m (16 lb ft). Refer to Illustration 106. Tighten the bolts in the sequence that is shown in Illustration 108.

10. Install the hose to the water pump inlet. Tighten the hose clamps securely.

11. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

**End By:**

a. Install the fan and the fan pulley. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933682

# Water Temperature Regulator - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system to a level below the water temperature regulator, into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

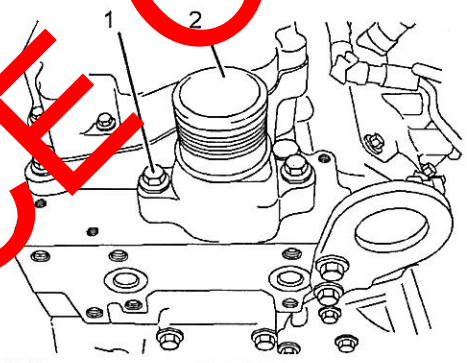



Illustration 109 g01269478

Typical example

2. Loosen the hose clamps from the upper radiator hose and disconnect the upper radiator hose from water temperature regulator housing (2).

3. Remove bolts (1) from water temperature regulator housing (2).

4. Remove water temperature regulator housing (2) from the cylinder head.

**Note:** Note the orientation of the water temperature regulator housing.

REFERENCE ONLY

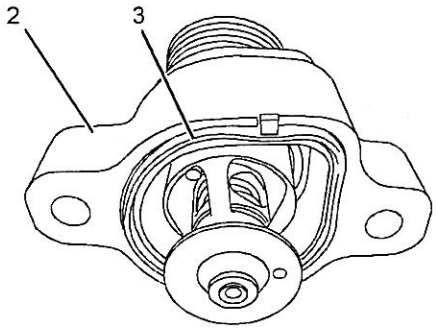



Illustration 110 g01269481
Typical example

5. Remove O-ring seal (3) from water temperature regulator housing (2).

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

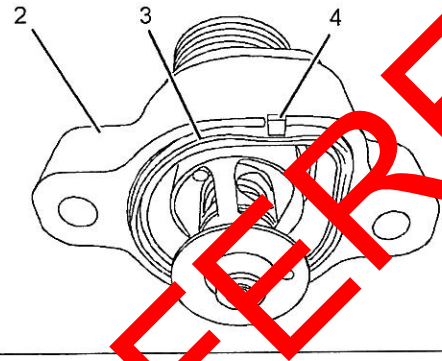



Illustration 111 g01263044
Typical example

1. Ensure that all components of water temperature regulator housing (2) are clean and free of wear or damage. Check the water temperature regulator for correct operation. Refer to Systems Operation, Testing and Adjusting, "Water Temperature Regulator - Test" for the procedure to test the water temperature regulator. If any components of the water temperature regulator housing are worn or damaged, the complete assembly must be replaced.

2. If the original water temperature regulator housing is installed, position a new O-ring seal (3) into the groove in the water temperature regulator housing (2). Ensure that locating tab (4) is correctly seated in water temperature regulator housing (2).

   A new water temperature regulator housing is supplied with a new O-ring seal.

3. Install water temperature regulator housing (2) to the cylinder head.

**Note:** Ensure the correct orientation of the water temperature regulator housing.

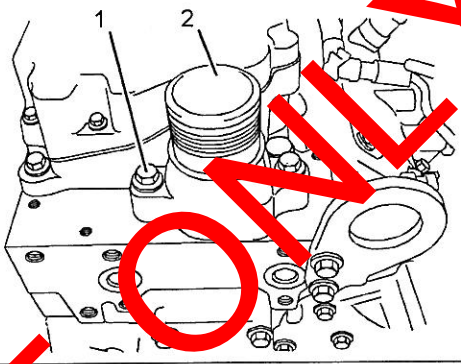



Illustration 112 g01269478
Typical example

4. Install bolts (1). Tighten the bolts to a torque of 44 N·m (32 lb ft).

5. Connect the upper radiator hose and tighten the hose clamps securely.

6. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check" and Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.

i02933633

# Flywheel - Remove

## Removal Procedure

Table 28

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Stud<br>1/2 inch - 20 UNF by 4 inch | 2 |

**Start By:**

a. Remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

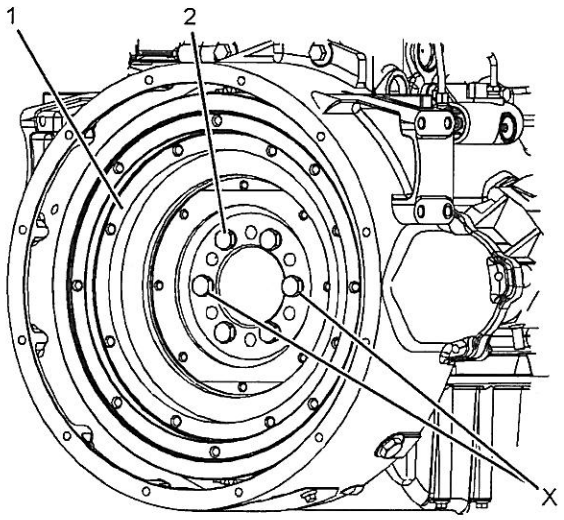



Illustration 113 g01245126
Typical example

1. Remove two bolts from Positions (X) on flywheel (1).
2. Install Tooling (A) to Positions (X) on flywheel (1).
3. Attach a suitable lifting device to flywheel (1). Support the weight of the flywheel. The weight of the flywheel is approximately 71 kg (155 lb).
4. Remove remaining bolts (2).
5. Use the lifting device in order to remove the flywheel from the engine.

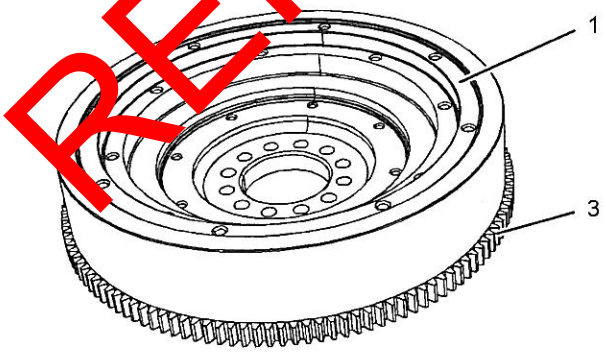



Illustration 114 g01245152
Typical example

6. Inspect flywheel (1) and ring gear (3) for wear or damage. Replace any components that are worn or damaged.
7. To remove the flywheel ring gear, follow Step 7.a and Step 7.b.
   a. Place the flywheel assembly on a suitable support.

**Note:** Identify the orientation of the teeth on the flywheel ring gear.

   b. Use a hammer and a punch in order to remove ring gear (3) from flywheel (1).

i02933632

# Flywheel - Install

## Installation Procedure

Table 29

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Stud<br>1/2 inch - 20 UNF by 4 inch | 2 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

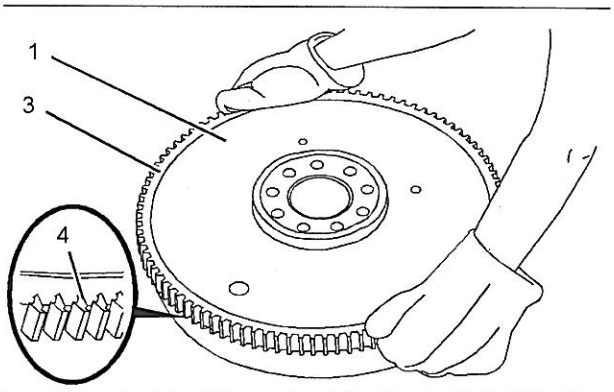



Illustration 115 g01470362
Typical example

**⚠ WARNING**

**Always wear protective gloves when handling parts that have been heated.**

REFERENCE ONLY

1. If the flywheel ring gear was removed, follow Step 1.a through Step 1.c in order to install a new ring gear to the flywheel.

   a. Identify the orientation of teeth (4) on new ring gear (3).

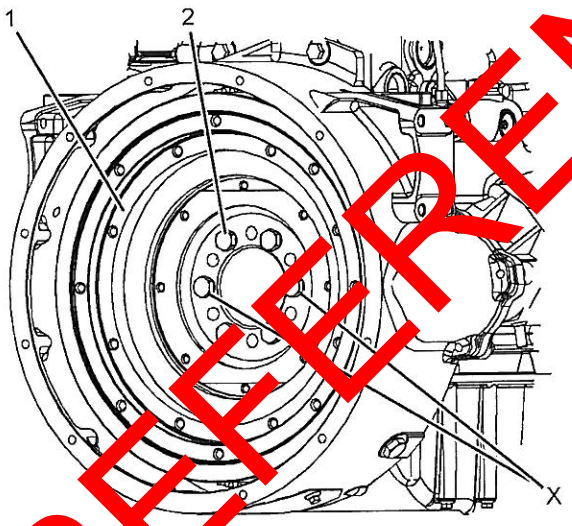
**Note:** The chamfered side of the ring gear teeth must face toward the starting motor when the flywheel is installed. This will ensure the correct engagement of the starting motor.

   b. Heat flywheel ring gear (3) in an oven to a maximum temperature of 250 °C (482 °F) prior to installation.

**Note:** Do not use a torch to heat the ring gear.

   c. Ensure that the orientation of ring gear (3) is correct and quickly install the ring gear onto flywheel (1).

2. Inspect the crankshaft rear seal for leaks. If there are any oil leaks, replace the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove" and Disassembly and Assembly, "Crankshaft Rear Seal - Install" for the correct procedure.




g01245126

Illustration 2
Typical example

3. Install a suitable lifting device to flywheel (1). The weight of the flywheel is approximately 71 kg (155 lb).

4. Install Tooling (A) to Positions (X) on the crankshaft.

5. Use the lifting device in order to position flywheel (1) onto Tooling (A).

6. Install bolts (2) to flywheel (1) finger tight.

7. Remove Tooling (A) and install remaining bolts (2) to flywheel (1).

8. Remove the lifting device from flywheel (1).

9. Use a suitable tool to prevent the flywheel from rotating. Tighten bolts (2) to a torque of 115 N·m (85 lb ft).

10. Check the run out of the flywheel. Refer to Specifications, "Flywheel" for further information.

**End By:**

a. Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

i02933610

# Crankshaft Rear Seal - Remove

## Removal Procedure

Table 30

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | E12 Torx Socket | 1 |

**Start By:**

a. Remove the flywheel. Refer to Disassembly and Assembly, "Flywheel - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** The crankshaft rear seal and the housing are manufactured as a one-piece assembly. The assembly is not serviceable. If the crankshaft rear seal is removed, the assembly must be replaced.

REFERENCE ONLY

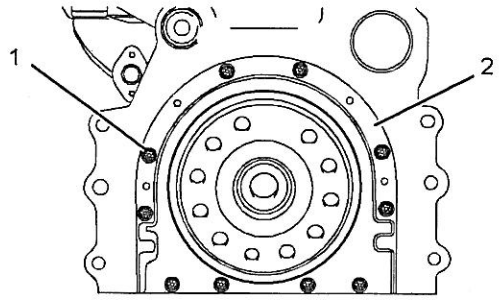



Illustration 117 g01269512
Typical example

1. Use Tooling (A) in order to remove torx screws (1) from crankshaft rear seal (2).
2. Remove crankshaft rear seal (2) from the cylinder block. Discard the crankshaft rear seal.

i02933609

# Crankshaft Rear Seal - Install

## Installation Procedure

Table 31

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | E12 Torx Socket | 1 |
| B | 27610306 | Alignment Tool | 1 |

**Note:** The crankshaft rear seal and the housing are manufactured as a one-piece assembly.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

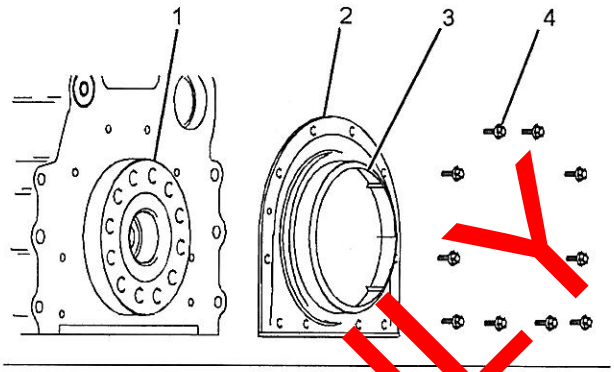



Illustration 118 g01258105

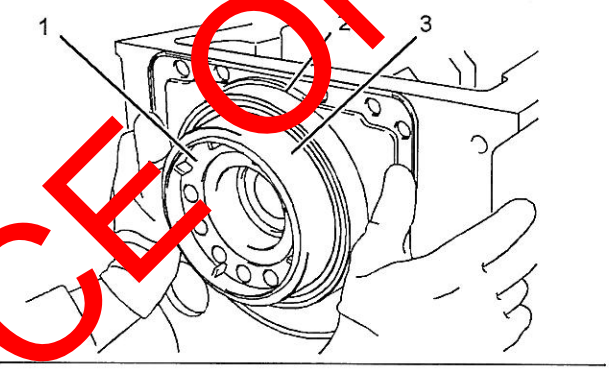



Illustration 119 g01255709
Typical example

1. Ensure that crankshaft flange (1) is clean, dry and free from damage.
2. Ensure that the face of the cylinder block and the bridge piece are clean and dry.
3. A new crankshaft rear seal is supplied with a plastic sleeve (3). Ensure that the plastic sleeve is squarely installed within crankshaft rear seal (2).

**Note:** The plastic sleeve is included in order to protect the lip of the seal as the seal is pushed over the crankshaft flange.

**Note: Do not lubricate the crankshaft rear seal or the crankshaft flange. The crankshaft rear seal must be installed dry.**

4. Align plastic sleeve (3) with crankshaft flange (1). Ensure that the plastic sleeve is engaged onto the crankshaft flange. Push new crankshaft rear seal (2) squarely onto the crankshaft flange.

   During this process, the plastic sleeve will be forced out of the crankshaft rear seal. Discard the plastic sleeve.

REFERENCE ONLY

5. Align the two molded locators on crankshaft rear seal (2) with the holes in the cylinder block. Ensure that the crankshaft rear seal is seated against the cylinder block.

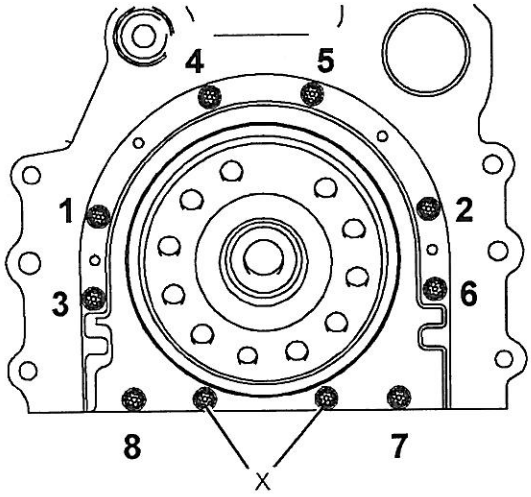



Illustration 120 g01258357
Tightening sequence for the crankshaft rear seal

6. Install torx screws (4) finger tight.

**Note:** Do not install torx screws to Positions (X) at this stage.

7. Install Tooling (B) to crankshaft rear seal (2) and to crankshaft flange (1).

8. Use Tooling (A) in order to tighten torx screws (4) to a torque of 22 N·m (16 lb ft). Tighten torx screws (4) in the sequence that is shown in Illustration 120.

9. Remove Tooling (B).

10. Install remaining torx screws (4) to Positions (X). Use Tooling (A) in order to tighten the torx screws to a torque of 22 N·m (16 lb ft). Refer to Illustration 120.

**End By:**

a. Install the flywheel. Refer to Disassembly and Assembly, "Flywheel - Install".

i02933634

# Flywheel Housing - Remove and Install

## Removal Procedure

Table 32

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | Guide Stud M10 by 100 mm | 2 |

**Start By:**

a. Remove the flywheel. Refer to Disassembly and Assembly, "Flywheel - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

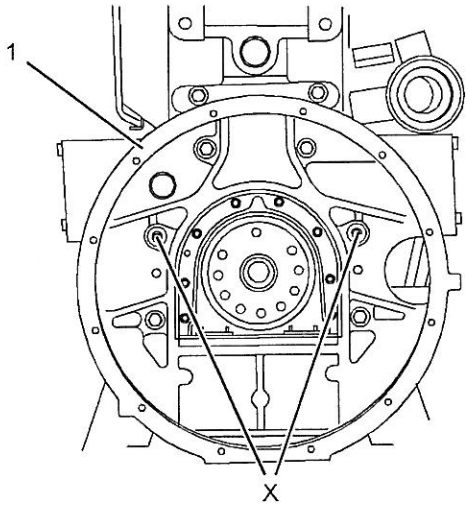



Illustration 121 g01470403
Typical example

1. Remove the bolts from Position (X) from flywheel housing (1).

2. Install Tooling (A) into Position (X) on flywheel housing (1).

3. Install a suitable lifting device to the flywheel housing in order to support the flywheel housing. The flywheel housing weighs approximately 30 kg (66 lb).

REFERENCE ONLY

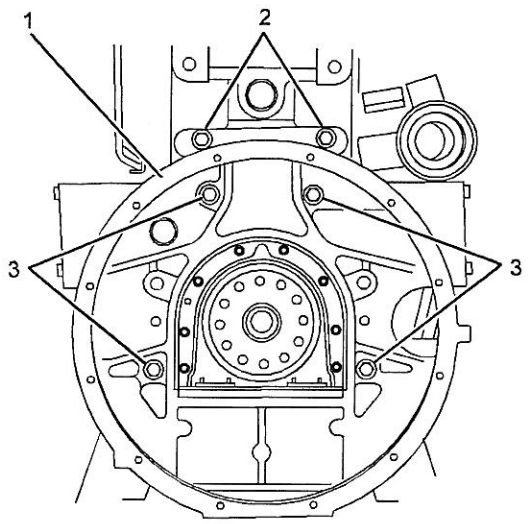



Illustration 122 g01763013
Typical example

4. Remove bolts (2) and remaining bolts (3) from flywheel housing (1).

5. Use the lifting device in order to remove flywheel housing (1) from the cylinder block.

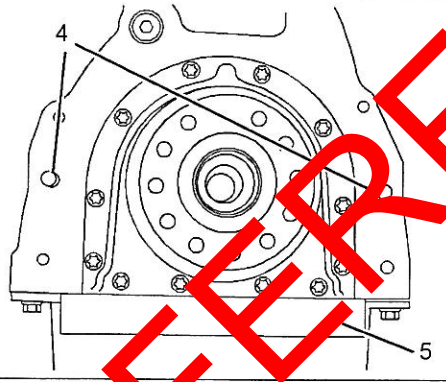



Illustration 123 g01470418
Typical example

6. If the engine has an aluminum oil pan, remove dust seal (5).

7. If necessary, remove dowels (4) from the cylinder block.

## Installation Procedure

Table 33

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Bolt M10 by 100 mm | 2 |
| B | 21825617 | Dial Indicator Group | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the flywheel housing is clean and free from damage. If necessary, replace the flywheel housing.

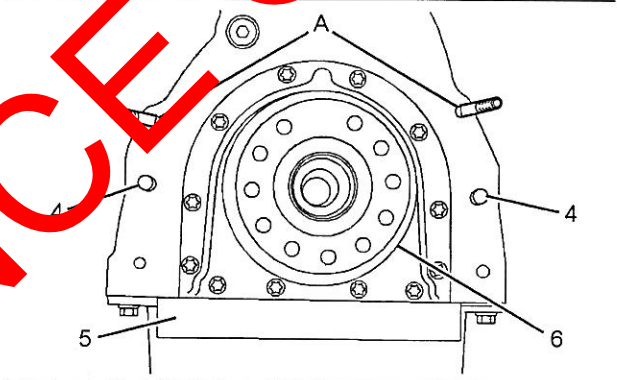



Illustration 124 g01244056
Typical example

2. Inspect crankshaft rear seal (6) for leaks. If there are any oil leaks, replace the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove" and refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

3. Clean the rear face of the cylinder block. If necessary, install dowels (4) to the cylinder block.

4. Install Tooling (A) to the cylinder block.

5. Install dust seal (5).

REFERENCE ONLY

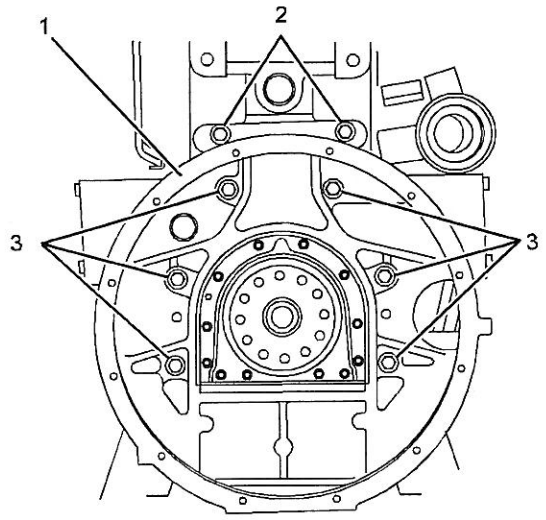



Illustration 125 g01763034
Typical example

6. Install a suitable lifting device to the flywheel housing. The flywheel housing weighs approximately 30 kg (66 lb).

7. Use the lifting device to align flywheel housing (1) with Tooling (A). Install the flywheel housing to the cylinder block.

8. Install bolts (2) and bolts (3) finger tight.

9. Remove Tooling (A). Install remaining bolts (3).

10. Tighten bolts (3) to a torque of 63 N·m (46 lb ft).

11. Tighten bolts (2) to a torque of 75 N·m (55 lb ft).

12. Use Tooling (B) to check the alignment of the flywheel housing with the crankshaft. Refer to Systems Operation, Testing and Adjusting, "Flywheel Housing - Inspect".

**End By:**

a. Install the flywheel. Refer to Disassembly and Assembly, "Flywheel - Install".

i02933607

# Crankshaft Pulley - Remove and Install (Engines With an Automatic Belt Tensioner)

## Removal Procedure

**Start By:**

a. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

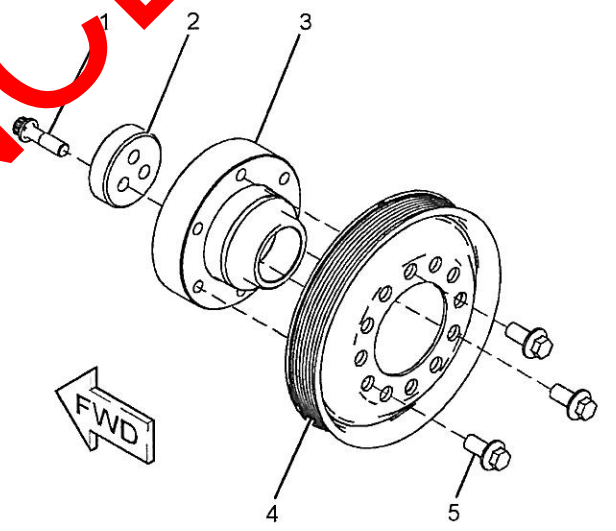



Illustration 126 g01249049

1. Use a suitable tool in order to prevent the crankshaft from rotating. Remove bolts (1).

2. Remove thrust block (2).

3. Carefully remove the assembly of the crankshaft pulley from the crankshaft.

4. Follow Step 4.a through Step 4.b in order to disassemble the crankshaft pulley.

   a. Remove bolts (5).

   b. Remove crankshaft pulley (4) from crankshaft adapter (3).

REFERENCE ONLY

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the crankshaft adapter, the pulley and the thrust block are clean and free from damage. Replace any components that are damaged.

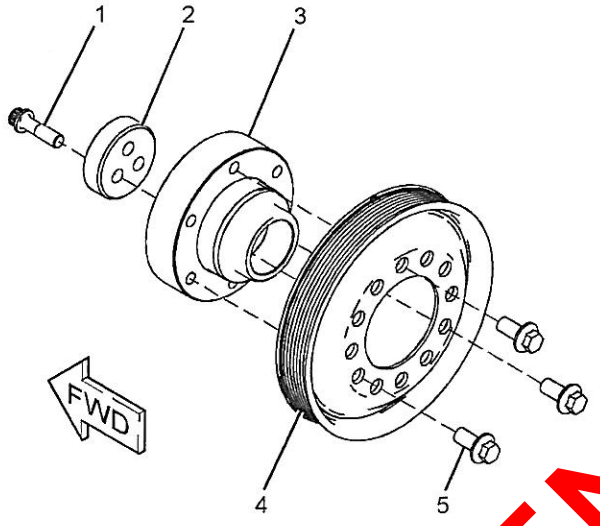



Illustration 127 g012[illegible]049

2. If necessary, follow Step 2.a through Step 2.b in order to assemble the crankshaft pulley.
   a. Install crankshaft pulley (4) to crankshaft adapter (3).
   b. Install bolts (5) to the assembly of the crankshaft pulley, and the crankshaft adapter. The bolts should be evenly spaced.
   c. Tighten the bolts to a torque of 78 N·m (58 lb ft).
3. Ensure that the front of the crankshaft is clean and free from damage. Install the assembly of crankshaft pulley (3) to the crankshaft.

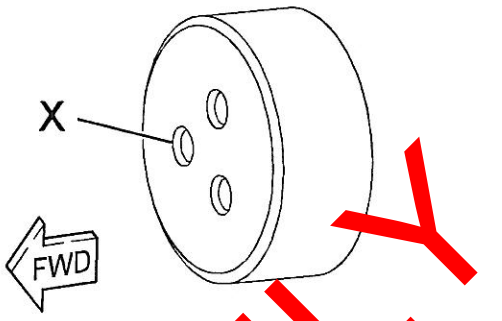



Illustration 128 g01471632

4. Align the holes in the thrust block with the holes in the crankshaft.

**Note:** Ensure chamfered Holes (X) in the thrust block. Face toward the front of the engine.

5. Install thrust block (2) to the assembly of the crankshaft pulley.
6. Install bolts (1) to thrust block (2).
7. Use a suitable tool in order to prevent the crankshaft from rotating. Tighten the bolts to a torque of 115 N·m (85 lb ft).
8. Repeat Step 7 in order to ensure correct torque.

**End By:**

a. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

i02933608

# Crankshaft Pulley - Remove and Install (Engines Without an Automatic Belt Tensioner)

## Removal Procedure

**Start By:**

a. Remove the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

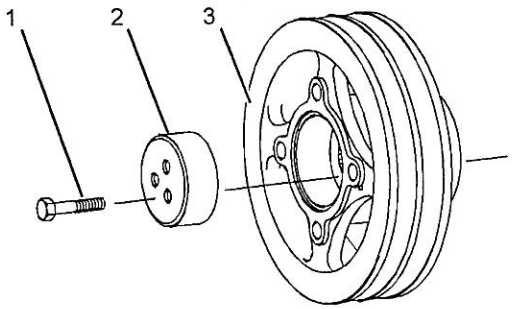



Illustration 129 g01255707

1. Use a suitable tool in order to prevent the crankshaft from rotating. Remove bolts (1).
2. Remove thrust block (2).
3. Carefully remove crankshaft pulley (3) from the crankshaft.

## Installation Procedure

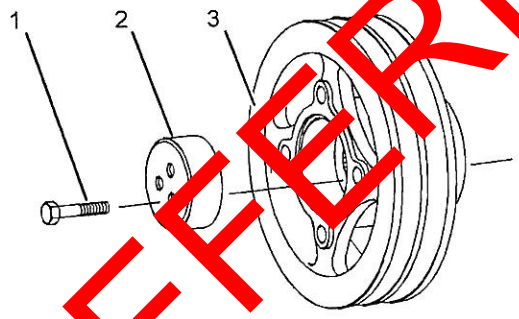



Illustration 130 g01255707

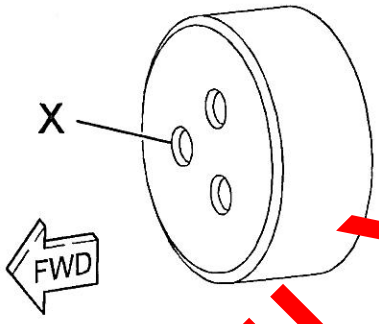



Illustration 131 g01471632

1. Ensure that the crankshaft pulley and the thrust block are clean and free from damage. Replace any components that are damaged.
2. Ensure that the front of the crankshaft is clean and free from damage. Install crankshaft pulley (3) to the crankshaft.
3. Align the holes in the thrust block with the holes in the crankshaft.

**Note:** Ensure that chamfered Holes (X) in the thrust block face toward the front of the engine.

4. Install thrust block (2) to the crankshaft pulley.
5. Install bolts (1) to thrust block (2).
6. Use a suitable tool in order to prevent the crankshaft from rotating. Tighten the bolts to a torque of 115 N·m (85 lb ft).
7. Repeat Step 6 in order to ensure correct torque.

**End By:**

a. Install the V-Belts. Refer to Disassembly and Assembly, “V-Belts - Remove and Install”.

i02933603

# Crankshaft Front Seal - Remove and Install

## Removal Procedure

Table 34

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610230 | Puller | 1 |

REFERENCE ONLY

**Start By:**

**a.** Remove the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

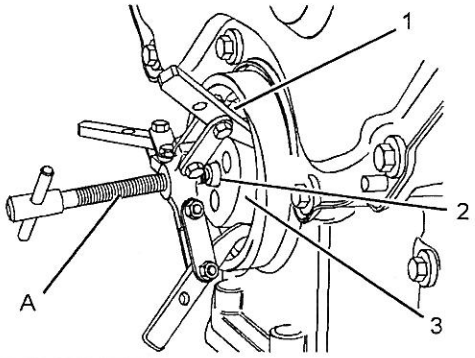



Illustration 132 g01266942

**1.** Install the legs of Tooling (A) behind crankshaft front seal (1). Install a suitable spacer (2) between Tooling (A) and crankshaft (3). Use Tooling (A) in order to pull the crankshaft front seal out of the front housing.

**Note:** Do not damage the bore for the crankshaft front seal in the front housing.

## Installation Procedure

Table 35

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 218[illegible]5577 | Threaded Bar | 1 |
| | 1825[illegible]0 | Anchor Plate | 1 |
| | 2[illegible]5579 | Sleeve | 1 |
| | 2182[illegible]8 | Pressure Plate | 1 |
| | 2[illegible]5581 | Adapter | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**1.** Ensure that the bore for the crankshaft front seal in the front housing is clean and free from damage.

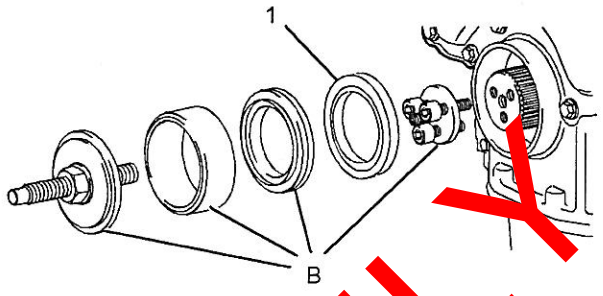



Illustration 133 g01266453
Typical example

**2.** Assemble Tooling (B).

**3.** Align a new crankshaft front seal (1) to the front housing.

**4.** Use Tooling (B) to install crankshaft front seal (1). Ensure that the front face of the seal is installed to a depth of [illegible] ± 0.2 mm (0.354 ± 0.008 inch) into the front housing.

**5.** Remove Tooling (B) from the crankshaft.

**End By:**

**a.** Install the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

i02933635

# Front Cover - Remove and Install

## Removal Procedure

**Start By:**

**a.** If the engine is equipped with a fan, remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

**b.** Remove the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove".

REFERENCE ONLY

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** In order to remove the front cover, it is not necessary to remove the crankshaft pulley or the alternator.

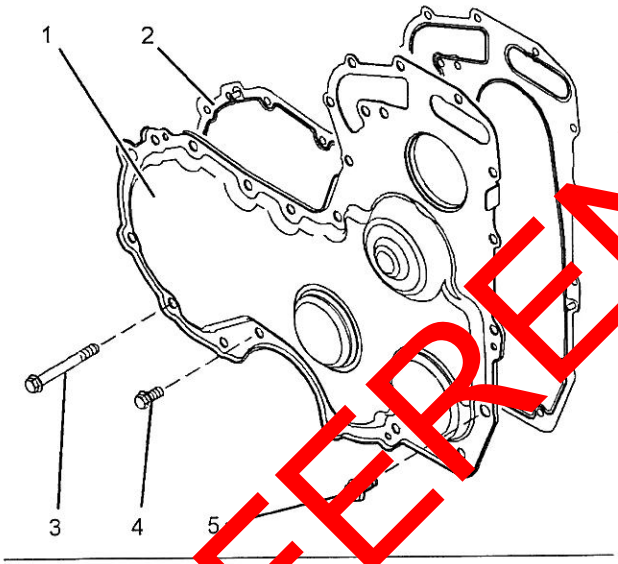



Illustration 134 g01258462
Typical example

1. Remove bolts (3), (4) and (5). Identify the positions of the different bolts.
2. Remove front cover (1) from the front housing.
3. Remove gasket (2) from front cover (1).

## Installation Procedure

Table 36

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Bolt M8 by 80 mm | 2 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

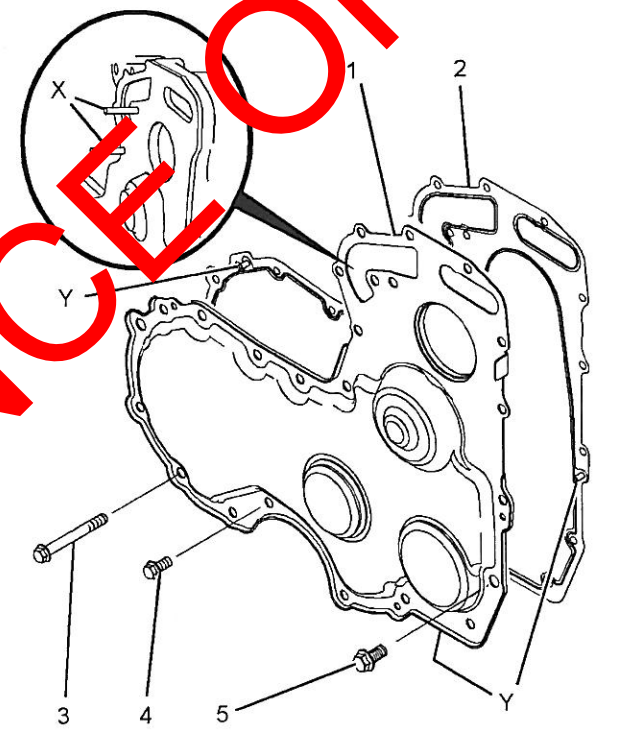



Illustration 135 g01471654
Typical example

1. Thoroughly clean the gasket surface of the front housing.
2. If the original front cover is installed, follow Step 2.a and Step 2.b in order to install the gasket.
   a. Thoroughly clean the gasket surface of the front cover.
   b. Install a new gasket (2) to front cover (1). Engage Locators (Y) into the holes in the front cover.
3. Install Tooling (A) into Holes (X) in the front housing.

REFERENCE ONLY

4. Use Tooling (A) in order to position the front cover assembly onto the front housing.

5. Install bolts (3), (4) and (5) finger tight. Ensure that the different bolts are installed in the correct positions.

6. Loosely install the water pump assembly and remove Tooling (A). Refer to Disassembly and Assembly, "Water Pump - Install" for the correct procedure.

7. Tighten bolts (3), (4) and (5) to a torque of 22 N·m (16 lb ft).

8. Tighten the bolts for the water pump to a torque of 22 N·m (16 lb ft).

**End By:**

a. If the engine is equipped with a fan, install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933652

# Gear Group (Front) - Remove and Install

## Removal Procedure

Table 37

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Bearing Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610274 | Crankshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

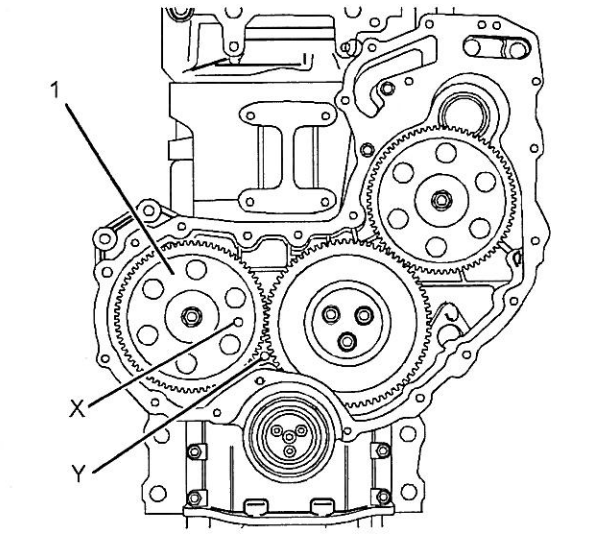
NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note: Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the front gear group. Carefully follow the procedure in order to remove the gear group.**

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

REFERENCE ONLY



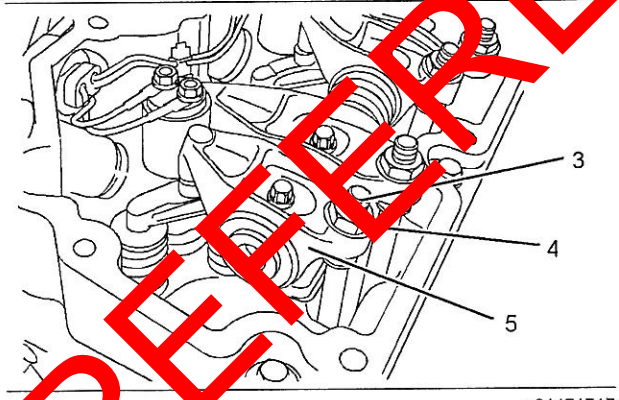

g01471714

Illustration 136

Typical example

2. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position. Install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

**Note:** Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.



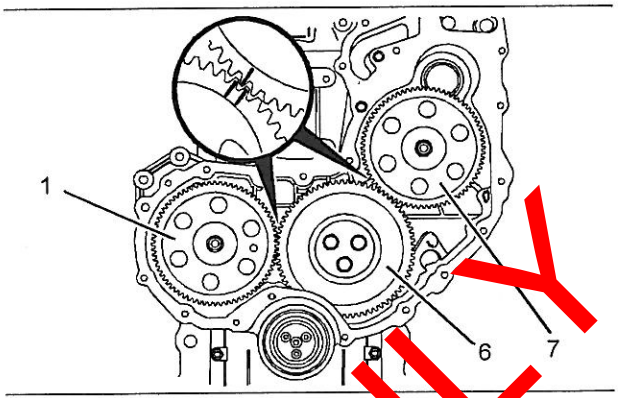

g01471717

Illustration 137

Typical example

3. Loosen nuts (4) on all rocker arms (5). Unscrew adjusters (3) on all rocker arms (5) until all valves are fully closed.

**Note:** Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.




g01471718

Illustration 138

Typical example

4. Apply sufficient pressure to fuel injection pump gear (7) in a counterclockwise direction in order to remove the backlash. Lock the fuel injection pump in this position. Refer to Disassembly and Assembly, "Fuel Pump Gear - Remove" for the correct procedure.

5. Mark gears (1), (6) and (7) in order to show alignment. Refer to Illustration 138.

**Note:** Identification will ensure that the gears can be installed in the original alignment.

6. Remove fuel pump gear (7). Refer to Disassembly and Assembly, "Fuel Pump Gear - Remove" for the correct procedure.

7. Remove camshaft gear (1). Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".

8. Remove idler gear (6). Refer to Disassembly and Assembly, "Idler Gear - Remove".

## Installation Procedure

Table 38

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610286 | Crankshaft Timing Pin | 1 |
| D | 21825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

**Note: The fuel injection pump must remain locked until the procedure instructs you to unlock the fuel injection pump.**

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

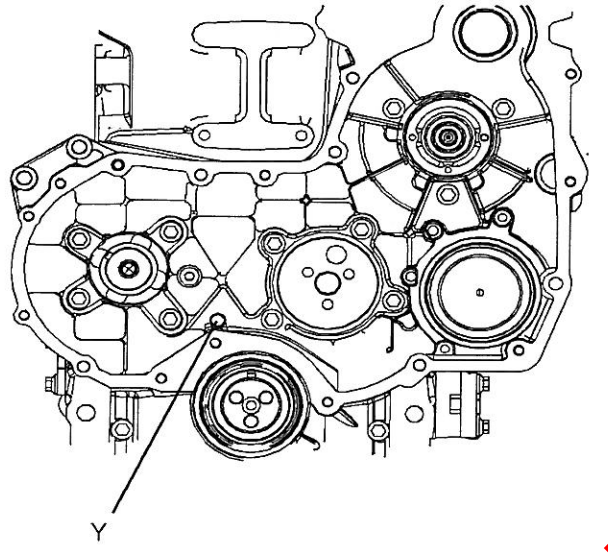



Illustration 139 g01488044
Typical example

2. If necessary, install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

**Note:** Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

3. Ensure that all of the components of the front gear group are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.

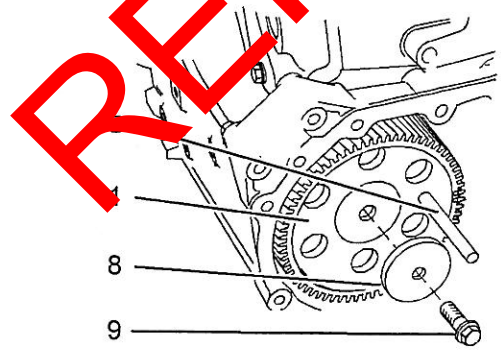



Illustration 140 g01471735
Typical example

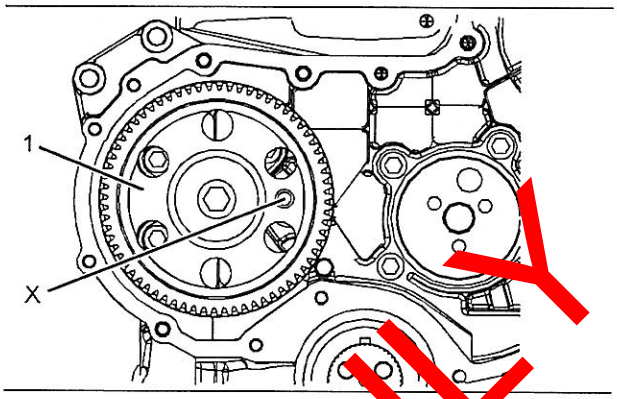



Illustration 141 g01488055
Typical example

4. Install camshaft gear (1). Loosely install bolt (9) and washer (8). Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install" for more information.

5. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing.

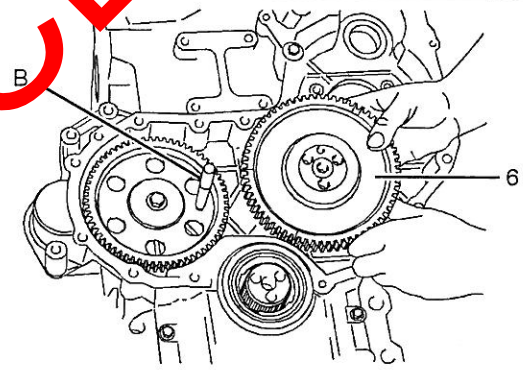



Illustration 142 g01471736
Typical example

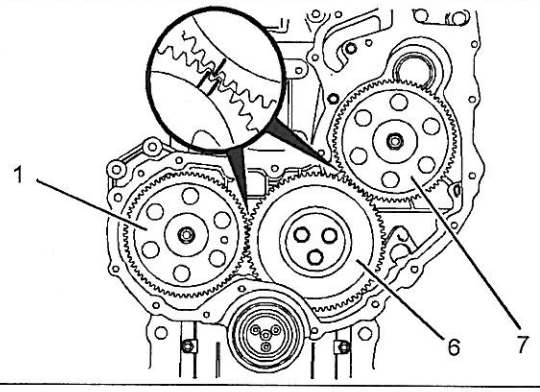



Illustration 143 g01471718
Alignment of timing marks

REFERENCE ONLY

6. Install idler gear (6). Ensure that the timing marks on gears (1) and (6) are in alignment and that the mesh of the gears is correct. Refer to Disassembly and Assembly, "Idler Gear - Install". Check the end play of the idler gear. Refer to Specifications, "Gear Group (Front)" and refer to Disassembly and Assembly, "Idler Gear - Install" for further information.

7. Remove Tooling (B) and Tooling (C). Tighten bolt (9) for the camshaft gear to a torque of 95 N·m (70 lb ft). Check the end play of the camshaft gear. Refer to Specifications, "Camshaft" for more information.

   Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing and install Tooling (C) into Hole (Y) in the front housing.

8. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

9. Install fuel injection pump gear (7). Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install" for the correct procedure. Ensure that timing marks on gear (6) and gear (7) are in alignment. See Illustration 143. Ensure that the mesh of the gears is correct.

10. Remove Tooling (B) and Tooling (C).

11. Use Tooling (D) in order to measure the backlash for gears (1), (6) and (7). Ensure that the backlash for the gears is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

12. Lubricate each gear with clean engine oil.

13. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

**End By:**

a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

b. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

c. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

d. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

e. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

i03496189

# Idler Gear - Remove

## Removal Procedure (Early Heavy-Duty Idler Gear)

Table 39

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 2761021 | Camshaft Timing Pin | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |

**Start By:**

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**Note:** Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

**Note:** The assembly of heavy-duty idler gear is not serviceable. Do not disassemble the heavy-duty idler gear.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to the Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

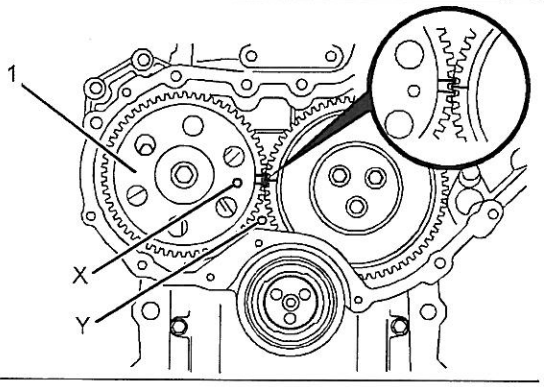



Illustration 144 g01473492
Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

**Note:** Ensure that the gears are marked in order to show alignment.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

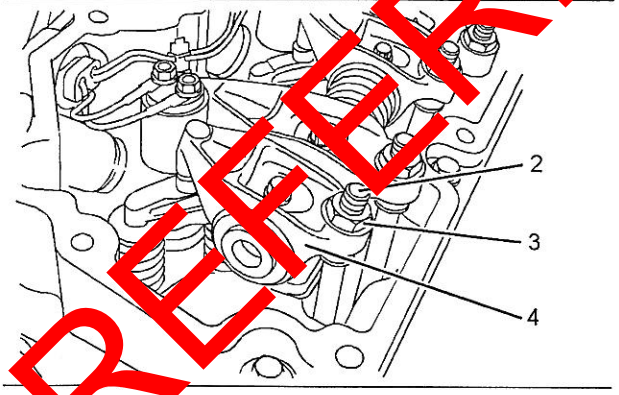



Illustration 145 g01831356
Typical example

4. Loosen nuts (3) on all rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

**Note:** Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.

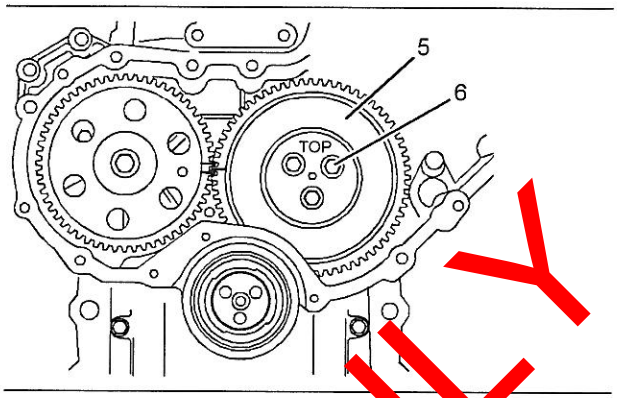



Illustration 146 g01832735
Typical example

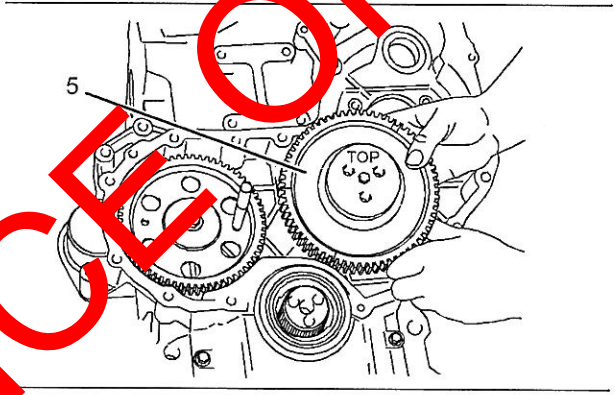



Illustration 147 g01832736
Typical example

5. Remove bolts (6) from the assembly of heavy-duty idler gear (5).

6. Remove the assembly of idler gear (5) from the recess in the front housing.

**Note:** The idler gear must be tilted during removal.

i03496187

# Idler Gear - Remove

## Removal Procedure (Standard Idler Gear)

Table 40

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610212 | Camshaft Timing Pin | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |

REFERENCE ONLY

**Start By:**

**a.** If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

**b.** If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

**c.** If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

**d.** Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove".

**e.** Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**Note:** Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**1.** Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

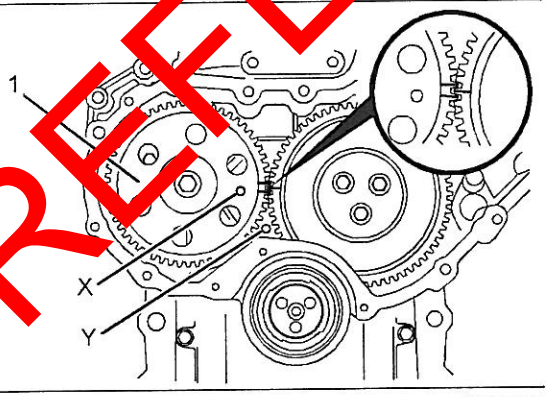



Illustration 148 g01473492
Alignment of timing marks

**2.** Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

**Note:** Ensure that the gears are marked in order to show alignment.

**3.** Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

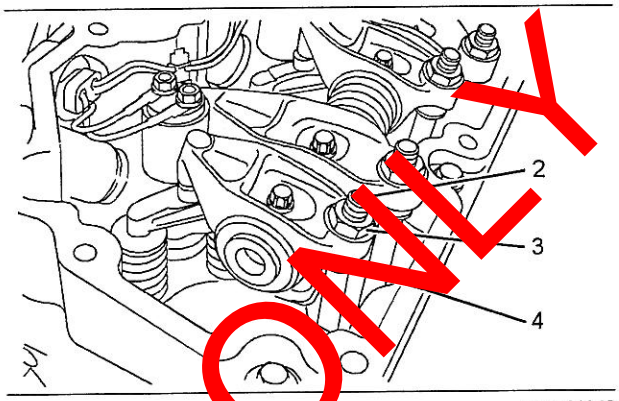



Illustration 149 g01831356
Typical example

**4.** Loosen nuts (3) on all rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

**Note:** Failure to ensure that ALL adjusters are fully loosened can result in contact between the valves and pistons.

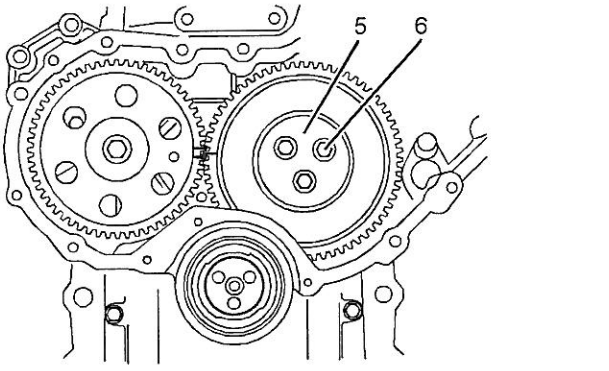



Illustration 150 g01473497
Typical example

**5.** Mark plate (5) in order to show orientation.

**Note:** Identification will ensure that the plate can be installed in the original orientation.

**6.** Remove bolts (6).

**7.** Remove plate (5).

REFERENCE ONLY

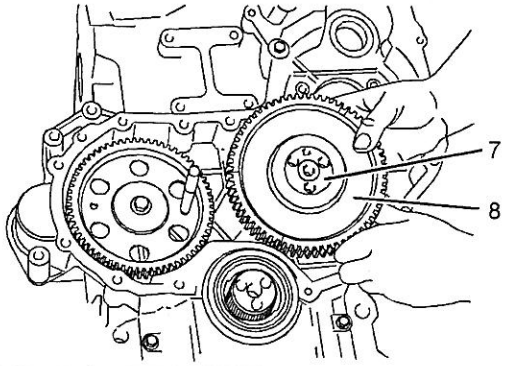



Illustration 151 g01473494
Typical example

8. Remove the assembly of idler gear (8) and hub (7) from the recess in the front housing.

**Note:** The idler gear must be tilted during removal.

9. Remove hub (7) from idler gear (8).

i02933658

# Idler Gear - Remove

## Removal Procedure (Latest Heavy-Duty Idler Gear)

Table 41

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610212 | Camshaft Timing Pin | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |
| C | - | Bolt M12x80mm | 1 |

**Start By:**

a. If the engine is equipped with an air compressor, remove the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

b. If the engine is equipped with a vacuum pump, remove the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

c. If the engine is equipped with an accessory drive, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

d. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove".

e. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**Note:** Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the fuel pump gear. Carefully follow the procedure in order to remove the fuel pump gear.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The assembly of heavy-duty idler gear is not serviceable. Do not disassemble the heavy-duty idler gear.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

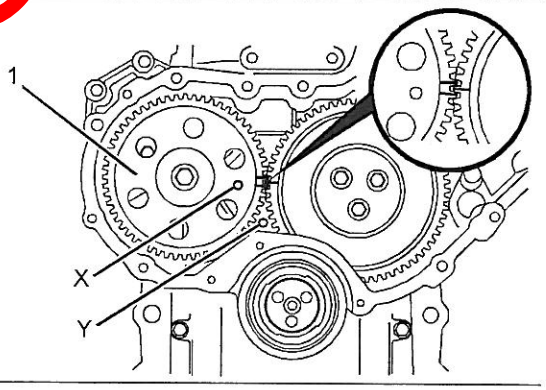


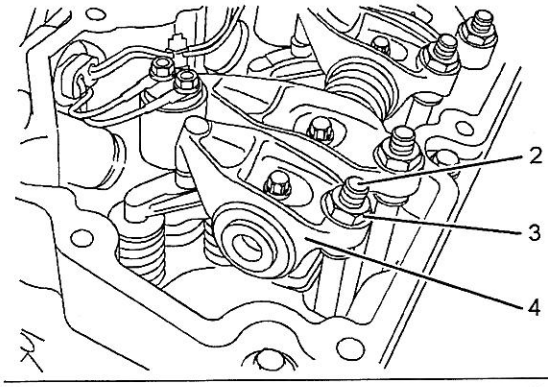

Illustration 152 g01473492
Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

**Note:** Ensure that the gears are marked in order to show alignment.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct Position.

REFERENCE ONLY



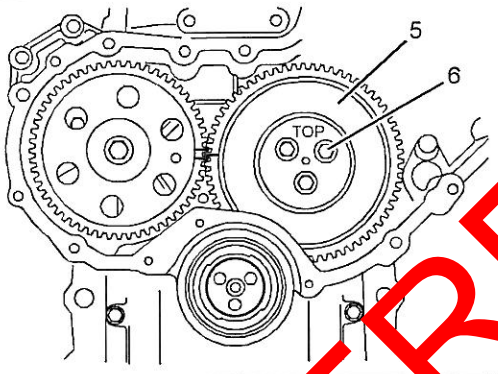

g01831356

Illustration 153

Typical example

4. Loosen nuts (3) on all rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

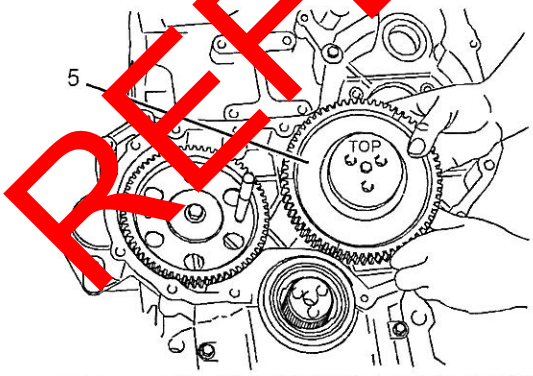
**Note:** Failure to ensure that ALL adjusters are fully unscrewed can result in contact between the valves and pistons.




g01832735

Illustration 154

Typical example




g01831467

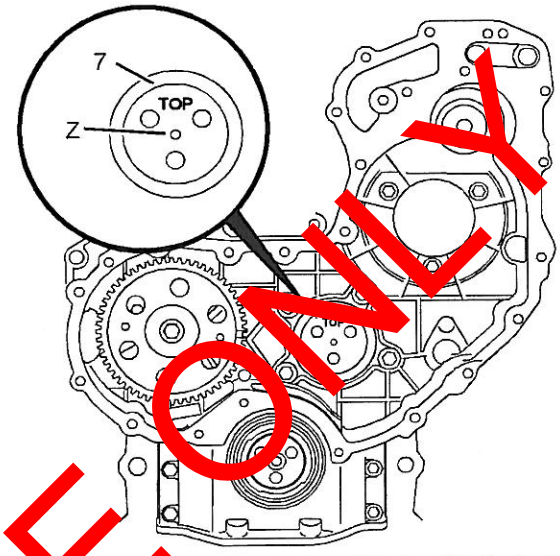
Illustration 155

Typical example

5. Remove bolts (6) from the assembly of heavy-duty idler gear (5).

6. Remove the assembly of idler gear (5) from the recess in the front housing.

**Note:** The idler gear must be tilted during removal.




g01831473

Illustration 156

Typical example

7. If necessary, remove plate (7). Install Tooling (C) into threaded Hole (Z) in order to remove plate (7).

i03496182

# Idler Gear - Install

## Installation Procedure (Heavy-Duty Idler Gear)

Table 42

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610212 | Camshaft Timing Pin | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |
| C | 21825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

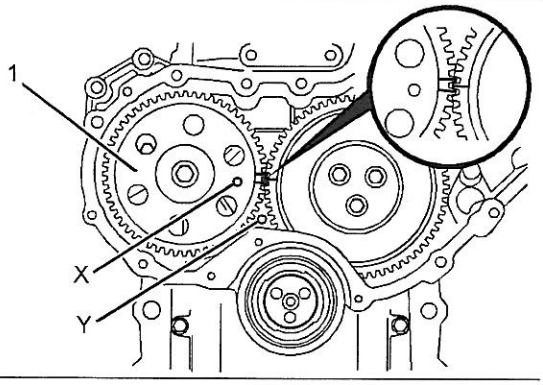



Illustration 157 g01473492
Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

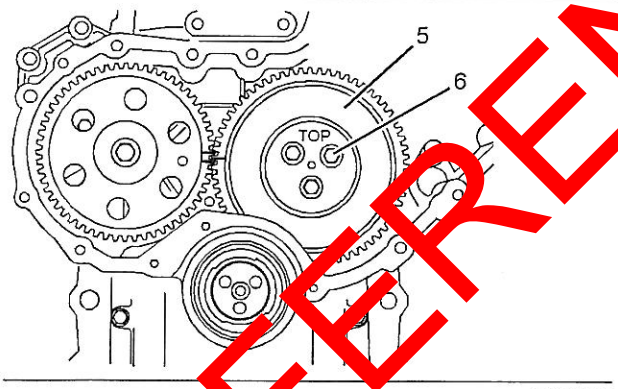



Illustration 158 g01832735
Typical example

4. Clean the assembly of idler gear (5) and inspect the assembly of the idler gear for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the assembly of the idler gear.

5. Lubricate the bearings in the assembly of idler gear (5) with clean engine oil.

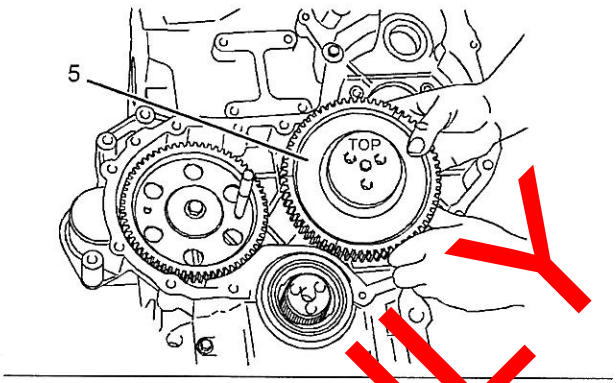



Illustration 159 g01831467
Typical example

6. Align the timing mark of idler gear (5) with the timing mark of the camshaft gear. Refer to Illustration 157. Install the assembly of idler gear (5) into the recess in the timing case. Ensure that the identification mark TOP is upward.

**Note:** The idler gear must be tilted during installation. Ensure that the holes in assembly of the idler gear are aligned with the holes in the cylinder block.

7. Install bolts (6). Tighten bolts (6) to a torque of 44 N·m (32 lb ft).

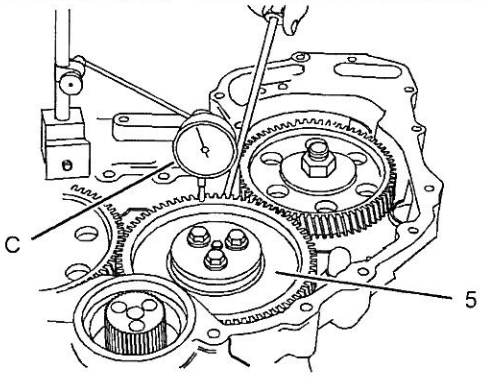



Illustration 160 g01832813
Checking end play by using a dial indicator group

8. Use Tooling (C) in order to check the end play of the idler gear. Refer to Specifications, "Gear Group (Front)" for more information.

9. Use Tooling (C) in order to check the backlash between the idler gear and the camshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

10. Use Tooling (C) in order to check the backlash between the idler gear and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

REFERENCE ONLY

11. Lightly lubricate all of the gears with clean engine oil.

12. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

**End By:**

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install".

b. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

c. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

d. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

e. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i03426180

# Idler Gear - Install

## Installation Procedure (Standard Idler Gear)

Table 43

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 2561212 | Camshaft Timing Pin | 1 |
| B | 2761211 | Crankshaft Timing Pin | 1 |
| C | 21825617 | Dial Indicator Group | 1 |
| D | - | Finger Clock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

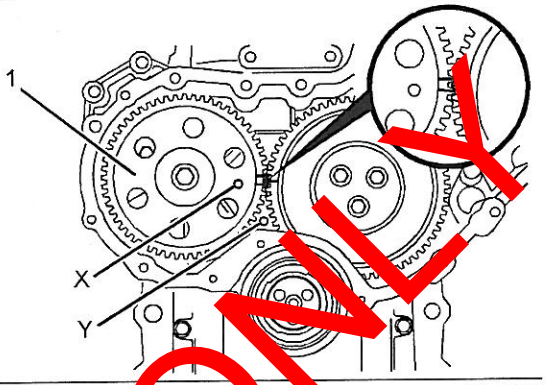



Illustration 161 g01473492
Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

3. Ensure that Tooling (B) is installed in Hole (Y) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

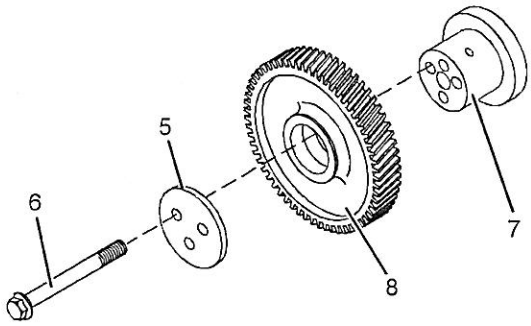



Illustration 162 g01832693
Typical example

4. Clean idler gear (8) and inspect the idler gear for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the idler gear.

5. Clean hub (7) and inspect the hub for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the hub.

6. Lubricate hub (7) with clean engine oil. Slide the hub into idler gear (8). Ensure that the timing marks are toward the front of the idler gear.

REFERENCE ONLY

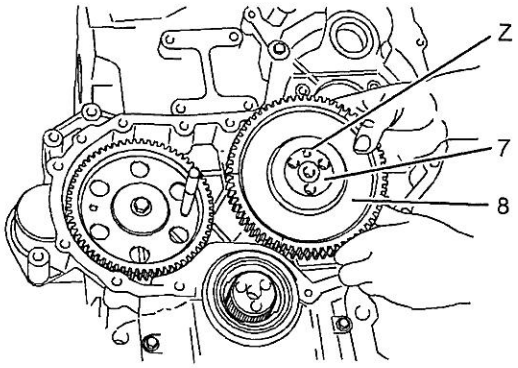



Illustration 163 g01832695
Typical example

7. Align the timing mark on idler gear (8) with the timing mark on the camshaft gear. Refer to the Illustration 161. Install the assembly of idler gear (8) and hub (7) into the recess in the timing case. Ensure that oil Hole (Z) is to the top of the hub.

**Note:** The idler gear must be tilted during installation. Ensure that the holes in the hub are aligned with the holes in the cylinder block.

8. Clean plate (5) and inspect the plate for wear or damage. If necessary, replace the plate.

9. Lubricate plate (5) with clean engine oil. A used plate should be installed in the original orientation. If a new plate is installed, ensure that the holes in plate (5) are aligned with the holes in hub (7). Install plate (5) to hub (7).

10. Install bolts (6). Tighten the bolts to a torque of 44 N·m (32 lb ft).

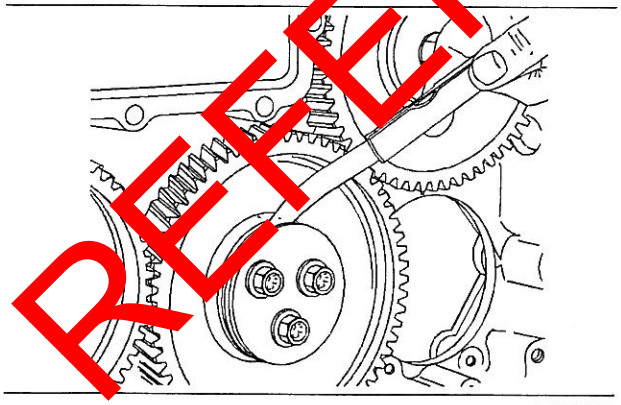


Illustration 164 g01269936
Checking end play by using a set of feeler gauge's

11. Use a set of feeler gauge's in order to check the end play of the idler gear. Refer to Specifications, "Gear Group (Front)" for more information.

12. Use Tooling (C) in order to check the backlash between the idler gear and the camshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

13. Use Tooling (C) in order to check the backlash between the idler gear and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

14. Lightly lubricate all of the gears with clean engine oil.

15. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

**End By:**

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install".

b. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

c. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

d. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

e. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933657

# Idler Gear - Install

## Installation Procedure (Latest Heavy-Duty Idler Gear)

Table 44

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610212 | Camshaft Timing Pin | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |
| D | 21825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center Position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

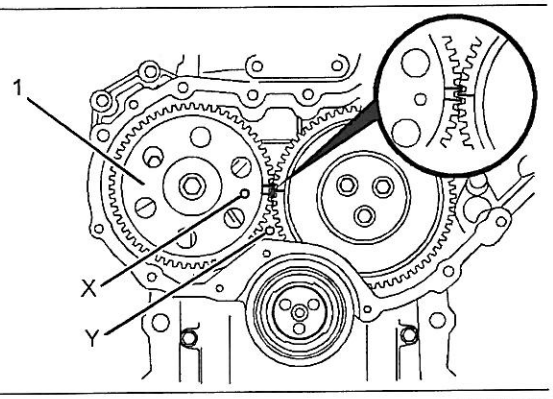



Illustration 165 g01473492
Alignment of timing marks

2. Ensure that Tooling (A) is installed into Hole (X) in camshaft gear (1). Use Tooling (A) in order to lock the camshaft in the correct position.

3. Ensure that Tooling (B) is installed in Hole (Y) in the cylinder block. Use Tooling (B) in order to lock the crankshaft in the correct position.

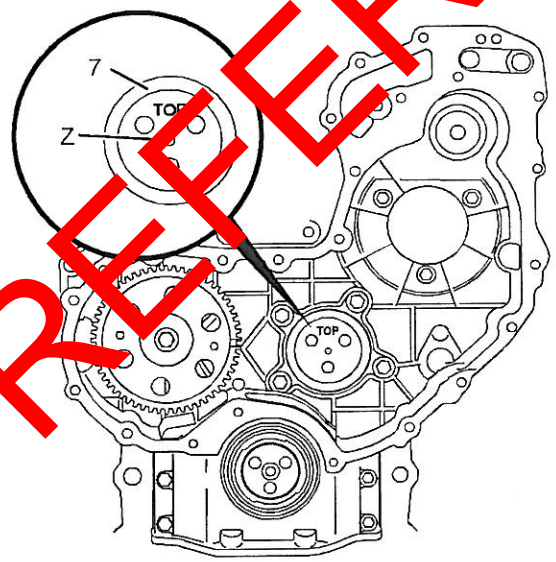



Illustration 166 g01831473
Typical example

4. Install plate (2) into the recess in the front housing.

**Note:** Ensure that the identification mark TOP is upward.

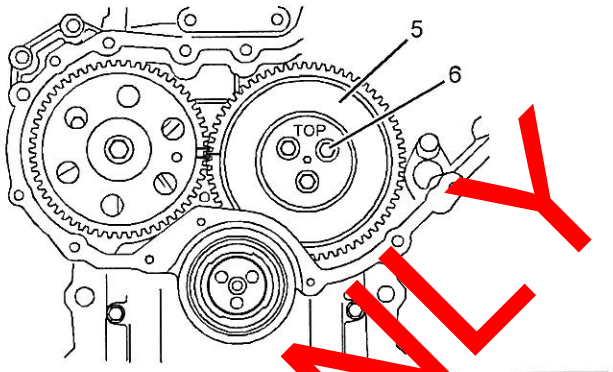



Illustration 167 g01832735
Typical example

5. Clean the assembly of idler gear (5) and inspect the assembly of the idler gear for wear or damage. Refer to Specifications, "Gear Group (Front)" for more information. If necessary, replace the assembly of the idler gear.

6. Lubricate the bearings in the assembly of idler gear (5) with clean engine oil.

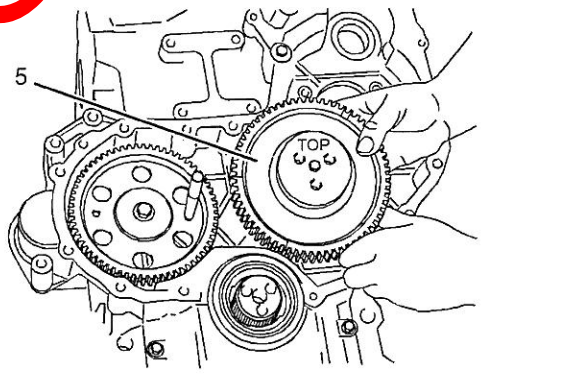



Illustration 168 g01831467
Typical example

7. Align the timing mark on idler gear (5) with the timing mark on the camshaft gear. Refer to Illustration 165. Install the assembly of idler gear (5) into the recess in the timing case. Ensure that the identification mark TOP is upward.

**Note:** The idler gear must be tilted during installation. Ensure that the holes in the assembly of the idler gear are aligned with the holes in the cylinder block.

8. Install bolts (6). Tighten the bolts to a torque of 44 N·m (32 lb ft).

REFERENCE ONLY

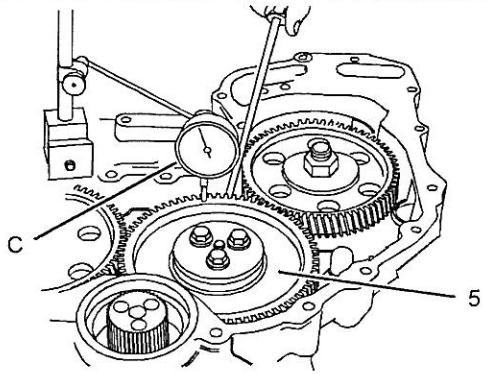



Illustration 169 g01832813

Checking end play by using a dial indicator group

9. Use Tooling (D) in order to check the end play of idler gear (5). Refer to Specifications, "Gear Group (Front)" for more information.

10. Use Tooling (D) in order to check the backlash between the idler gear and the camshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

11. Use Tooling (D) in order to check the backlash between the idler gear and the crankshaft gear. Refer to Specifications, "Gear Group (Front)" for more information.

12. Lightly lubricate all of the gears with clean engine oil.

13. Adjust the engine valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

**End By:**

a. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install".

b. If the engine is equipped with an air compressor, install the air compressor. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

c. If the engine is equipped with a vacuum pump, install the vacuum pump. Refer to Disassembly and Assembly, "Vacuum Pump - Remove and Install".

d. If the engine is equipped with an accessory drive, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install".

e. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933656

# Housing (Front) - Remove

## Removal Procedure

**Start By:**

a. Remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

b. Remove the alternator. Refer to Disassembly and Assembly, "Alternator - Remove".

c. Remove the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

d. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

e. Remove the timing gears. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install".

f. Remove the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Ensure that the coolant is drained into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

REFERENCE ONLY

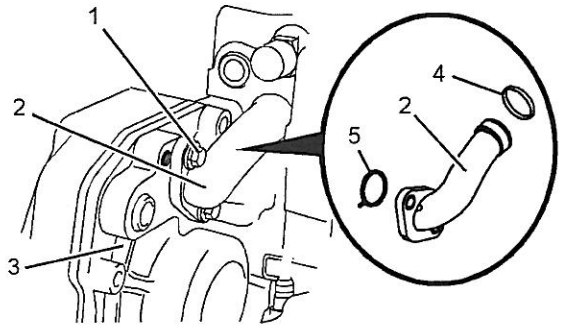



Illustration 170 g01475066
Typical example

2. Remove bolts (1) that secure bypass tube (2) to front housing (3). Remove bypass tube (2). Remove O-ring seal (4) and O-ring seal (5) from bypass tube (2).

**Note:** Note the position of any brackets that are secured by the bolts.

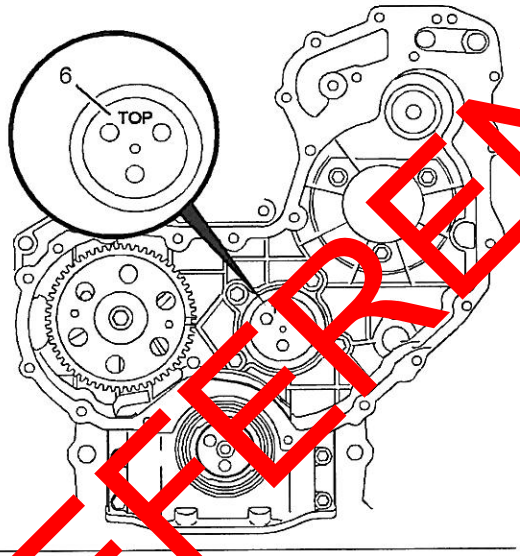



Illustration 171 g01475068
Typical example

3. If the engine is equipped with a heavy duty idle gear. Remove plate (6). Refer to Disassembly and Assembly, "Idler Gear - Remove" for the correct procedure.

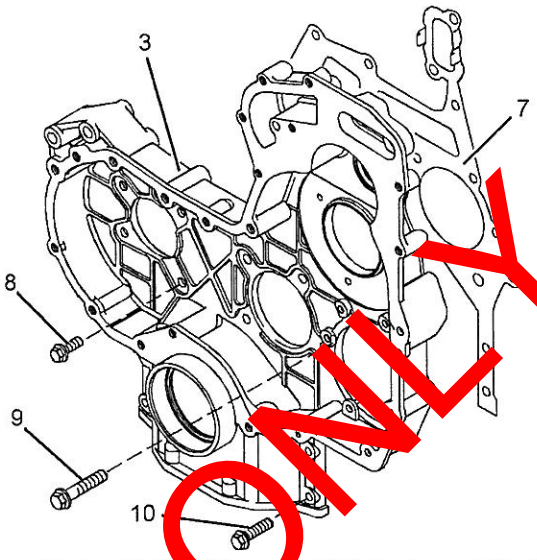



Illustration 172 g01475067
Typical example

4. Remove bolts (8), (9) and (10) from front housing (3).

**Note:** The bolts are three different lengths. Note the positions of the different bolts.

5. Remove front housing (3) from the cylinder block.

6. Remove gasket (7).

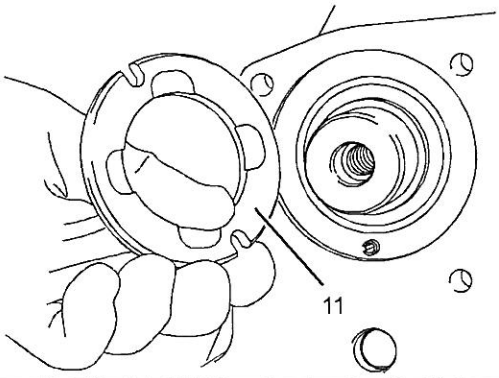



Illustration 173 g01475069
Typical example

7. Remove thrust washer (11) from the cylinder block.

REFERENCE ONLY

i02933655

# Housing (Front) - Install

## Installation Procedure

Table 45

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21820117 | POWERPART Threadlock and Nutlock | 1 |
| B | - | Guide Stud (M8 by 80 mm) | 2 |
| C | 27610216 | Alignment Tool | 1 |
| | - | Bolts (M10 by 50 mm) | 3 |
| D | - | Straight Edge | 1 |
| E | 21820221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten component life.

1. Ensure that the front housing is clean and free from damage. If necessary, replace the front housing.

   If necessary, install blanking plugs to a new front housing. Use Tooling (A) to seal all the plugs.

2. Check the condition of the crankshaft front seal. If the front seal is damaged, remove the front seal from the front housing.

3. Clean the surfaces of the cylinder block.

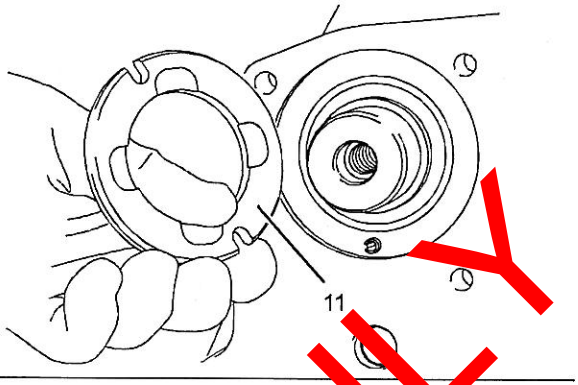



Illustration 174 g01475069
Typical example

4. Install thrust washer (11) into the recess in the cylinder block. Refer to Disassembly and Assembly, "Camshaft - Install" for more information.

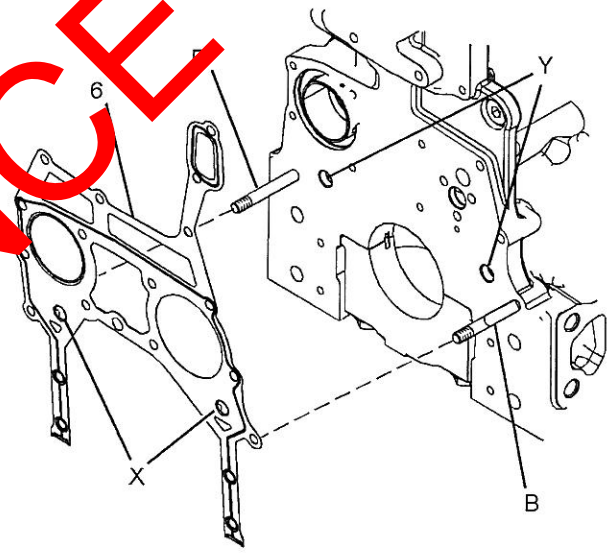



Illustration 175 g01475134
Typical example

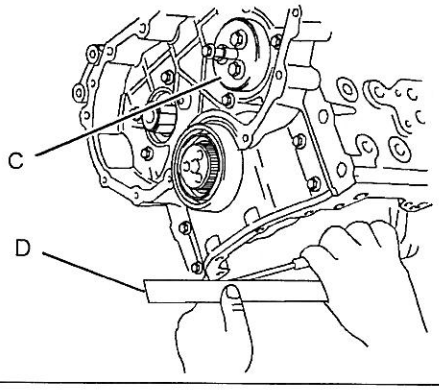



Illustration 176 g01269947
Typical example

REFERENCE ONLY

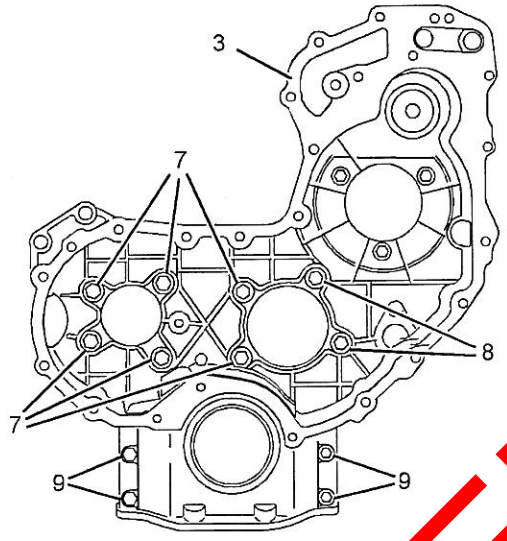
5. Install Tooling (B) to the cylinder block. Refer to Illustration 175.

6. Install Tooling (C) to the cylinder block.

7. Align a new gasket (6) with Tooling (B) and Tooling (C). Install the gasket to the cylinder block.

**Note:** Ensure that Tabs (X) on the gasket are engaged in Holes (Y) in the cylinder block.

8. Install the front housing over Tooling (B) and over Tooling (C) onto the cylinder block.




g01269948

Illustration 177

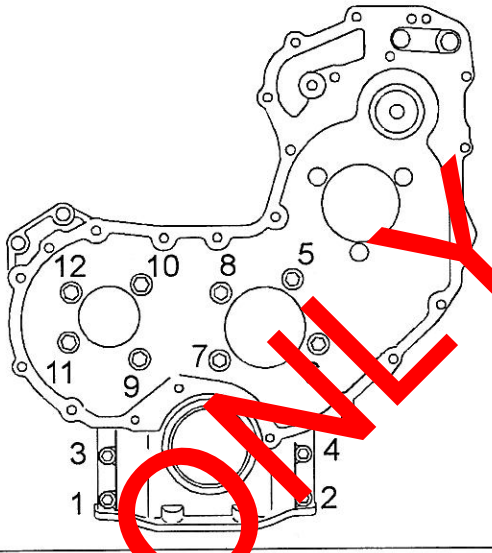
(7) M8 by 20 mm
(8) M8 by 35 mm
(9) M8 by 25 mm

9. Install bolts (9) to front housing (3) finger tight.

10. Remove Tooling (B).

11. Loosely install bolt (7) and bolt (8). Refer to Illustration 177 for the correct position of the bolts.

12. Align the bottom face of front housing (3) to the lower machined face of the cylinder block. Use Tooling (D) and a feeler gauge in order to check the alignment between the front housing and the cylinder block. Refer to Illustration 176. Refer to Specifications, "Front Housing and Covers" for further information.




g01269949

Illustration 178

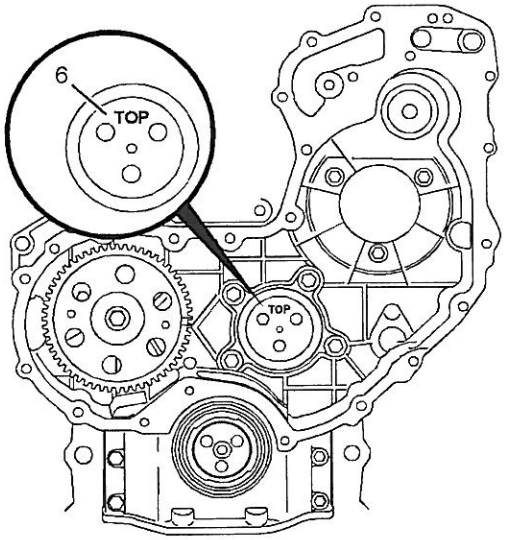
Tightening sequence for the front housing

13. Tighten bolts (7), (8) and (9) to a torque of 28 N·m (20 lb ft). Tighten the bolts in the sequence that is shown in Illustration 178.

**Note:** Ensure that the housing and the cylinder block are correctly aligned.

14. Remove Tooling (C) from the cylinder block.

15. If necessary, install a new crankshaft front seal. Refer to Disassembly and Assembly, "Crankshaft Front Seal - Remove and Install".




g01475068

Illustration 179

Typical example

REFERENCE ONLY

**16.** If the engine is equipped with a heavy duty idle gear. Install plate (6). Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure.

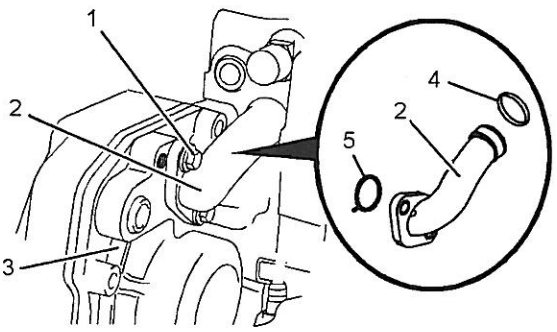



Illustration 180 g01475066
Typical example

**17.** Install new O-ring seal (4) and O-ring seal (5) to bypass tube (2). Use Tooling (E) in order to lubricate O-ring seal (5). Install bypass tube (2) to front housing (3). Install bolts (1). Tighten the bolts to a torque of 22 N·m (16 lb ft).

**Note:** Ensure that any brackets that are secured by the bolts are installed in the correct location.

**18.** Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

**End By:**

**a.** Install the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

**b.** Install the timing gears. Refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install".

**c.** Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

**d.** Install the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install".

**e.** Install the alternator. Refer to Disassembly and Assembly, "Alternator - Install".

**f.** Install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933583

# Accessory Drive - Remove

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

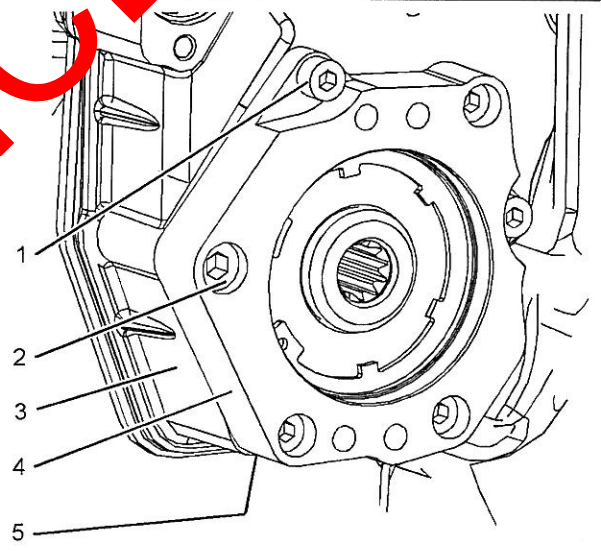



Illustration 181 g01441026
Typical example

**1.** Remove allen head screw (1) from accessory drive housing (4). Remove allen head screws (2) from accessory drive housing (4).

**2.** Remove accessory drive housing (4) from front housing (3).

**3.** Remove O-ring seal (5) (not shown) from accessory drive housing (4).

REFERENCE ONLY

i02933581

# Accessory Drive - Disassemble

## Disassembly Procedure

Table 46

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Bearing Puller | 1 |
| | - | Puller | 1 |
| | - | Crossblock | 1 |
| | - | Puller Leg | 2 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

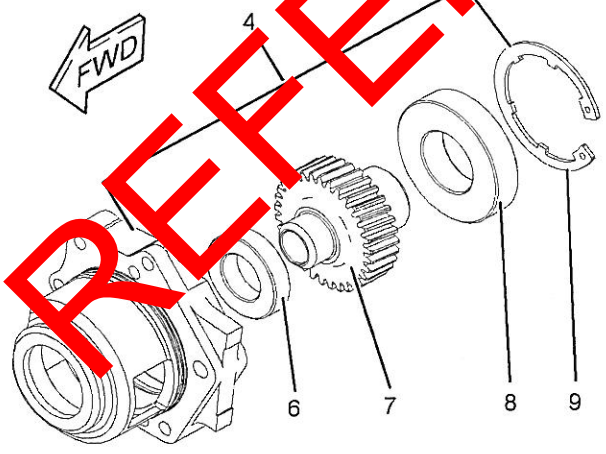



Illustration 182 g01440573
Typical example

1. Remove circlip (9) from accessory drive housing (4).
2. Place accessory drive housing (4) onto a suitable support. Press the assembly of gear (7), bearing (6) and bearing (8) out of accessory drive housing (4).
3. Use a Tooling (A) in order to remove bearing (6) and bearing (8) from gear (7).

i02933580

# Accessory Drive - Assemble

## Assembly Procedure

Table 47

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| B | 21820603 | POWERPART Retainer | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

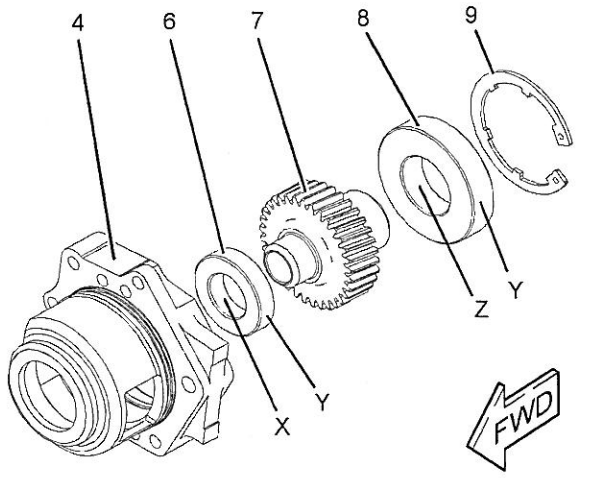



Illustration 183 g01440577
Typical example

1. Inspect the condition of the teeth and the splines of gear (7) for wear or damage. Inspect bearing (6) and bearing (8). Inspect circlip (9), and front housing (4) for wear or damage. Replace any components that are worn or damaged.

REFERENCE ONLY

2. Apply a small continuous bead of Tooling (B) to inner Surface (X) of bearing (6). Place the gear shaft on a suitable support. Press on the inner race of bearing (6) until bearing (6) is against the shoulder of gear (7). Remove any excess sealant.

3. Apply a small continuous bead of Tooling (B) to inner Surface (Z) of bearing (8). Place the inner race of bearing (8) onto a suitable support. Press the shaft of gear (7) onto bearing (8) until the shoulder of the gear is against the bearing. Remove any excess sealant.

4. Apply a small continuous bead of Tooling (B) to outer Surface (Y) of bearing (6) and bearing (8). Place accessory drive housing (4) on a suitable support. Press the assembly of the gear into the accessory drive housing. Ensure that bearing (6) is against the front face of the recess in accessory drive housing (4). Remove any excess sealant.

5. Install circlip (9) into the groove in accessory drive housing (4). Ensure that circlip (9) is correctly positioned in the groove.

i02933582

# Accessory Drive - Install

## Installation Procedure

Table 48

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| C | 21820221 | POWERPART Rubber Lubricant | 1 |
| D | 21820117 | POWERPART Threadlock and Nutlock | 1 |

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

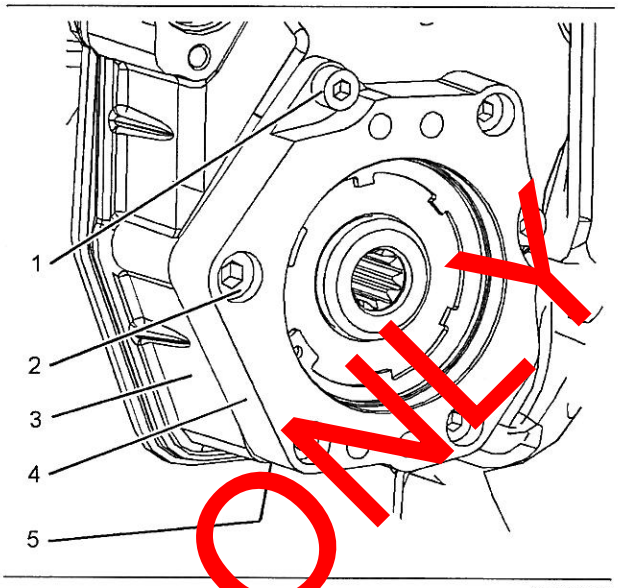



Illustration 184 g01441026
Typical example

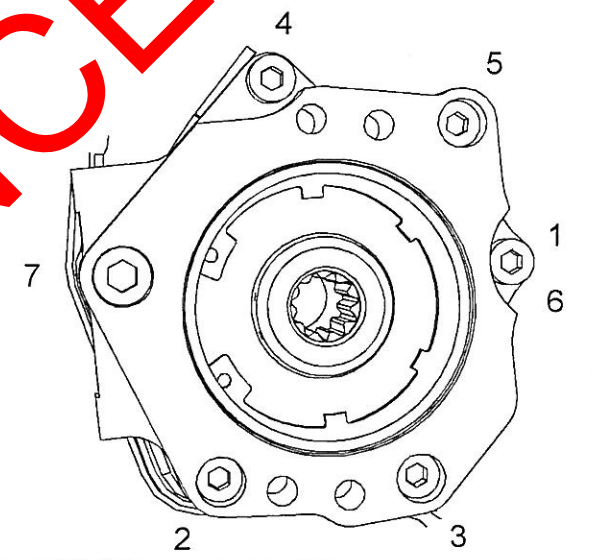



Illustration 185 g01444555
Sequence for tightening accessory drive

1. Inspect the bore in front housing (3) for damage. If necessary, replace the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove" and Disassembly and Assembly, "Housing (Front) - Install".

2. Lightly lubricate a new O-ring seal (5) (not shown) with Tooling (C). Install the O-ring seal (not shown) into the groove in accessory drive housing (4).

3. Lightly lubricate all bearings, and all gears with clean engine lubricating oil. Install the assembly of the accessory drive to the front housing. Ensure that the flange on the accessory drive housing is flush with the front housing.

REFERENCE ONLY

4. Apply Tooling (D) to allen head screws (1) and allen head screw (2).

5. Install allen head screws (1) and allen head screw (2) to accessory drive housing (4).

6. Tighten allen head screws (1) to a torque of 22 N·m (16 lb ft).

   Tighten allen head screw (2) to a torque of 44 N·m (32 lb ft). Tighten allen head screws (1) and (2) in the sequence that is shown in Illustration 185.

7. Ensure that there is tactile backlash between the idler gear and the accessory drive gear.

i02933599

# Crankcase Breather - Remove and Install (Filtered Breather)

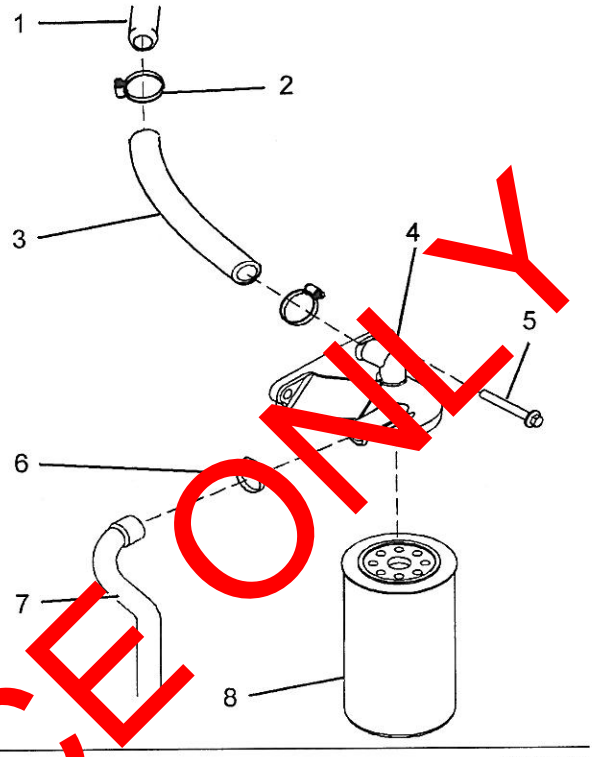
## Removal Procedure

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, ing, adjusting, and repair of the product. Be prepa to collect the fluid with suitable contain before opening any compartment or disassembl any om-ponent containing fluids.

Dispose of all fluids according to l cal re ulatio and mandates.

NOTICE
Keep all parts clean f m c aminan s.

Contaminants m cau e rapi wear and shortened component lif




Illustratio 186 g01475258
xample

1. Remove canister (8). Refer to Operation and Maintenance Manual, "Crankcase Breather (Canister) - Replace".

2. Loosen clamp (6) and remove hose (7).

3. Release spring clamps (2) in order to remove hose (3). Remove the hose from connection (1) on the valve mechanism cover and from filter base (4).

4. Remove bolts (5) and remove filter base (4).

**Note:** If a spacer is installed between the filter base and the engine, remove the spacer.

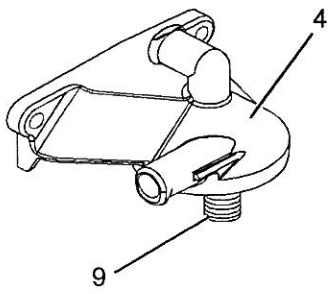



Illustration 187 g01903114

REFERENCE ONLY

5. If necessary, use a suitable tool in order to remove connection (9) from filter base (4).

## Installation Procedure

Table 49

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21820118 | Thread Lock Compound | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.

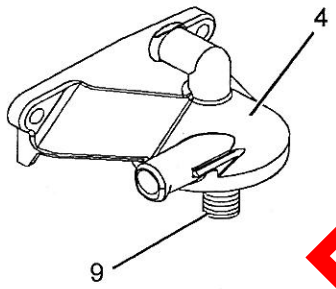



Illustration 188 g01503114

2. If necessary, install connection (9) to filter base (4). Follow Step 2.a through Step 2.c in order to install connection (9) to filter base (4).
   a. Apply a bead of Tooling (A) to the threads of connection (9).
   b. Install connection (9) to filter base (4).
   c. Tighten connection (9) to a torque of 50 N·m (37 lb ft).

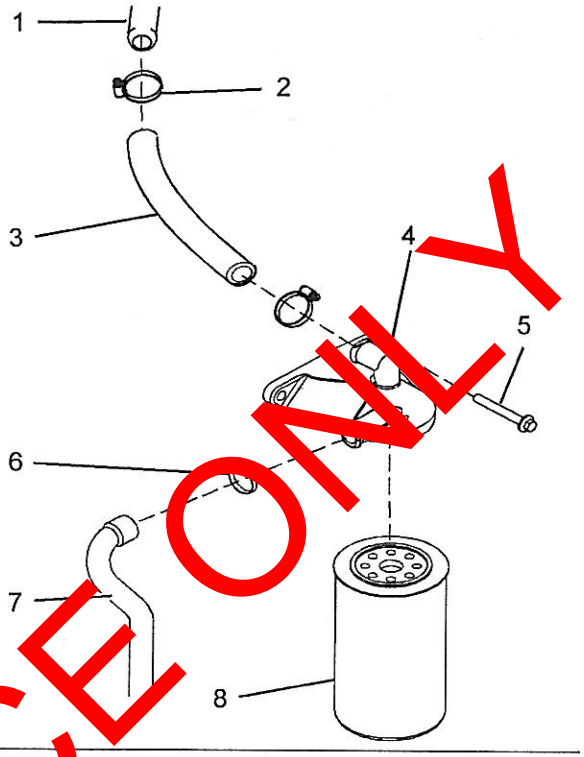



Illustration 189 g01475258
Typical example

3. Install bolts (5) to filter base (4).

**Note:** If spacers are installed, position the spacers over the bolts.

4. Install the assembly of the filter base to the engine.
5. Tighten bolts (5) to a torque of 22 N·m (16 lb ft).
6. Install spring clamps (2) to hose (3). Install hose (3) to connection (1) on the valve mechanism cover and to filter base (4).

**Note:** Ensure that the spring clamps are correctly positioned in order to secure the hose.

7. Install clamp (6) to hose (7). Install hose (7) to filter base (4). Tighten the clamp securely.
8. Install a new canister (8) to filter base (4). Refer to Operation and Maintenance Manual, “Crankcase Breather (Canister) - Replace”.

REFERENCE ONLY

i02933600

# Crankcase Breather - Remove and Install (Unfiltered Breather)

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

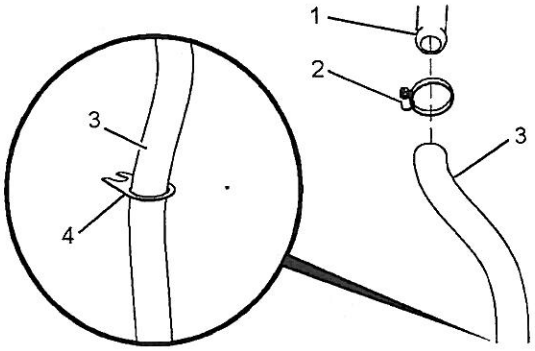



Illustration 190
Typical example

1. Loosen clamp (2) and remove hose (3) from connection (1) on the valve mechanism cover. Withdraw hose (3) from clip (4) and remove the hose.

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Ensure that all components of the crankcase breather are clean and free from damage. Replace any components that are damaged.

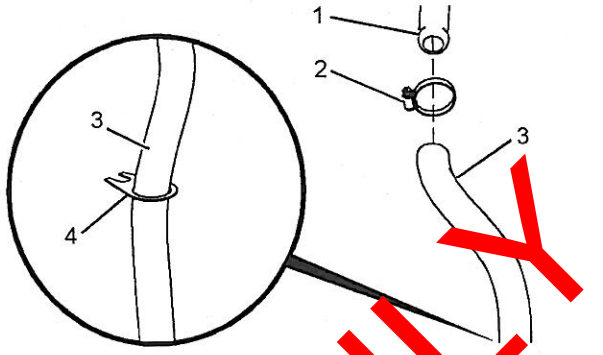



Illustration 191
Typical example

g01475234

2. Connect hose (3) to connection (1) on the valve mechanism cover. Tighten clamp (2). Install hose (3) into clip (4).

i02933677

# Valve Mechanism Cover - Remove and Install

## Removal Procedure

**Start By:**

a. Disconnect the crankcase breather or remove the crankcase breather. Refer to Disassembly and Assembly, “Crankcase Breather - Remove and Install”.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

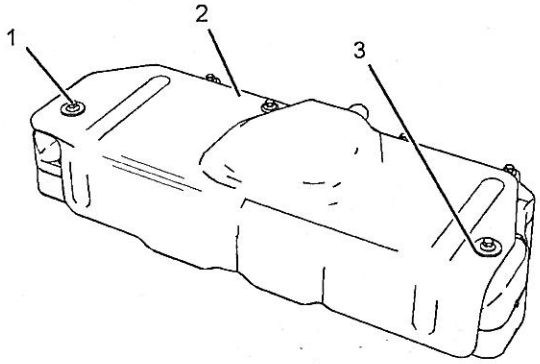



Illustration 192

g01788614

REFERENCE ONLY

1. If the valve mechanism cover is equipped with a heat shield, remove bolts (1) and washers (3) from heat shield (2).

**Note:** The washers are two different sizes. Note the position of the washers for installation purposes.

2. Remove heat shield (2).

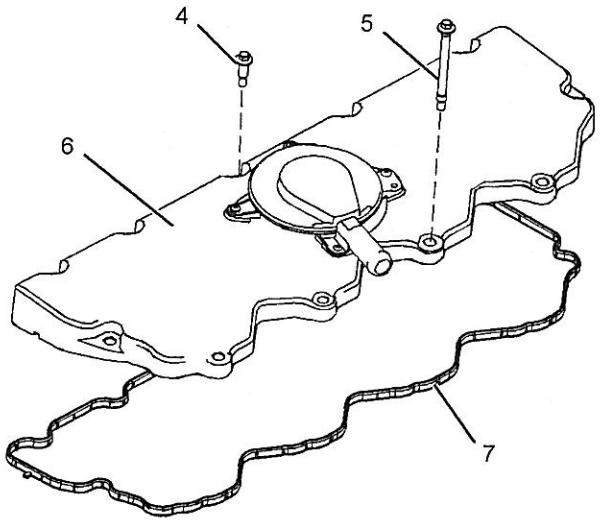



Illustration 193 g01788720
Typical example

3. Remove bolts (4) and bolts (5) from valve mechanism cover (6).

4. Remove valve mechanism cover (6) from the valve mechanism cover base.

5. Remove gasket (7) from valve mechanism cover (6).

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the valve mechanism cover. Clean the faces of the valve mechanism cover base.

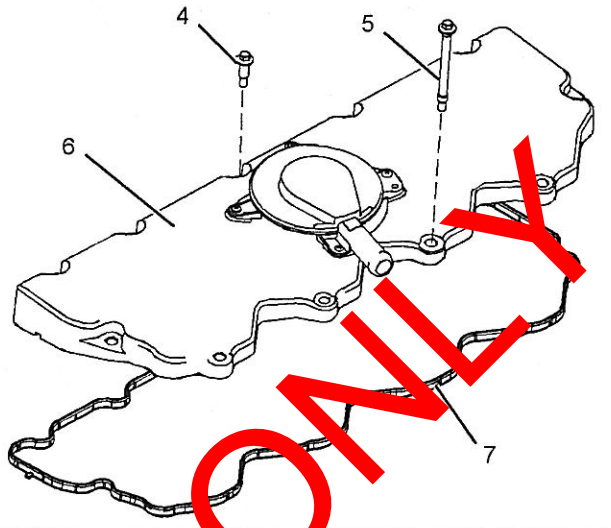



Illustration 194 g01788720
Typical example

2. Install a new gasket (7) to valve mechanism cover (6).

**Note:** Ensure that the gasket is fully seated into the groove of the valve mechanism cover.

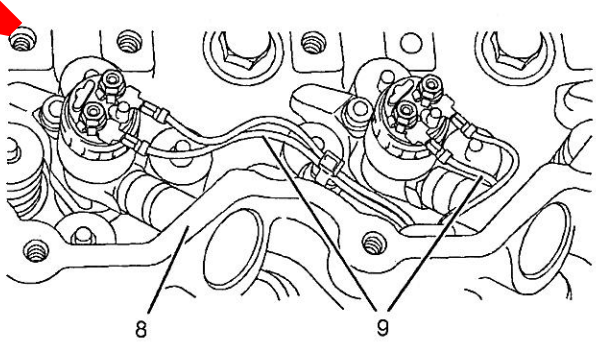



Illustration 195 g01788815
Typical example

3. Ensure that harness assemblies (9) are not in contact with the rocker arms or in contact with the valve mechanism cover base. Position valve mechanism cover (6) onto valve mechanism cover base (8). Ensure that harness assemblies (9) are not trapped during the assembly procedure. Install bolts (4) and bolts (5).

REFERENCE ONLY

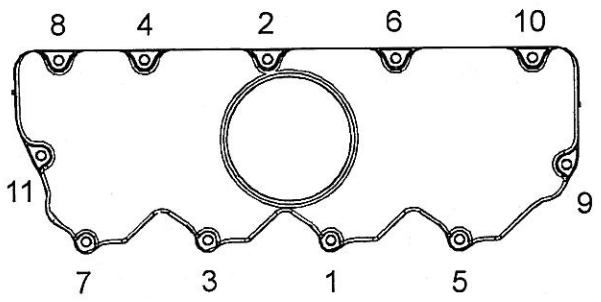



Illustration 196 g01245162

Tightening sequence for the valve mechanism cover

4. Tighten bolts (4) and bolts (5) in the numerical sequence that is shown in Illustration 196. Tighten the bolts to a torque of 6 N·m (53 lb in).

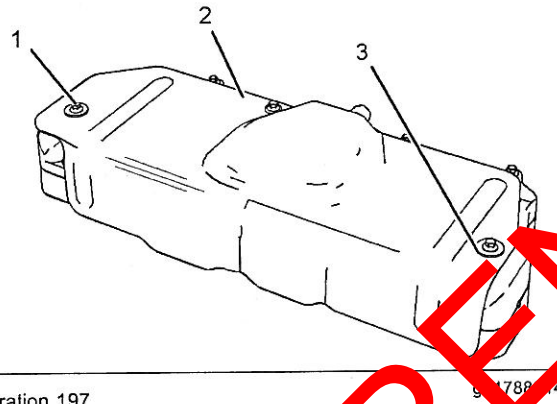



Illustration 197

5. If necessary, position heat shield (2) onto the valve mechanism cover.

6. Install bolts (1) and washers (3). Tighten the bolts to a torque of 9 N·m (80 lb in).

**End By:**

a. Connect the crankcase breather or install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

i02933678

# Valve Mechanism Cover Base - Remove and Install

## Removal Procedure

Table 50

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Circlip Pliers | 1 |

**Start By:**

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

b. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

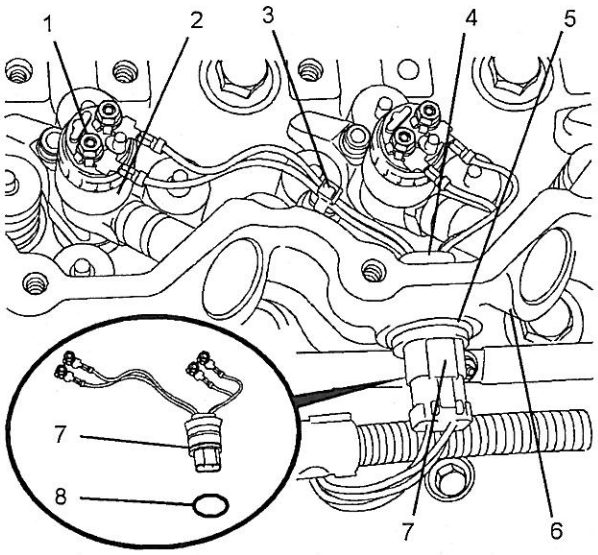



Illustration 198 g01476212

Typical example

REFERENCE ONLY

1. Make a temporary identification mark on connections (1).
2. Use a deep socket to remove connections (1) from electronic unit injectors (2).
3. Disconnect plugs (7) from harness assemblies (4).
4. If necessary, follow Step 4.a through Step 4.e in order to remove harness assemblies (4) from valve mechanism cover base (6).
   a. Cut cable strap (3).
   b. Use Tooling (A) to remove circlip (5).
   c. From the outside of valve mechanism cover base (6), push harness assembly (4) inward. Withdraw the harness assembly from valve mechanism cover base (6).
   d. Remove O-ring seal (8) from harness assembly (4).
   e. Repeat Step 4.a through Step 4.d in order to remove the remaining harness assembly.

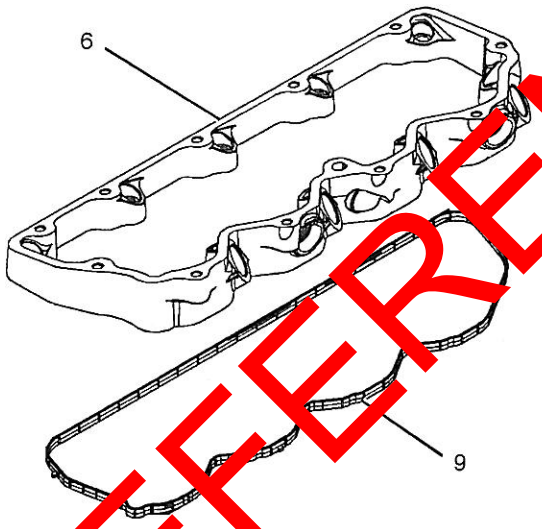



Illustration 199 g01245186
Typical example

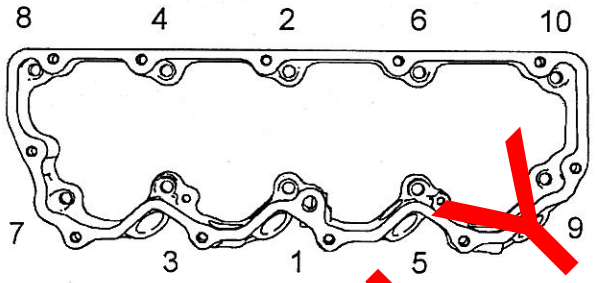



Illustration 200 g01245190
Sequence for loosening captive bolts in valve mechanism

5. Progressively loosen the captive bolts that secure the valve mechanism cover base in reverse numerical order. Refer to Illustration 200. This will help prevent distortion of the valve mechanism cover base.

**Note:** The captive bolts cannot be removed from the valve mechanism cover base.

6. Remove the valve mechanism cover base from the cylinder head.
7. Remove gasket (9) from the valve mechanism cover base .

## Installation Procedure

Table 51

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | Circlip Pliers | 1 |
| B | 21820221 | POWERPART Rubber Grease | 1 |
| C | 27610296 | Torque wrench | 1 |
| D | 27610349 | Alignment Pins | 2 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Use a deep socket in order to remove the electrical connections from the electronic unit injectors. Use of incorrect tooling will result in damage to the electronic unit injectors.

1. Clean the valve mechanism cover base. Ensure that the gasket surfaces are free from damage.

REFERENCE ONLY

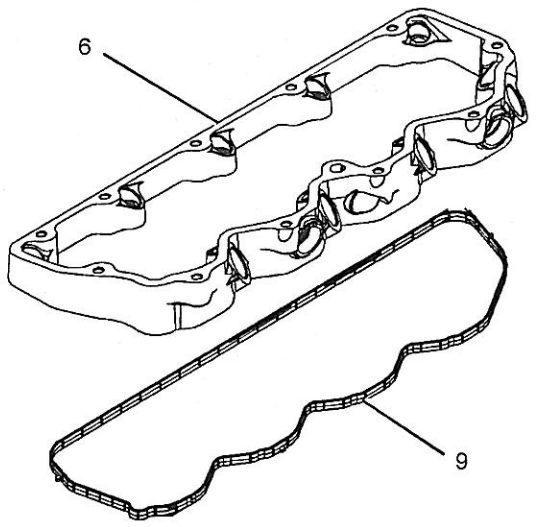



Illustration 201 g01245186
Typical example

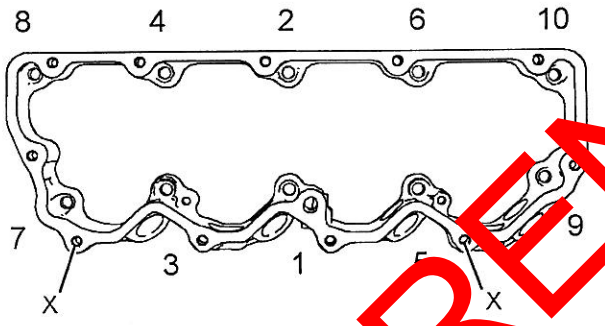



Illustration 202 g01272185
Tightening sequence for the valve mechanism cover base

2. Install gasket (9) to valve mechanism cover base (6). Ensure that the gasket is seated correctly in the groove in the valve mechanism cover base.

3. Position valve mechanism cover base (6) on the cylinder head.

4. Install Tooling (D) into the valve mechanism cover base Positions (X).

5. Progressively tighten the captive bolts that secure the valve mechanism cover base. Tighten the captive bolts to a torque of 9 N·m (79 lb in) in the sequence that is shown in Illustration 202.

6. Remove Tooling (D).

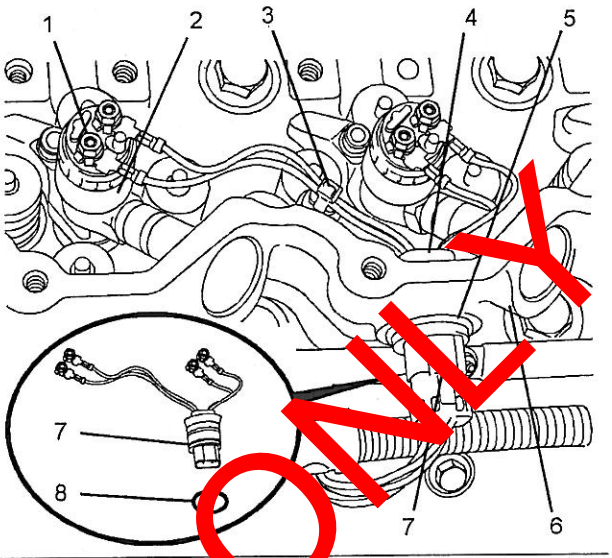



Illustration 203 g01476212
Typical example

7. If necessary, install the harness assemblies for the electronic unit injectors. Follow Step 7.a through Step 7.e in order to install the harness assemblies to the electronic unit injectors.

   a. Ensure that harness assembly (4) and the bore in valve mechanism cover base (6) are clean and free from damage. Replace any damaged components.

   b. Use Tooling (B) to lubricate a new O-ring seal (8). Install O-ring seal (8) onto harness assembly (4).

   c. From the inside of valve mechanism cover base (6), push harness assembly (4) into the valve mechanism cover base.

   d. Use Tooling (A) to install circlip (5).

   e. Repeat Step 7.a through Step 7.e for the remaining harness assembly.

8. Use a deep socket to connect harness (4) to electronic unit injectors (2). Use Tooling (C) to tighten connectors (1) to a torque of 2.4 N·m (21 lb in).

9. If necessary, install new cable strap (3) to harness assemblies (4).

**Note:** Ensure that the cable straps conform to the Perkins specification.

10. Connect plugs (7) to harness assemblies (4).

REFERENCE ONLY

**End By:**

a. Install new fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

b. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933672

# Rocker Shaft and Pushrod - Remove

## Removal Procedure

Table 52

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | E12 Torx Socket | 1 |

**Start By:**

a. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

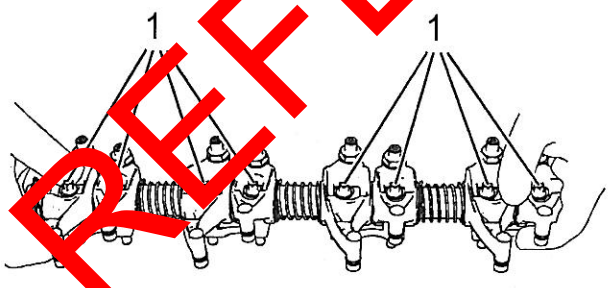



Illustration 204 g01476297

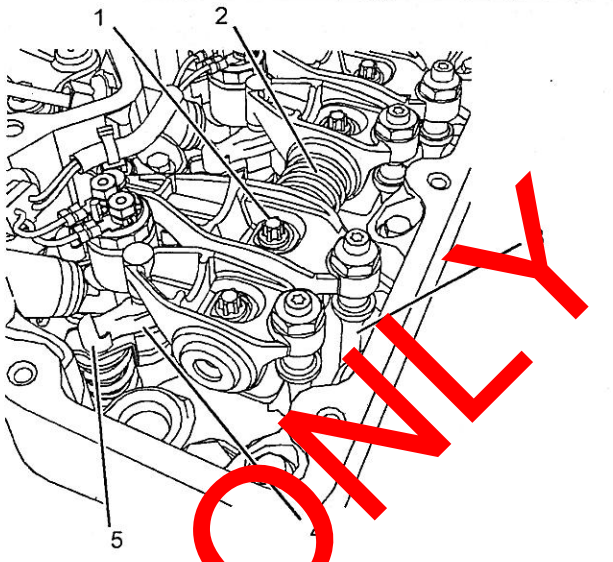



Illustration 205 g01792634
Typical example

1. Use Tooling (A) in order to progressively loosen torx screws (1). Begin at the ends of the rocker shaft assembly and work toward the center.

**Note:** To avoid distortion of the rocker shaft assembly, each torx screw should be loosened by a quarter of a turn at one time. Repeat the procedure until all torx screws are loosened.

2. Remove torx screws (1) from rocker shaft assembly (2).

3. Remove rocker shaft assembly (2) from the cylinder head.

4. Make a temporary mark on pushrods (3) in order to show the location. Remove the pushrods from the cylinder head.

**Note:** Identification will ensure that the pushrods can be reinstalled in the original positions. Do not interchange the positions of used pushrods.

5. Make a temporary mark on valve bridges (4) in order to show the location and the orientation. Remove the valve bridges from the cylinder head. If the valve bridges are equipped with shrouds (5), ensure that the shrouds are removed from the cylinder head.

**Note:** Identification will ensure that the valve bridges can be reinstalled in the original location and the original orientation. Do not interchange the location or the orientation of used valve bridges.

REFERENCE ONLY

i02933670

# Rocker Shaft - Disassemble

## Disassembly Procedure

**Start By:**

a. Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

**⚠ WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Make an identification mark on each rocker arm assembly in order to show the location.

**Note:** The components must be reinstalled in the original location. Do not interchange components.

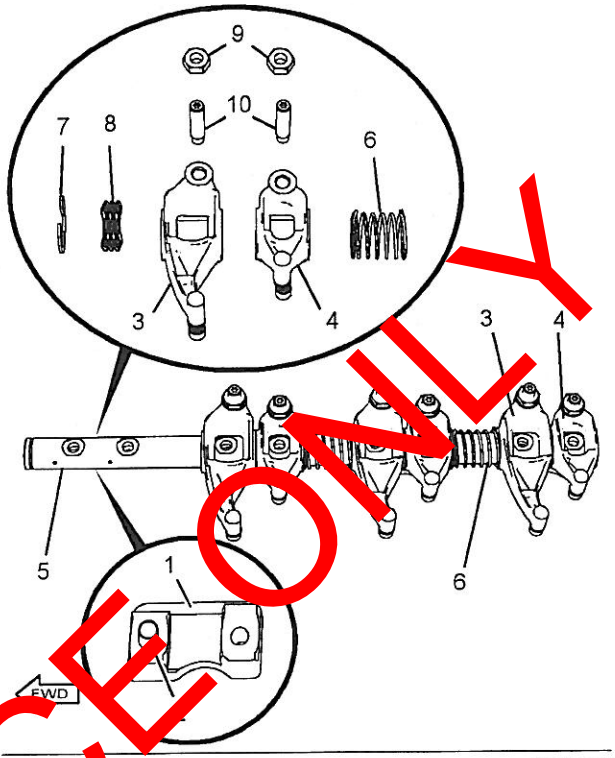



Illustration 206 g01476312
Typical example

2. Remove pedestals (1) from rocker shaft (5). Do not remove dowels (2) from the pedestals.

3. Remove rocker arm assembly (4) for the exhaust valve from rocker shaft (5). Remove rocker arm assembly (3) for the inlet valve from rocker shaft (5). Begin at the rear of the rocker shaft assembly.

**Note:** The rocker arm assembly for the inlet valve is longer than the rocker arm assembly for the exhaust valve.

4. Remove spring (6) from rocker shaft (5).

5. Repeat Step 3 and Step 4 in order to remove the remaining rocker arms from rocker shaft (5).

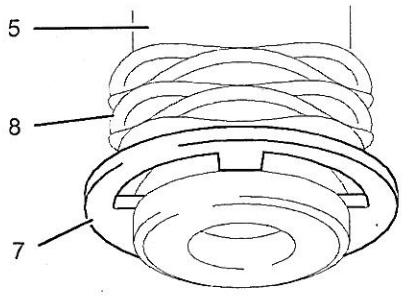



Illustration 207 g01181801

REFERENCE ONLY

6. If necessary, remove retaining clip (7) and remove spring (8) from the front end of rocker shaft (5).

7. If necessary, remove nuts (9) and adjusters (10) from the rocker arms. Make a temporary identification mark on each adjuster in order to show the location.

**Note:** The components must be reinstalled in the original location. Do not interchange components.

i02933669

# Rocker Shaft - Assemble

## Assembly Procedure

**⚠ WARNING**

**Personal injury can result from being struck by parts propelled by a released spring force.**

**Make sure to wear all necessary protective equipment.**

**Follow the recommended procedure and use all recommended tooling to release the spring force.**

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. Refer to Specifications, "Rocker Shaft" for more information. If necessary, replace any components that are worn or damaged.

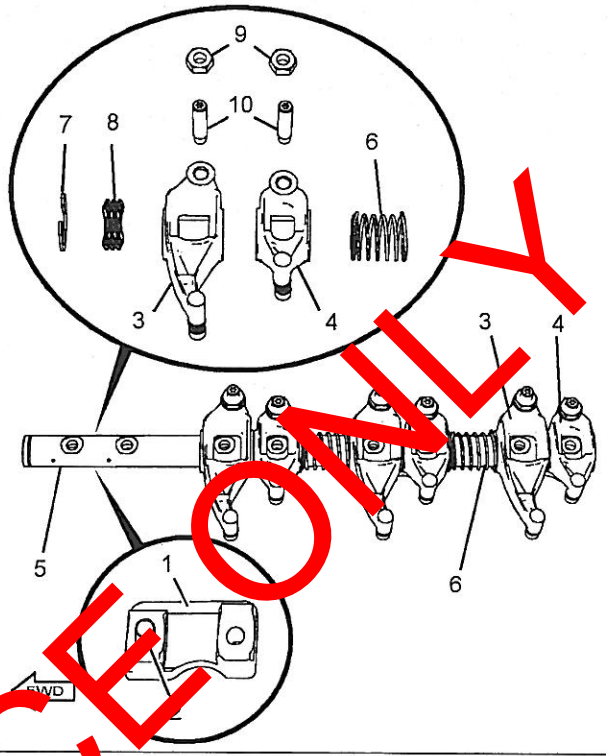



Illustration 208 g01476312
Typical example

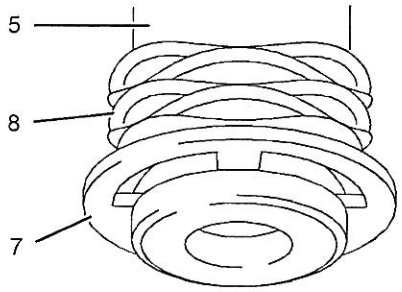



Illustration 209 g01270008

2. If necessary, install nuts (9) and adjusters (10) to rocker arm assemblies (3) and (4). If the original adjusters are reused, ensure that the adjusters are installed in the original positions.

3. Install retaining clip (7) and spring (8) to the front end of rocker shaft (5).

4. Lubricate the bores of rocker arm assemblies (3) and (4) and rocker shaft (5) with clean engine oil.

REFERENCE ONLY

5. Place the rocker shaft in the inverted position with the counterbores for the holes downward. Install rocker arm assembly (3) for number 1 cylinder inlet valves to the rocker shaft. Install rocker arm assembly (4) for number 1 cylinder exhaust valves to rocker shaft (5).

**Note:** The rocker arms for the inlet valves are longer than the rocker arms for the exhaust valves. Install rocker arms in the inverted position. Used components should be installed in the original location.

6. Ensure that dowel (2) is correctly seated in pedestal (1). Align the dowel with the appropriate hole in rocker shaft (5). Install the pedestal to the rocker shaft.

7. Install spring (6) to rocker shaft (5).

8. Repeat Step 5 through Step 7 in order to assemble the remaining components to rocker shaft (5).

**End By:**

a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install".

i02933671

# Rocker Shaft and Pushrod - Install

## Installation Procedure

Table 53

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | | E10 Torx Socket | 1 |
| B | 2610298 | Feeler Gauge | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the valve bridges. Inspect the valve bridges for wear or damage. Replace any valve bridges that are worn or damaged.

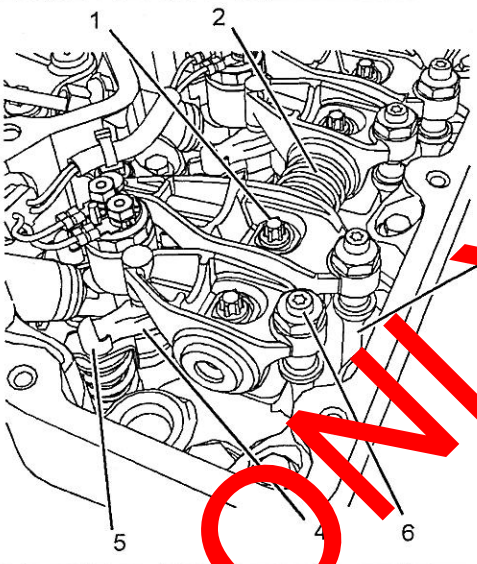



Illustration 210 g01794035

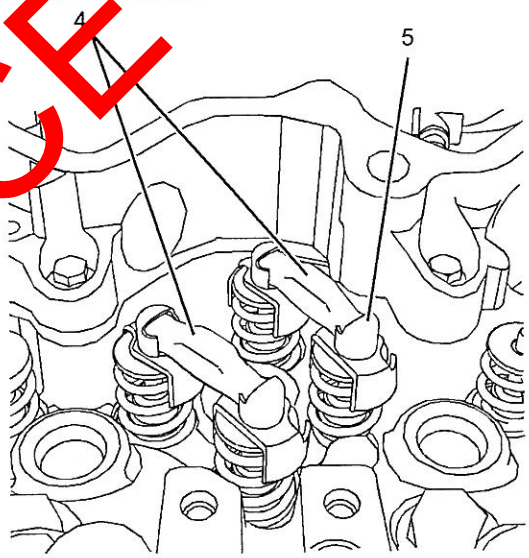



Illustration 211 g01794053

The correct location of valve bridges on valve stems is shown. The electronic unit injector is not shown for clarity.

NOTICE
Failure to ensure that ALL valve bridges are correctly seated onto the valve stems will cause interference between the pistons and the valves, resulting in damage to the engine.

2. Lubricate valve bridges (4) with clean engine oil. Install the valve bridges to the cylinder head.

3. Install valve bridges (4) to the cylinder head. If the valve bridges are equipped with shrouds (5), ensure that the shrouds are located correctly.

REFERENCE ONLY

**Note:** Install used valve bridges in the original location and in the original orientation. Ensure that the valve bridges are correctly seated on the valves. New valve bridges may be installed in either orientation.

4. Clean pushrods (3). Inspect the pushrods for wear or damage. Replace any pushrods that are worn or damaged.

5. Apply clean engine lubricating oil to both ends of pushrods (3). Install the pushrods to the engine with the cup upward.

**Note:** Ensure that the pushrods are installed in the original location and that the ball end of each pushrod is correctly seated in the valve lifters.

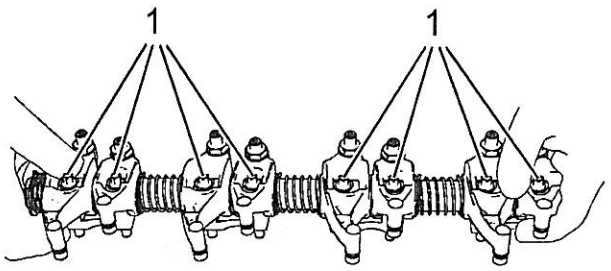



Illustration 212 g014

6. Ensure that the rocker shaft assembly is clean and free from wear or damage. Install torx screws (1) in the rocker shaft.

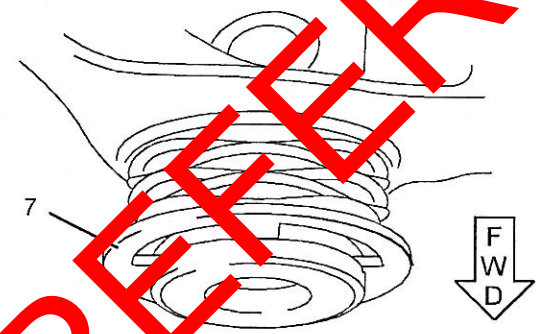



Illustration 213 g01794061

7. Position rocker shaft assembly (2) onto the cylinder head. Retaining clip (7) should face the front of the engine.

**Note:** Ensure that adjustment screws (6) are properly seated in the ends of pushrods (3).

8. Use Tooling (A) to gradually tighten torx screws (1).

**Note:** To avoid distortion of rocker shaft assembly (2), tighten the torx screws in the center first. Work toward the outside of the rocker shaft assembly.

Tighten the torx screws to a torque of 35 N·m (26 lb ft).

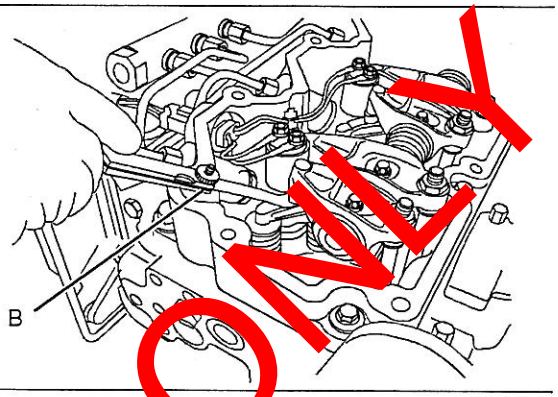



Illustration 214 g01259267
Typical example

9. Use Tooling (B) in order to check the valve lash. If necessary, adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust" for the correct procedure.

**End By:**

a. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933613

# Cylinder Head - Remove

## Removal Procedure

**Start By:**

a. Remove the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install".

b. Remove the fuel manifold. Refer to Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install".

c. Remove the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, "ECM Mounting Bracket- Remove and Install".

d. Remove the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

REFERENCE ONLY

**e.** Remove the valve mechanism cover base. Refer to Disassembly and Assembly, "Valve Mechanism Cover Base - Remove and Install".

**f.** Remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

**1.** If the alternator bracket is mounted on the cylinder head, remove the alternator. Refer to Disassembly and Assembly, " Alternator - Remove".

**2.** If the fuel priming pump and the primary fuel filter are mounted on the cylinder head, remove the fuel priming pump and the primary fuel filter. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

**3.** Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

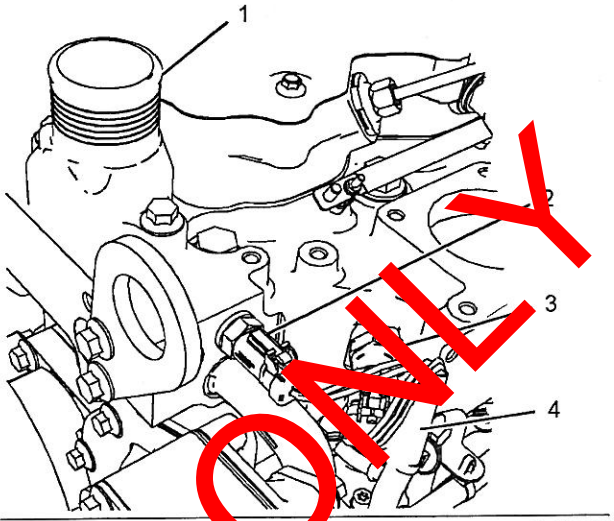



Illustration 2.5 g01245537
Typical example

**4.** Disconnect the upper radiator hose from water temperature regulator housing (1).

**5.** If necessary, remove the air hose from the inlet connection.

**6.** Follow Step 6.a and Step 6.b in order to disconnect harness assembly (4) from coolant temperature sensor (2).

**a.** Slide the locking tab into the unlocked position.

**b.** Disconnect harness assembly (4) from coolant temperature sensor (2).

**7.** If necessary, follow Step 7.a and Step 7.b in order to disconnect harness assembly (4) from boost pressure sensor (3).

**a.** Slide the locking tab into the unlocked position.

**b.** Disconnect harness assembly (4) from boost pressure sensor (3).

REFERENCE ONLY

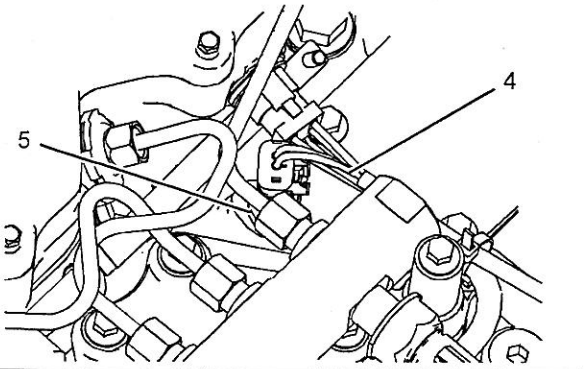



Illustration 216 g01249835
Typical example

**8.** Follow Step 8.a and Step 8.b in order to disconnect harness assembly (4) from inlet air temperature sensor (5).

**a.** Slide the locking tab into the unlocked position.

**b.** Disconnect harness assembly (4) from inlet air temperature sensor (5).

**9.** Remove all cable straps that secure harness assembly (4) to the cylinder head. The harness assembly should be positioned in order to avoid causing an obstruction during the removal of the cylinder head.

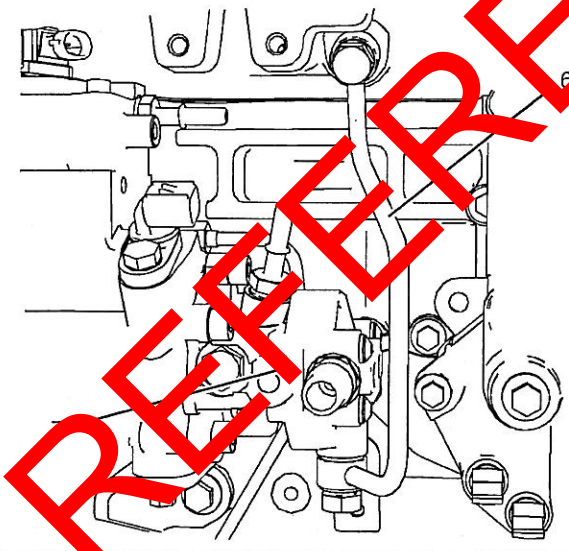



Illustration 217 g01249474
Typical example

**10.** Remove tube assembly (6) from the cylinder head and from transfer pump (7).

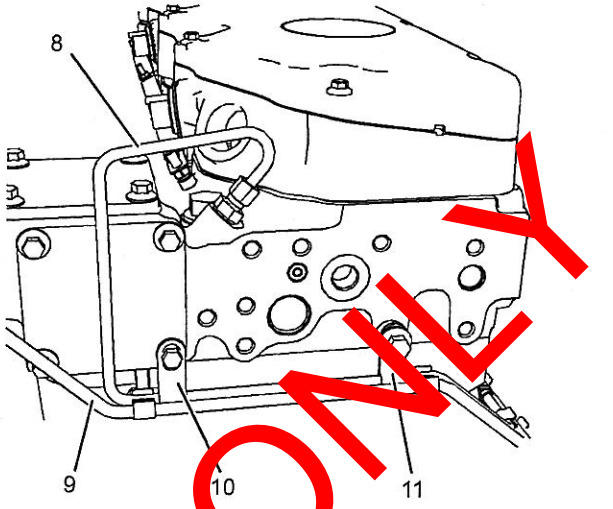



Illustration 218 g01249479
Typical example

**11.** If the engine is equipped with a wastegate solenoid, remove harness assembly (9) from tube assembly (8). Remove the bolts for tube clip (10) and tube clip (11). Remove tube assembly (8) from the wastegate solenoid and from the cylinder head.

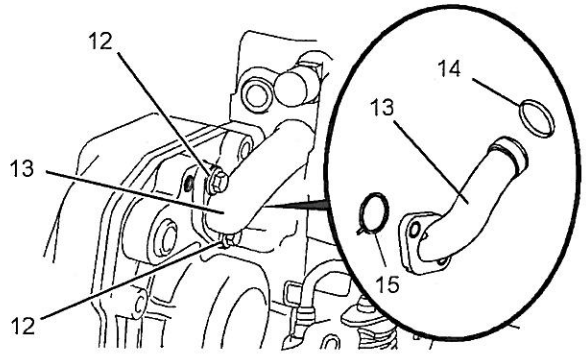



Illustration 219 g01476537
Typical example

**12.** Remove bolts (12). Note the position of any brackets that are secured by the bolts. Remove bypass tube (13) from the cylinder head. Remove O-ring seals (14) and (15) from the bypass tube.

REFERENCE ONLY

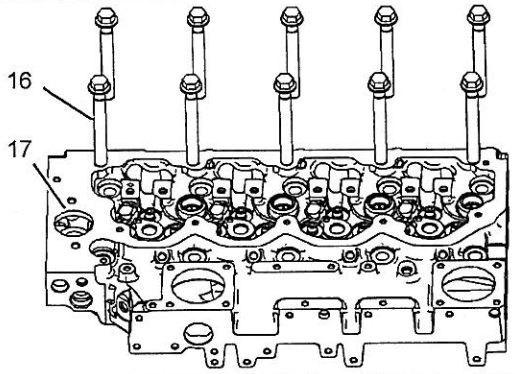



Illustration 220 g01245538

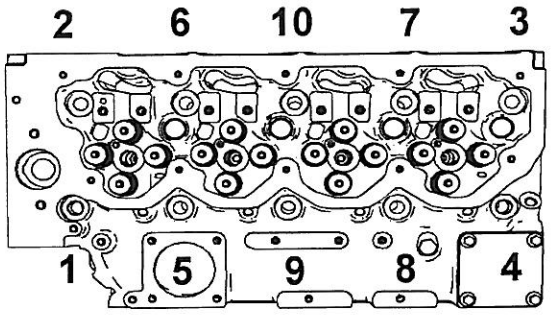



Illustration 221 g012[illegible]
Sequence for loosening the bolts for the cylinder head

**13.** Gradually loosen bolts (16) in the reverse numerical order to the sequence that is shown in Illustration 221.

**Note:** Follow the correct sequence in order to help prevent distortion of the cylinder head.

**14.** Remove bolts (16) from cylinder head (17).

**15.** Attach a suitable lifting device to cylinder head (17). Support the weight of the cylinder head. The weight of the cylinder head is approximately 56 kg (124 lb).

**16.** Use the suitable lifting device to carefully lift cylinder head (17) off the cylinder block.

**Note:** Do not use a lever to separate the cylinder head from the cylinder block. Take care not to damage the machined surfaces of the cylinder head during the removal procedure.

NOTICE
Place the cylinder head on a surface that will not scratch the face of the cylinder head.

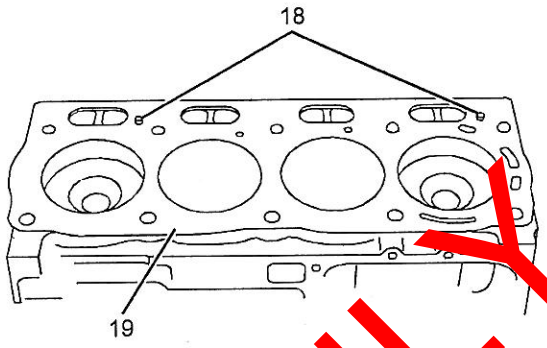



Illustration 222 g01763153
Typical example

**17.** Remove cylinder head gasket (19).

**18.** Note the position of dowels (18) in the cylinder block. Do not remove the dowels unless the dowels are damaged.

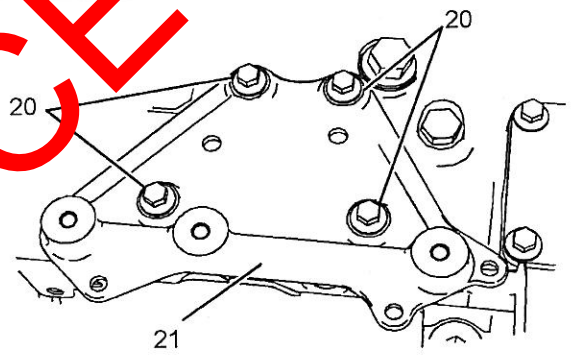



Illustration 223 g01763173
Typical example

**19.** If necessary, remove screws (20) and remove mounting bracket (21) from the cylinder head.

**20.** If necessary, remove the water temperature regulator from the cylinder head. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

**21.** If necessary, remove the electronic sensors from the cylinder head. Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Air Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Boost Pressure Sensor - Remove and Install".

REFERENCE ONLY

i02933612

# Cylinder Head - Install

## Installation Procedure

Table 54

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Guide Bolt M16 by 115mm | 2 |
| B | - | Straight Edge | 1 |
| C | 21825607 | Angle gauge | 1 |
| D | 2180221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the gasket surfaces of the cylinder head and the cylinder block. Do not damage the gasket surfaces of the cylinder head or the cylinder block. Ensure that no debris enters the cylinder bores, the coolant passages or the lubricant passages.

2. Inspect the gasket surface of the cylinder head for distortion. Refer to Specifications, "Cylinder Head" for more information. If the gasket surface of the cylinder head is distorted beyond maximum permitted limits, replace the cylinder head.

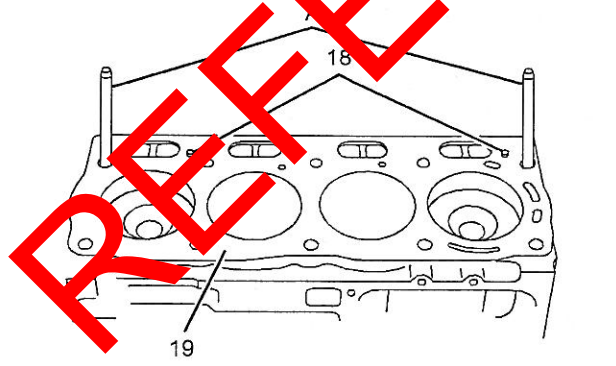



Illustration 224 g01763193

3. Inspect dowels (18) for damage. If necessary, replace the dowels in the cylinder block.

4. Install Tooling (A) to the cylinder block. Refer to Illustration 224.

5. Align cylinder head gasket (19) with Tooling (A) and with dowels (18). Install the cylinder head gasket onto the cylinder block.

6. Use a suitable lifting device to lift the cylinder head. The weight of the cylinder head is approximately 56 kg (124 lb).

7. Use Tooling (A) to align cylinder head (17) with the cylinder block. Install the cylinder head to the cylinder block.

**Note:** Ensure that the cylinder head is correctly positioned onto dowels (18).

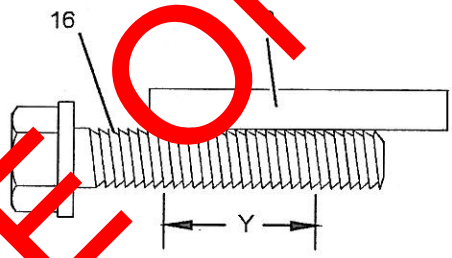



Illustration 225 g01250784

8. Clean bolts (16). Follow Step 8.a and Step 8.b for the procedure to inspect the bolts.

   a. Check the length of the bolts.

   b. Use Tooling (B) in order to check the threads of the bolts. Refer to Illustration 225. Replace any bolts that show visual reduction in the diameter of the thread over length (Y).

9. Lubricate the threads and the shoulder of bolts (16) with clean engine oil.

10. Remove Tooling (A).

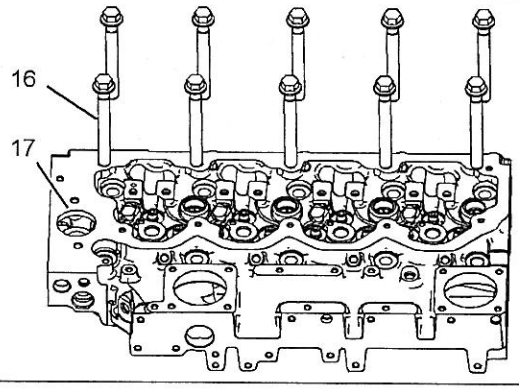



Illustration 226 g01245538

REFERENCE ONLY

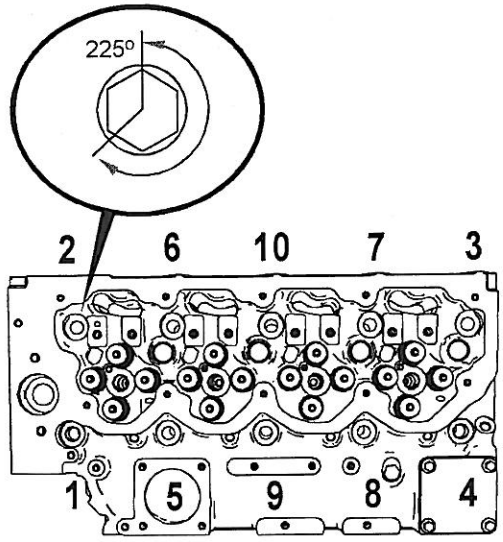



Illustration 227 g01476553

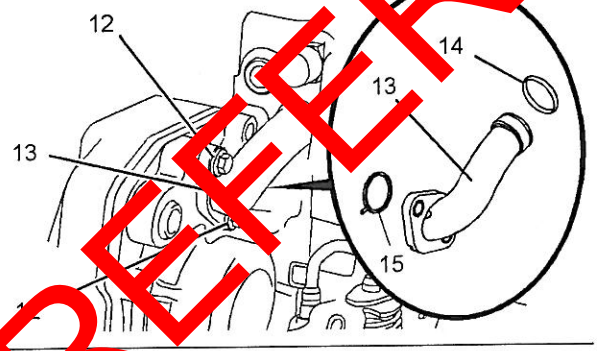
Sequence for tightening the bolts for the cylinder head

**11.** Install bolts (16) to cylinder head (17).

**12.** Tighten bolts (16) to a torque of 50 N·m (37 lb ft) in the sequence that is shown in Illustration 227.

**13.** Tighten bolts (16) to a torque of 100 N·m (74 lb ft) in the sequence that is shown in Illustration 22

**14.** Use Tooling (C) to turn bolts (16) throu an additional 225 degrees. Turn bolts (1 in th sequence that is shown in Illustration 22




Illu on 228 g01476537

Typica xample

**15.** Install new O-ring seal (14) and O-ring seal (15) to bypass tube (13). Use Tooling (D) in order to lubricate O-ring seal (14). Install the bypass tube to the cylinder head. Install bolts (12). Tighten the bolts to a torque of 22 N·m (16 lb ft).

**Note:** Ensure that any brackets that are secured by the bolts are installed in the correct position.

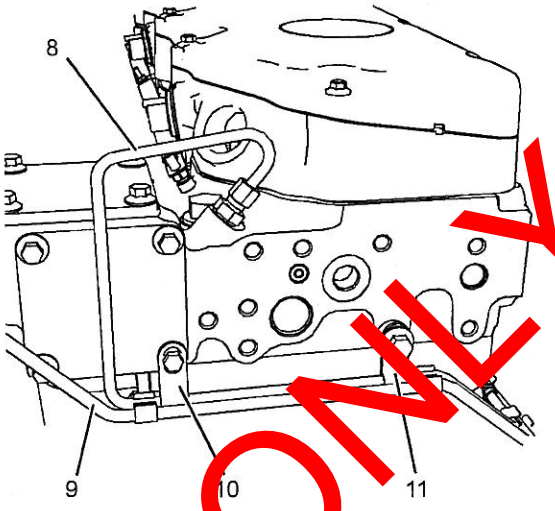



Illustration 229 g01249479

Typical example

**16.** If t ngine is equipped with a wastegate solen d, in all tube assembly (9) to the wastega solenoid and to the cylinder head. Insta the bolts for tube clip (10) and tube clip (11). Tigh n M8 bolts to a torque of 22 N·m (16 lb ft). ighten M10 bolts to a torque of 44 N·m (32 lb ft). Secure harness assembly (9) to tube assembly (8).

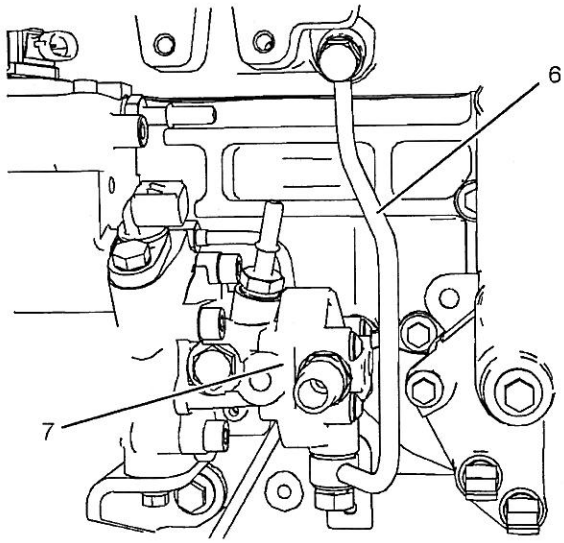



Illustration 230 g01249474

Typical example

**17.** Follow Step 17.a through Step 17.c in order to install tube assembly (6) for the fuel return.

**a.** Install the banjo bolts and new sealing washers to tube assembly (6).

REFERENCE ONLY

**b.** Install tube assembly (6) to the cylinder head and to transfer pump (7).

**c.** Tighten the banjo bolts to a torque of 21 N·m (15 lb ft).

**18.** If necessary, install the electronic sensors to the cylinder head. Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Air Temperature Sensor - Remove and Install". Refer to Disassembly and Assembly, "Boost Pressure Sensor - Remove and Install".

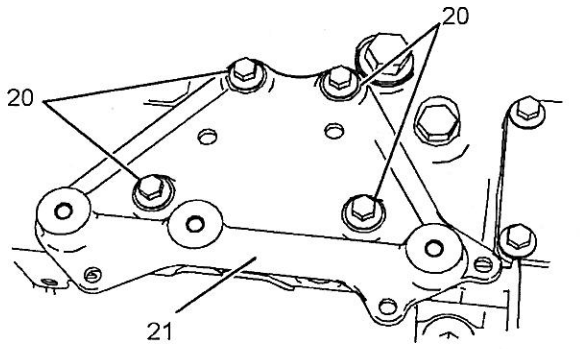



Illustration 231 g01763173
Typical example

**19.** If necessary, install mounting bracket (21) and install screws (20) to the cylinder head. Tighten the screws to a torque of 22 N·m (16 lb ft).

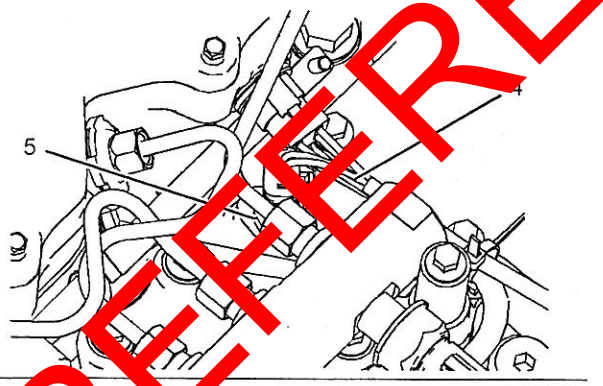



Illustration 232 g01249835
Typical example

**20.** Follow Step 20.a and Step 20.b in order to connect harness assembly (4) to inlet air temperature sensor (5).

**a.** Connect harness assembly (4) to inlet air temperature sensor (5).

**b.** Slide the locking tab into the locked position.

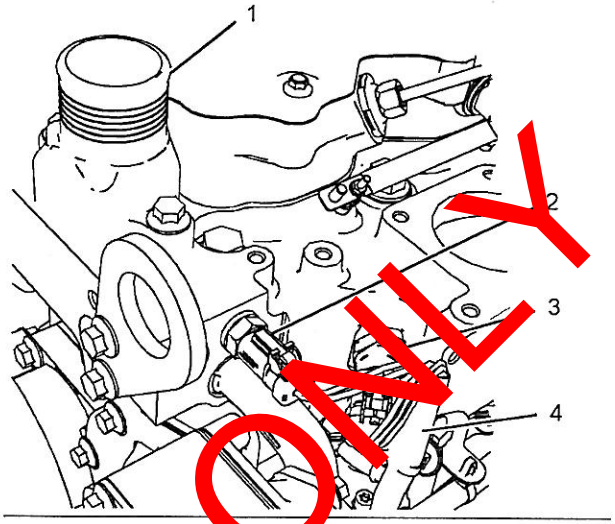



Illustration 233 g01245537
Typical example

**21.** If necessary, install water temperature regulator housing (1) to the cylinder head. Refer to Disassembly and Assembly, "Water Temperature Regulator Housing - Remove and Install".

**22.** Connect the upper radiator hose to water temperature regulator housing (1). Tighten the hose clip securely.

**23.** Follow Step 23.a and Step 23.b in order to connect harness assembly (4) to boost pressure sensor (3).

**a.** Connect harness assembly (4) to boost pressure sensor (3).

**b.** Slide the locking tab into the locked position.

**24.** Follow Step 24.a and Step 24.b in order to connect harness assembly (4) to coolant temperature sensor (2).

**a.** Connect harness assembly (4) to coolant temperature sensor (2).

**b.** Slide the locking tab into the locked position.

**25.** Use new cable straps in order to secure the harness assembly to the cylinder head. Ensure that the harness assembly is not strained.

**Note:** Ensure that the harness assembly is clear of other engine components.

**26.** Install the mounting bracket for the electronic control module. Refer to Disassembly and Assembly, "ECM Mounting Bracket - Remove and Install".

REFERENCE ONLY

27. Install the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

28. Install the valve mechanism cover base. Refer to Disassembly and Assembly, "Valve Mechanism Cover Base - Remove and Install".

29. Install the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

30. Install the fuel manifold. Refer to Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install".

31. Install the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install".

32. If necessary, install the fuel filter base and the secondary fuel filter. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install".

33. If necessary, install the fuel priming pump and the primary fuel filter. Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

34. If the alternator bracket is mounted on the cylinder head, install the alternator. Refer to Disassembly and Assembly, " Alternator - Install".

35. If necessary, install the air hose to the inlet connection.

36. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.

37. If necessary, fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check".

i02933662

# Lifter Group - Remove and Install

## Removal Procedure

Table 55

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825576 | Crankshaft Turning Tool | 1 |
| B | - | Telescopic Magnet | 1 |

**Start By:**

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

b. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft in order to gain access to the lifters.

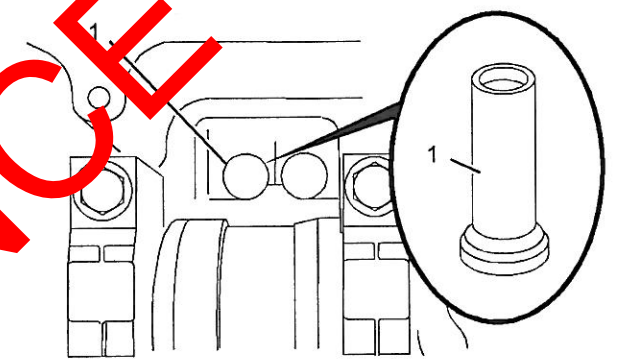



Illustration 234 g01476632
Typical example

2. Use Tooling (B) in order to remove lifters (1).

**Note:** Place a temporary identification mark on each lifter in order to identify the correct location.

3. Repeat Step 1 through Step 2 in order to remove the remaining lifters.

## Installation Procedure

Table 56

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825576 | Crankshaft Turning Tool | 1 |
| B | - | Telescopic Magnet | 1 |

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
It is strongly recommended that all lifters should be replaced when a new camshaft is installed.

1. Clean the lifters. Follow Step 1.a through Step 1.c in order to inspect the lifters. Replace lifters that are worn or damaged.
   a. Inspect the seat of the pushrod in the lifter for visual wear or damage.
   b. Inspect the shank of the lifter for wear or damage. Refer to Specifications, "Lifter Group" for more information.
   c. Inspect the face of the lifter that runs on the camshaft for visual wear or damage.
2. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft. Rotate the crankshaft to access to the cylinder block in order to install lifters (1).
3. Lubricate lifters (1) with clean engine oil.

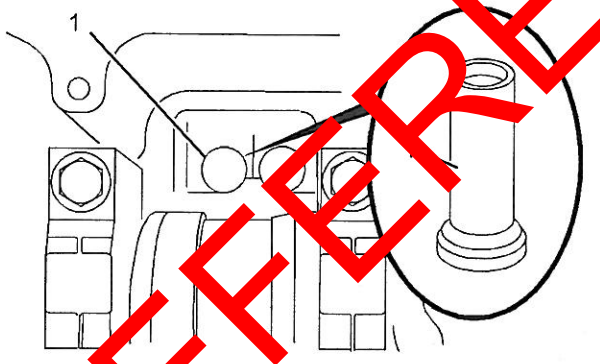



Illustration 235 g01476632
Typical example

4. Use Tooling (B) to install lifters (1) to the cylinder block. Ensure that used lifters are installed in the correct location.

**Note:** The lifters should be free to rotate.

5. Repeat Step 1 through Step 4 in order to install the remaining lifters.

**End By:**

a. Install the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

i02933593

# Camshaft - Remove and Install

## Removal Procedure

**Start By:**

a. Remove the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

b. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. The engine should be mounted on a suitable stand and placed in the inverted position.

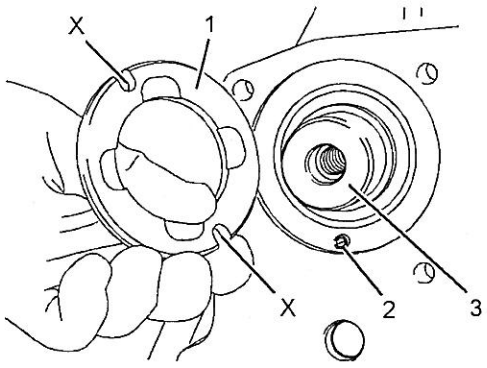



Illustration 236 g01266056
Typical example

2. Remove thrust washer (1) from the cylinder block. Do not remove dowel (2) from the cylinder block unless the dowel is damaged.

**Note:** The thrust washer can have one or two Slots (X).

REFERENCE ONLY

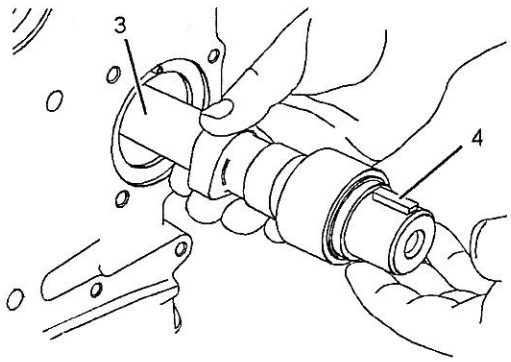



Illustration 237 g01266057

NOTICE
Do not damage the lobes or the bearings when the camshaft is removed or installed.

3. Carefully remove camshaft (3) from the cylinder block.

4. Do not remove key (4) from camshaft (3) unless the key is damaged.

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the camshaft and the thrust washer. Inspect the camshaft and the thrust washer for wear and for damage. Refer to Specifications, "Camshaft" for more information. Replace any components that are worn or damaged.

2. Clean the camshaft bearings in the cylinder block. Inspect the camshaft bearing for wear and for damage. Refer to Specifications, "Camshaft Bearings" for more information. If necessary, replace the camshaft bearing. Refer to Disassembly and Assembly, "Camshaft Bearings - Remove and Install".

NOTICE
It is strongly recommended that all lifters should be replaced when a new camshaft is installed.

3. Inspect the lifters for wear and for damage. Refer to Specifications, "Lifter Group" for more information. Replace any worn lifters or any damaged lifters. Refer to Disassembly and Assembly, "Lifter Group - Remove and Install".

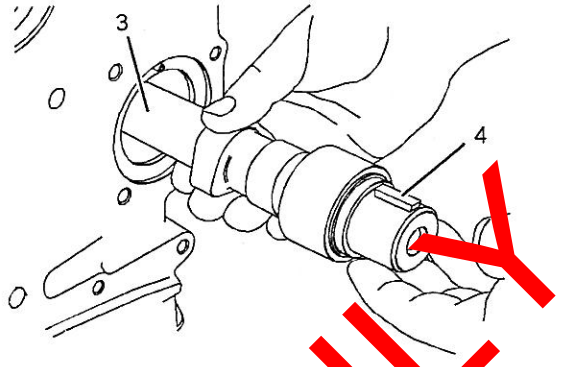



Illustration 238 g01266057

4. If necessary, install a new key (4) to camshaft (3).

5. Lubricate the bearing surfaces of camshaft (3) and lubricate the lobes of the camshaft with clean engine oil.

NOTICE
Do not damage the lobes or the bearings when the camshaft is removed or installed.

6. Carefully install camshaft (3) into the cylinder block.

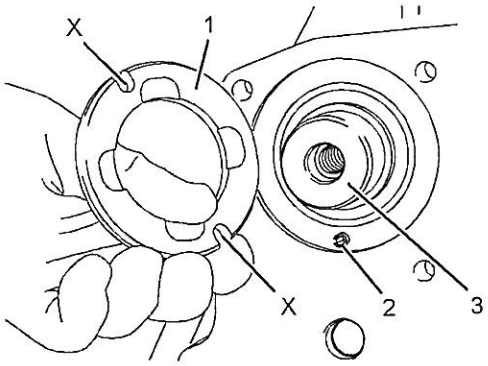



Illustration 239 g01266056
Typical example

7. Lubricate the thrust washer with clean engine oil. Align Slot (X) in thrust washer (1) with dowel (2) in the cylinder block. Install thrust washer (1) into the recess in the cylinder block.

**Note:** The thrust washer can have one or two slots.

**End By:**

a. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

b. Install the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install".

REFERENCE ONLY

i02933595

# Camshaft Gear - Remove and Install

## Removal Procedure

Table 57

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

**a.** Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**b.** Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**1.** Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

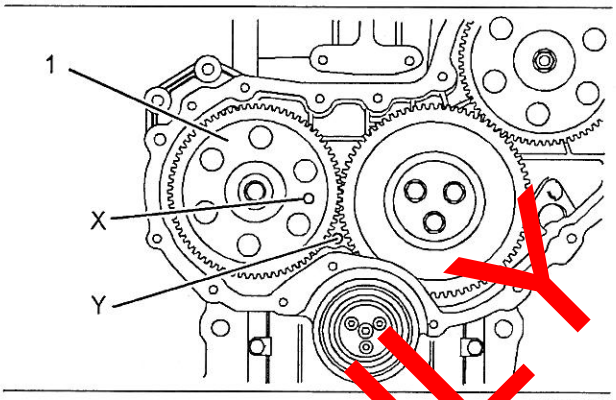



Illustration 240 g01476661
Typical example

**2.** Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position.

**3.** Install Tooling (C) into Hole (Y) in the front housing. Use Tooling (C) in order to lock the crankshaft in the correct position.

**Note:** Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

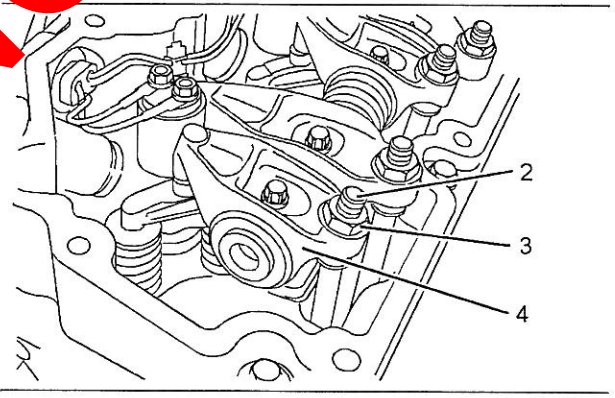



Illustration 241 g01476663
Typical example

**4.** Loosen nuts (3) on ALL rocker arms (4). Unscrew adjusters (2) on all rocker arms (4) until all valves are fully closed.

**Note:** Failure to ensure that all adjusters are fully unscrewed can result in contact between the valves and pistons.

REFERENCE ONLY

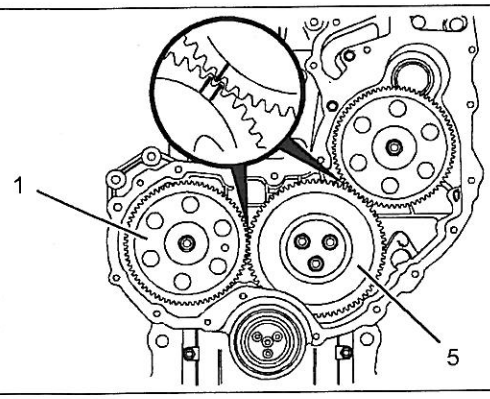



Illustration 242 g01476666
Alignment of timing marks

5. Mark gear (1) and gear (5) in order to show alignment. Refer to Illustration 242.

**Note:** Identification will ensure that the gears can be installed in the original alignment.

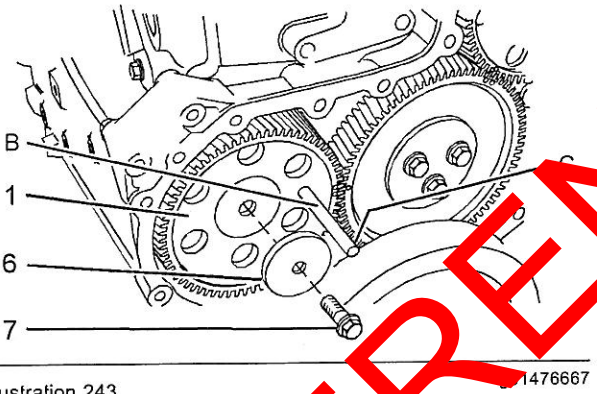



Illustration 243 g01476667
Typical example

6. Remove Tooling (B) and Tooling (C) (not Shown). Remove bolt (7) and washer (6) from camshaft gear (1).

7. Remove camshaft gear (1) from the camshaft.

**Note:** If the camshaft gear is a tight fit on the nose of the camshaft, use a prybar in order to remove the camshaft gear.

8. If necessary, remove the key from the nose of the camshaft.

## Installation Procedure

Table 58

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 27610212 | Camshaft Timing Pin | 1 |
| C | 27610211 | Crankshaft Timing Pin | 1 |
| D | 21825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

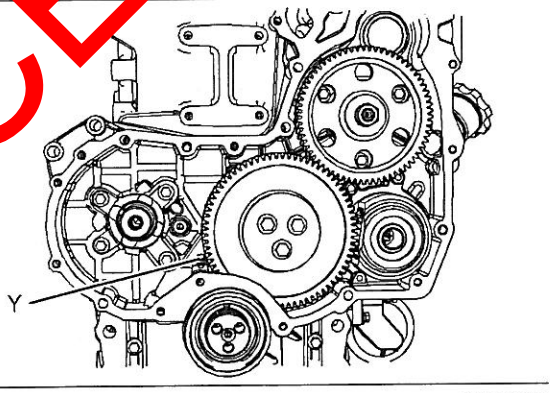



Illustration 244 g01478060
Typical example

2. Install Tooling (C) into Hole (Y) in the cylinder block. Use Tooling (C) in order to lock the crankshaft in the correct position.

3. Ensure that the camshaft gear and the key are clean and free from wear or damage.

4. If necessary, install the key into the nose of the camshaft.

**Note:** Ensure that the key is squarely seated.

REFERENCE ONLY

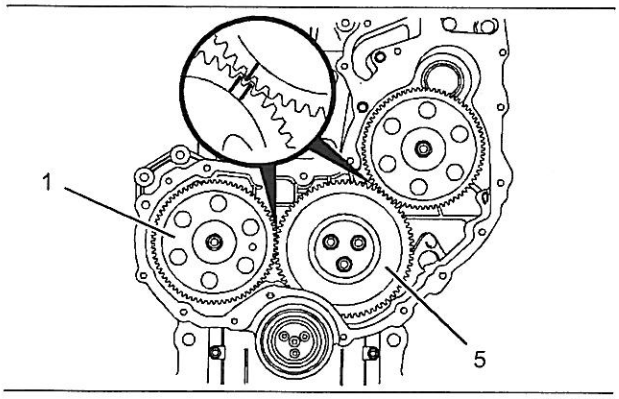



Illustration 245 g01476666

Alignment of timing marks

5. Align the keyway in camshaft gear (1) with the key in the camshaft. Install the camshaft gear onto the camshaft. Ensure that the timing marks on gear (1) and gear (5) are in alignment and that the mesh of the gears is correct. Refer to Illustration 245.

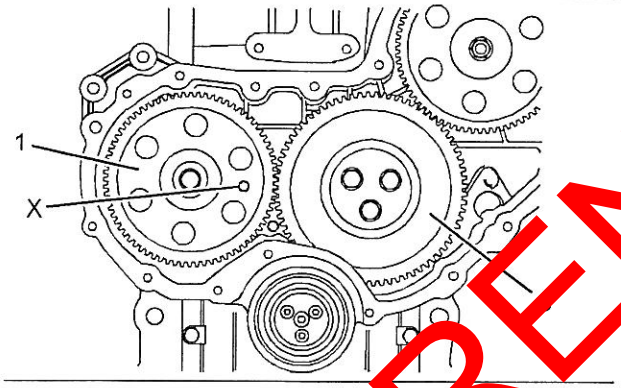



Illustration 246 1478078

Typical example

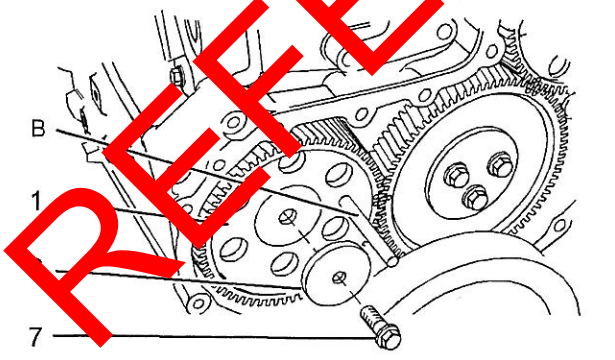



Illustration 247 g01794063

Typical example

6. Install Tooling (B) through Hole (X) in camshaft gear (1) into the front housing.

7. Install washer (6) and bolt (7) to the camshaft gear.

8. Remove Tooling (B) and (C) (not shown).

9. Tighten bolt (7) to a torque of 95 N·m (70 lb ft).

10. Use Tooling (D) to check the backlash for gear (1) and gear (5). Ensure that the backlash for the gears is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

11. Use Tooling (D) to check the end play for camshaft gear (1). Ensure that the end play is within specified values. Refer to Specifications, "Camshaft" for further information.

12. Lubricate the teeth of the gears with clean engine oil.

13. Adjust the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

**End By:**

a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

b. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i02933594

# Camshaft Bearings - Remove and Install

## Removal Procedure

Table 59

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610275 | Bearing Puller | 1 |

**Start By:**

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

b. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

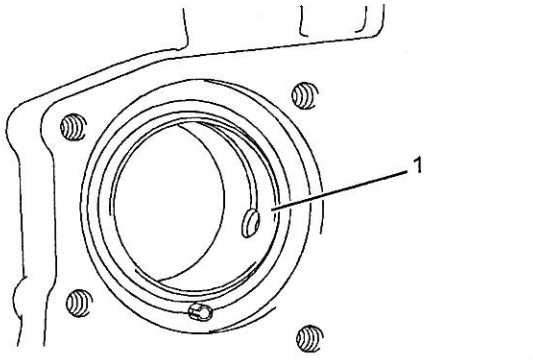



Illustration 248 g01270437

1. Inspect camshaft bearing (1). Refer to Specifications, "Camshaft Bearings" for more information.

2. If camshaft bearing (1) is worn or damaged use Tooling (A) in order to remove the camshaft bearing from the cylinder block.

**Note:** Remove the camshaft bearing from the front of the cylinder block.

## Installation Procedure

Table 60

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 27610275 | Bearing Puller | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the bearing housing in the cylinder block. Ensure that the oil holes in the bearing housing are free from debris.

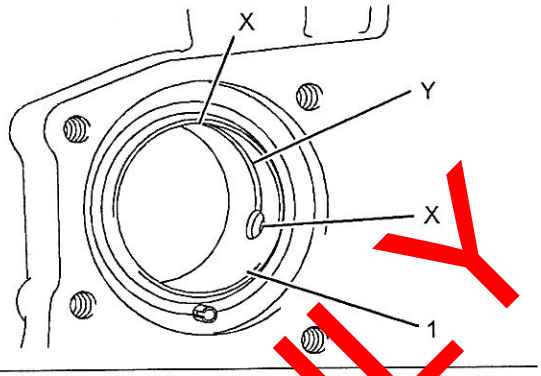



Illustration 249 g01266512

2. Lubricate the bearing housing in the cylinder block with clean engine oil.

3. Accurately align the two Oil Holes (X) in camshaft bearing (1) with the two oil holes in the cylinder block.

**Note:** The groove (Y) in the camshaft bearing must be to the top of the cylinder block.

4. Use Tooling (A) in order to install camshaft bearing (1) into the cylinder block. Install the camshaft bearing so that the front edge of the bearing is flush with the face of the recess in the cylinder block.

**Note:** Ensure that all oil holes are correctly aligned. If the oils are not correctly aligned, the camshaft bearing should be removed.

**End By:**

a. Install the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install".

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

REFERENCE ONLY

i02933623

# Engine Oil Pan - Remove and Install (Aluminum and Pressed Steel Oil Pans)

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

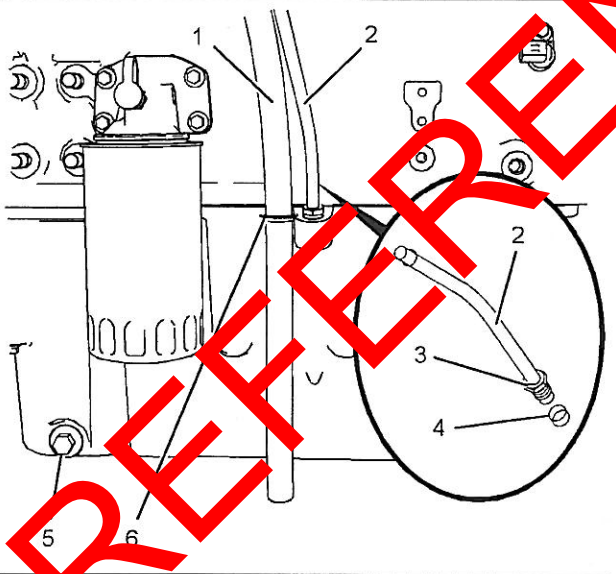



Illustration 250 g01478088
Typical example

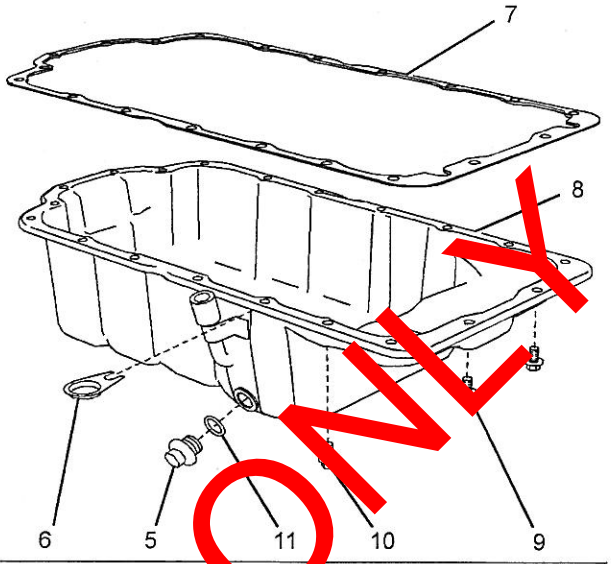



Illustration 251 g01797036
Typical example

1. Place a suitable container below the engine oil pan. Remove drain plug (5) and drain the engine lubricating oil. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.
2. Remove O-ring seal (11) from drain plug (5).
3. Disconnect breather hose (1) from clip (6). Position the breather hose away from the engine oil pan.
4. If necessary, remove the assembly of the dipstick tube. Loosen nut (3) and remove tube assembly (2). Remove seal (4) from the tube assembly.

**Note:** Identify the position and orientation of the tube assembly.

5. Support the assembly of the engine oil pan. Mark the position of clip (6). Loosen bolts (9) and bolts (10). Remove the clip and remove the bolts.
6. Remove engine oil pan (8) and remove gasket (7) from the cylinder block.

REFERENCE ONLY

## Installation Procedure

Table 61

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | Guide Bolt<br>M8 by 100 mm | 4 |
| B | 21826038 | POWERPART<br>Silicon Rubber Sealant | 1 |
| C | 21820117 | POWERPART<br>Threadlock and NutLock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the face of the cylinder block is clean and free from damage.




Illustration 252 g01251768
Typical example

2. Install Tooling (A) to Positions (X) in the cylinder block.

3. Ensure that the engine oil pan is clean and free from damage.

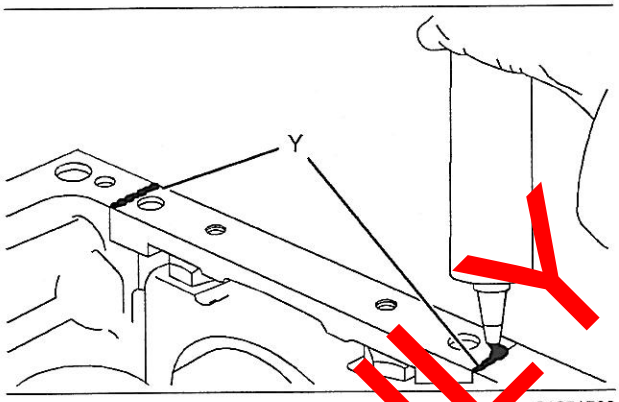



Illustration 253 g01251763
Typical example

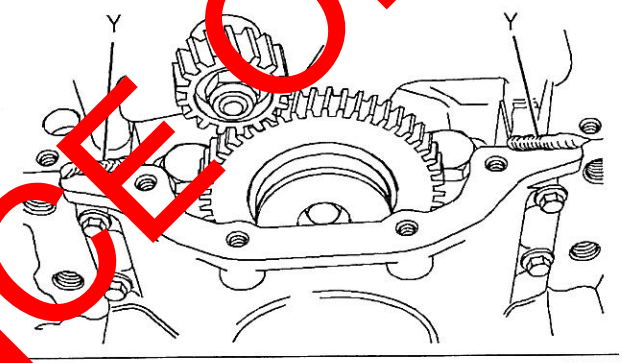



Illustration 254 g01803754
Typical example

4. Apply a bead of Tooling (B) to Positions (Y) on the cylinder block.

**Note:** If the bridge piece for the cylinder block has just been installed, the engine oil pan must be installed before Tooling (B) has cured.

REFERENCE ONLY

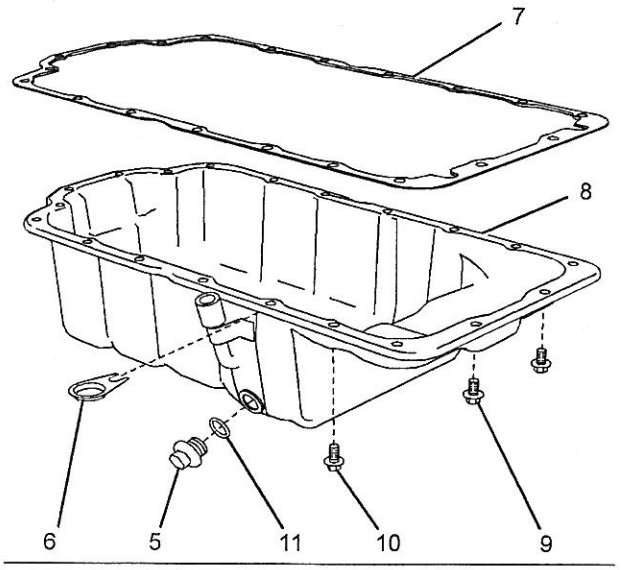



Illustration 255 g01797036
Typical example

5. Position a new gasket (7) onto engine oil pan (8).

6. Align the assembly of the engine oil pan with Tooling (A). Install the assembly of the engine oil pan to the cylinder block. Install clip (6) in the correct position.

7. Install bolts (10) finger tight.

8. Remove Tooling (A).

9. Apply Tooling (C) to bolts (9).

10. Install bolts (9) and the remaining bolts (10).

11. Tighten bolts (9) and bolts (10) to a torque of 22 N·m (16 lb ft). Refer to Specifications, "Engine Oil Pan" for the correct tightening sequence.

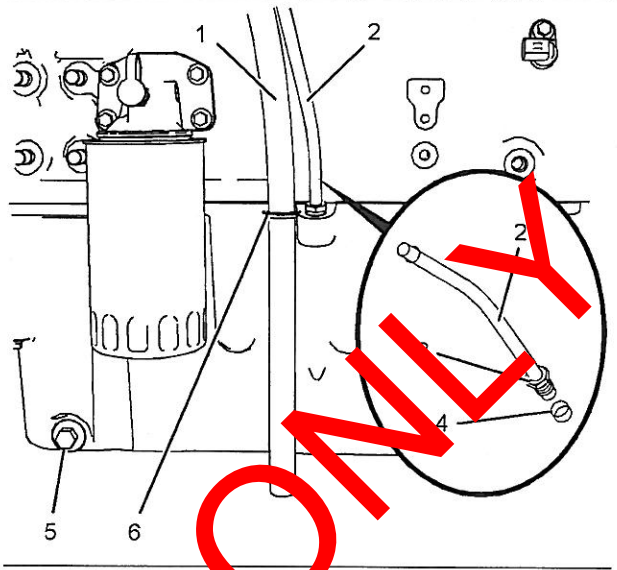



Illustration 256 g01478088
Typical example

12. Install a new O-ring seal to drain plug (5). Install the drain plug to the engine oil pan. Tighten the oil drain plug to a torque of 34 N·m (25 lb ft).

13. If necessary, follow Step 13.a through Step 13.c in order to install the assembly of the dipstick tube.

   a. Install a new seal (4) to tube assembly (2).

   b. Apply Tooling (C) to nut (3). Install the tube assembly to the engine oil pan.

**Note:** Ensure that the orientation of the tube assembly is correct.

   c. Tighten nut (3) to a torque of 18 N·m (13 lb ft). Install the dipstick.

14. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

i02933622

# Engine Oil Pan - Remove and Install (Cast Iron Oil Pan)

## Removal Procedure

**Note:** In order to remove a cast iron oil pan, the engine must be removed from the machine.

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Ensure that the engine lubricating oil is drained. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

2. The engine should be mounted in a suitable stand and placed in the inverted position.

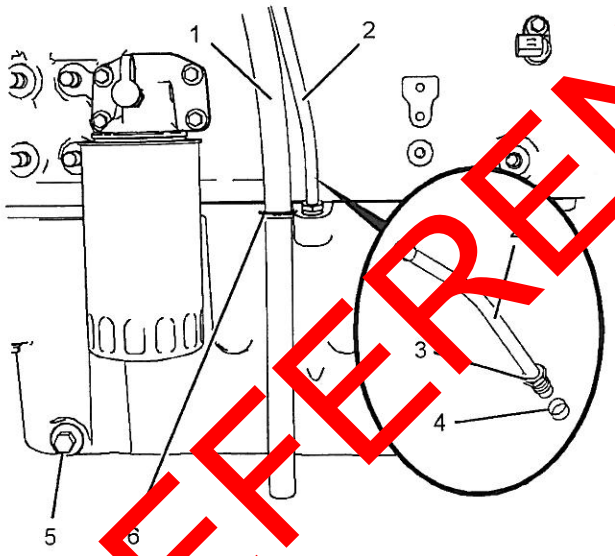



Illustration 257 g01478088
Typical example

3. Disconnect breather hose (1) from clip (6). Position the breather hose away from the engine oil pan.

**Note:** Identify the position and orientation of the tube assembly before removal.

4. Remove the assembly of the dipstick tube. Loosen nut (3) and remove tube assembly (2). Remove seal (4) from the tube assembly.

5. Mark the position of clip (6). Refer to Illustration 257. Loosen the bolt that secures the clip and remove the clip.

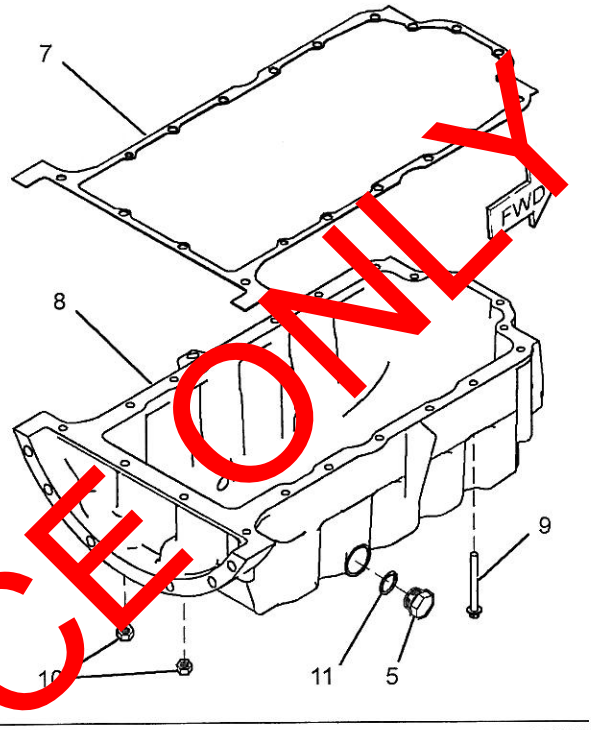



Illustration 258 g01251978
Typical example

6. Remove nuts (10) and bolts (9).

**Note:** The bolts are different lengths. Note the position of the different bolts.

7. Attach a suitable lifting device to engine oil pan (8). Support the weight of the engine oil pan. The engine oil pan weighs approximately 41 kg (90 lb).

8. Use the lifting device to remove engine oil pan (8) from the cylinder block.

9. Remove gasket (7) from the cylinder block.

10. If necessary, remove drain plug (5). Remove O-ring seal (11) from oil drain plug (5).

REFERENCE ONLY

## Installation Procedure

Table 62

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21826038 | POWERPART Silicon Rubber Sealant | - |
| B | 21820117 | POWERPART Threadlock and NutLock | - |
| C | - | Straight Edge | 1 |

**Note:** In order to install a cast iron oil pan, the engine must be removed from the machine.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the face of the cylinder block is clean and free from damage. Inspect the studs in the cylinder block for damage. If necessary, replace the studs.
2. Ensure that the engine oil pan is clean and free from damage.

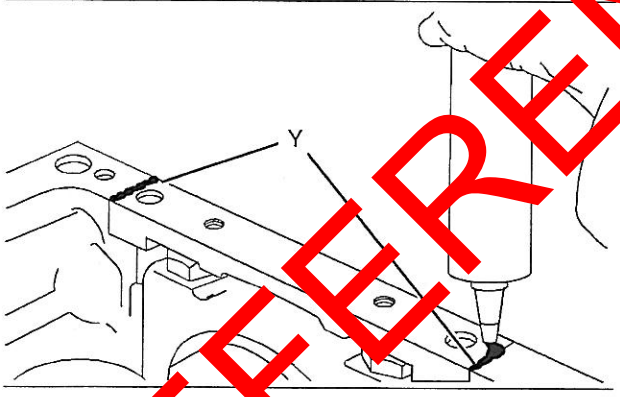



Illustration 259 g01251763
Typical example

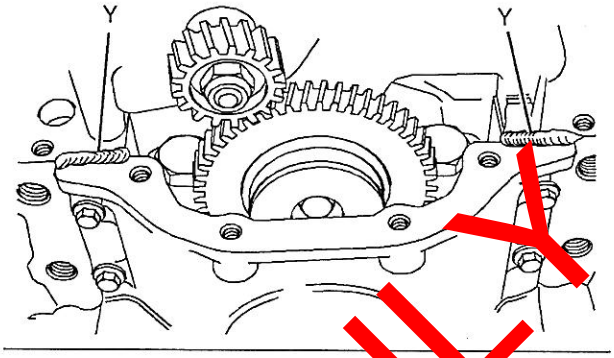



Illustration 260 g01803754
Typical example

3. Apply a bead of Tooling (A) to Positions (Y) on the cylinder block.

**Note:** If the bridge face for the cylinder block has just been installed, the engine oil pan must be installed before Tooling (A) has cured.

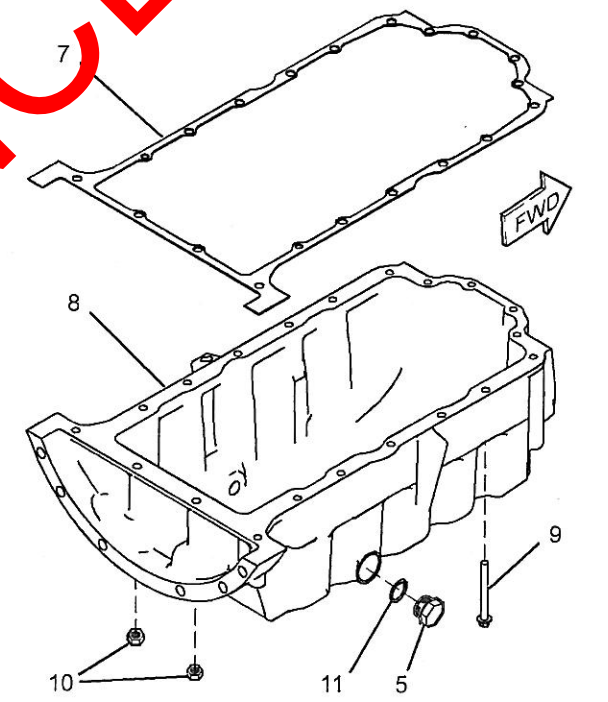


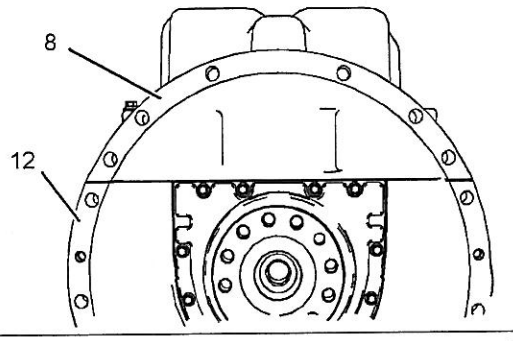

Illustration 261 g01251978
Typical example

4. Align a new gasket (7) with the studs in the cylinder block. Install the gasket to the cylinder block.
5. Attach a suitable lifting device to engine oil pan (8). The engine oil pan weighs approximately 41 kg (90 lb).

REFERENCE ONLY

6. Use the lifting device to align engine oil pan (8) with the studs in the cylinder block. Install the engine oil pan to the cylinder block. Remove the lifting device from the engine oil pan.

7. Install bolts (9) and nuts (10) finger tight. Install clip (6).



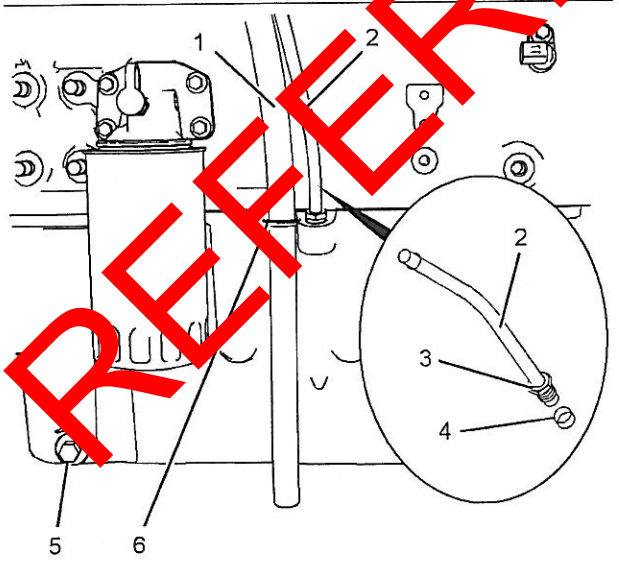

g01251982

Illustration 262

Typical example

8. Align the rear face of engine oil pan (8) to the rear face of cylinder block (12). Use Tooling (C) and a feeler gauge in order to check the alignment between the engine oil pan and the cylinder block. The maximum step that is allowed between the cylinder block and the sump is 0.1 mm (0.004 inch).

9. Tighten bolts (9) and nuts (10) to a torque of 22 N·m (16 lb ft). Refer to Specification "Engine Oil Pan" for the correct tightening sequence.




g01251772

Illustration 263

Typical example

10. If necessary, install a new O-ring seal to drain plug (5). Install drain plug (5) to engine oil pan (8). Tighten the drain plug to a torque of 34 N·m (25 lb ft).

11. Follow Step 11.a through Step11.c in order to install the assembly of the dipstick tube.

   a. Install a new seal (4) to tube assembly (2).

   b. Apply Tooling (B) to nut (3). Install the tube assembly to the engine oil pan.

**Note:** Ensure that the orientation of the tube assembly is correct.

   c. Tighten the nut to a torque of 13 N·m (13 lb ft). Install the dipstick.

12. Install breather hose (1) to clip (6).

**Note:** After the engine has been installed, ensure that the engine oil pan is filled with lubricating oil to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

i02933591

# Balancer - Remove

## Removal Procedure

Table 63

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825576 | Crankshaft Turning Tool | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |
| C | 27610225 | Timing Pin (Balancer) | 1 |
| D | - | Puller (Two Leg) | 1 |

**Start By:**

a. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

b. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

**Note:** In order to remove the balancer, the engine must be removed from the machine. The engine should be mounted in a suitable stand and placed in the inverted position.

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position.

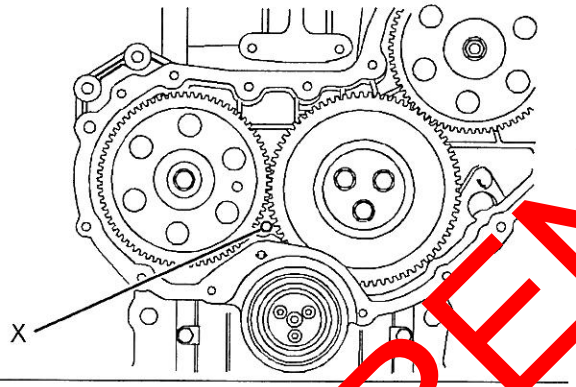



Illustration 264 g01259627
Typical example

2. Install Tooling (B) through Hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

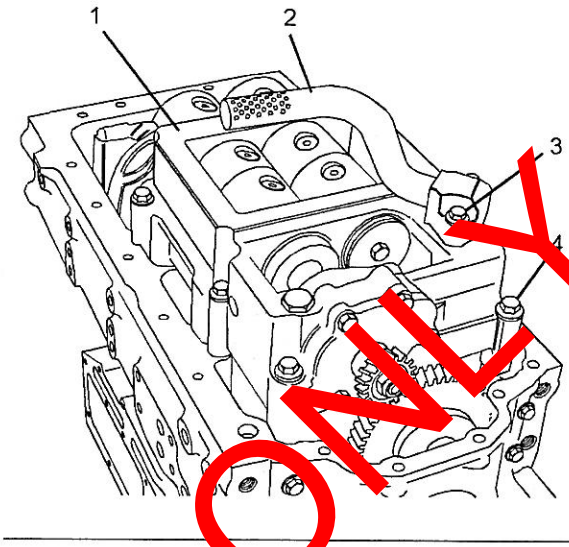



Illustration 265 g01259635
Typical example

3. Remove bolts (3) and suction pipe (2).

4. Remove the gasket from the suction pipe.

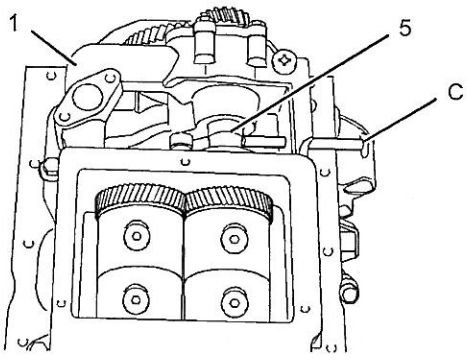



Illustration 266 g01252310
Typical example

5. Install Tooling (C) into balancer (1). Ensure that Tooling (C) is engaged into the hole in drive shaft (5).

6. Attach a suitable lifting device to balancer (1). Support the weight of the balancer. The balancer weighs approximately 23 kg (51 lb).

7. Remove bolts (4). Use the lifting device to remove the balancer.

REFERENCE ONLY

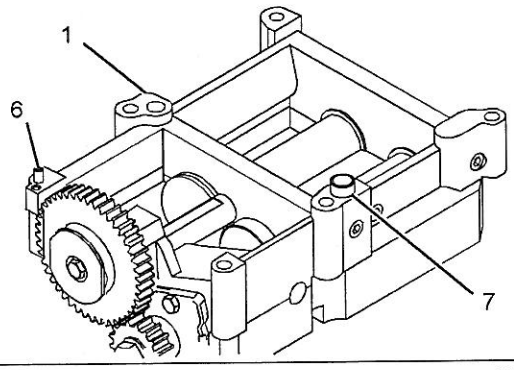



Illustration 267 g01259636

8. Do not remove dowel (6) and dowel (7) unless the dowels are damaged.

**Note:** The balancer unit is not a serviceable item. The engine oil pump and the engine oil relief valve are the only serviceable parts of the balancer.

## Disassembly Procedure

1. Remove the engine oil relief valve. Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install".

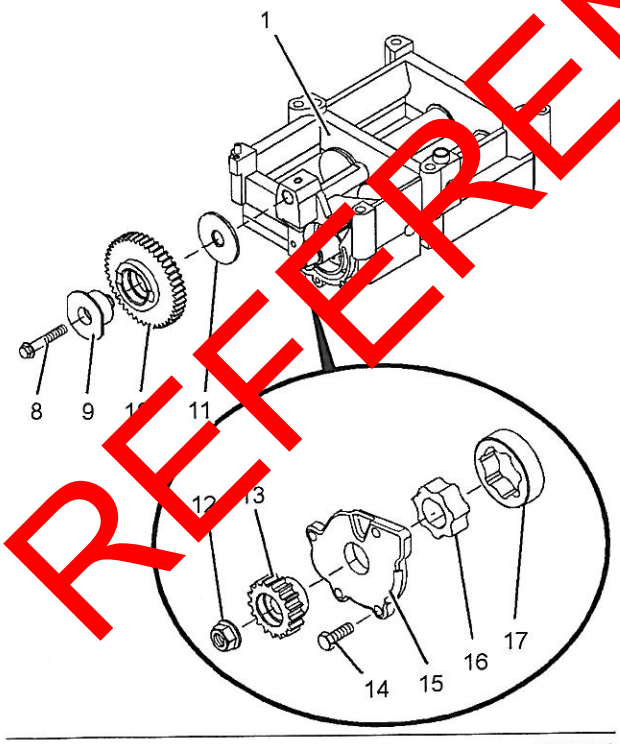



Illustration 268 g01478152

Typical example

2. Remove bolt (8) and hub (9). Remove idler gear (10) and thrust washer (11).

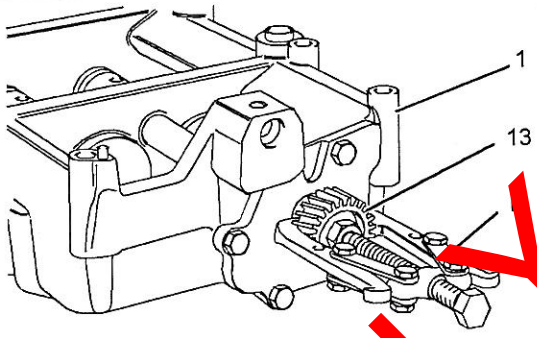



Illustration 269 g01259631

Typical example

3. Remove nut (12). Use Tool (D) in order to remove gear (13) from the shaft of the oil pump.

**Note:** Do not use a timing pin to lock the balancer in order to loosen nut (12).

4. Remove bolts (14) and remove front cover (15).

5. Remove outer rotor (17) and remove inner rotor (16).

**Note:** Mark the direction of rotation of the rotors.

i02933590

# Balancer - Install

## Assembly Procedure

Table 64

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| E | 21820117 | POWERPART Threadlock and Nutlock | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components of the engine oil pump are clean and free from wear or damage.

REFERENCE ONLY

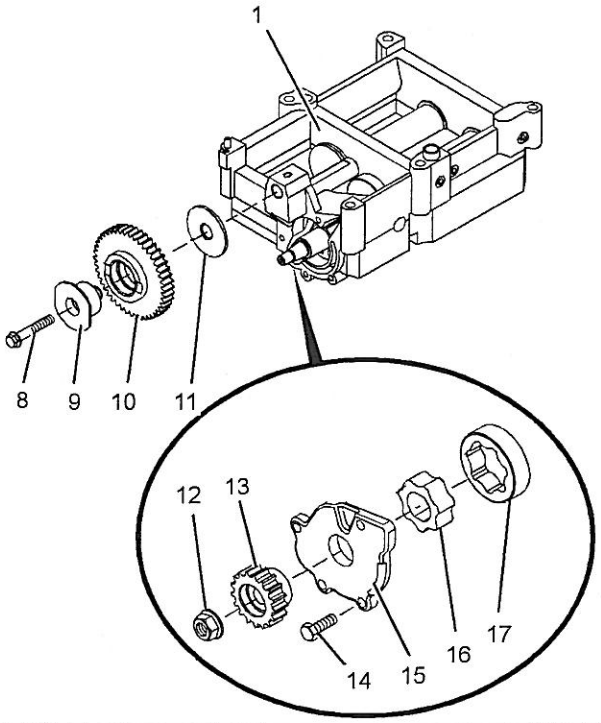



Illustration 270 g01478152

Typical example

2. Install inner rotor (16) and install outer rotor (17). Used rotors should be installed in the original direction of rotation. Check the clearance between the outer rotor and the body of the oil pump. Check the clearance between the inner rotor and the outer rotor. Check the end play of the rotor assembly. Refer to Specifications, "Engine Oil Pump" for more information.

3. Lubricate the assembly of the oil pump with clean engine oil. Install front cover (15). Install bolts (14). Tighten the bolts to a torque of 25 N·m (19 lb ft).

4. Ensure that the shaft of the oil pump is clean and dry. Position gear (13) onto the shaft. Install nut (12). Tighten the nut to a torque of 95 N·m (70 lb ft).

**Note:** Do not use a timing pin to lock the balancer in order to tighten nut (12).

5. Lubricate hub (9), thrust washer (11) and the bush of idler gear (10) with clean engine oil. Install hub (9) and thrust washer (11) to idler gear (10).

**Note:** Ensure the correct orientation of the idler gear.

6. Install the assembly of the idler gear to balancer (1).

7. Ensure that the threads of bolt (8) are clean and dry. Apply Tooling (E) to the threads of the bolt. Install bolt (8). Tighten the bolt to a torque of 26 N·m (19 lb ft).

8. Check the end play of idler gear (10). Refer to Specifications, "Engine Oil Pump".

9. Install the engine oil relief valve . Refer to Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install" for further information.

## Installation Procedure

Table 65

| Required Tooling | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| B | 2761021 | Crankshaft Timing Pin | 1 |
| C | 2761022 | Timing Pin (Balancer) | 1 |
| F | 1825617 | Dial Indicator Group | 1 |
| | - | Finger Clock | 1 |
| | - | Guide Studs (M10 by 75 mm) | 1 |

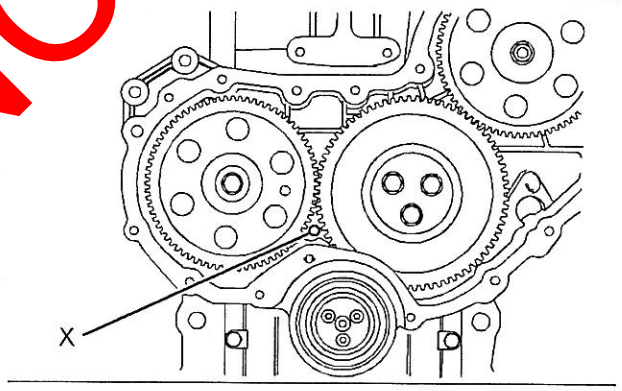



Illustration 271 g01259627

1. Ensure that No. 1 piston is at the top center position and that Tooling (B) is installed to Position (X) in the front housing.

2. Clean the faces of the cylinder block.

REFERENCE ONLY

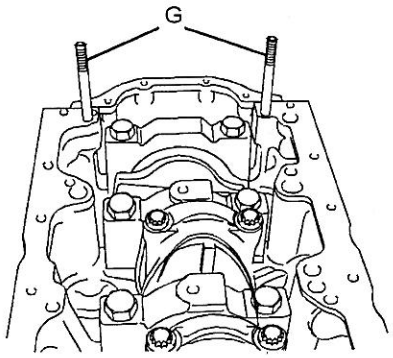



Illustration 272 g01252312

3. Install Tooling (G) to the cylinder block.

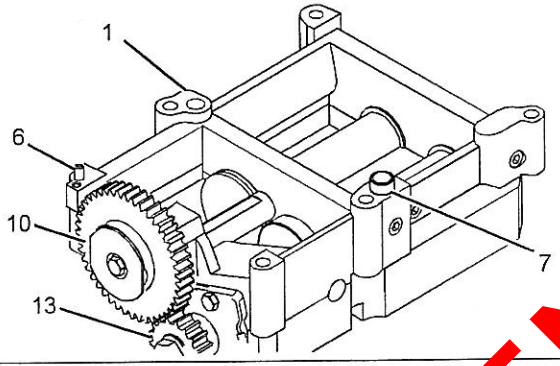



Illustration 273 g01260306

4. Ensure that dowel (6) and dowel (7) are located in the housing of balancer (1).

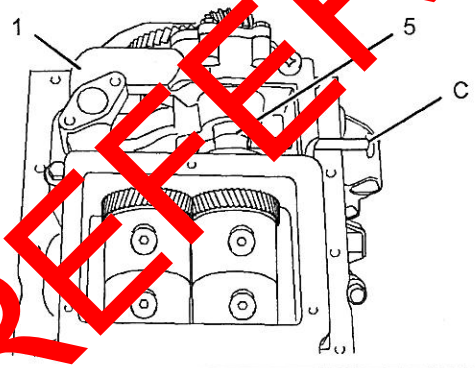



Illustration 274 g01252310

5. Install Tooling (C) to balancer (1). Ensure that Tooling (C) is engaged into shaft (5).

6. Attach a suitable lifting device to the balancer. The balancer weighs approximately 23 kg (51 lb).

7. Use the lifting device to align balancer (1) with Tooling (G). Install the balancer to the cylinder block. Ensure that dowels (6) and (7) are aligned with the holes in the cylinder block. Ensure that gear (10) and the crankshaft gear mesh. Remove the lifting device.

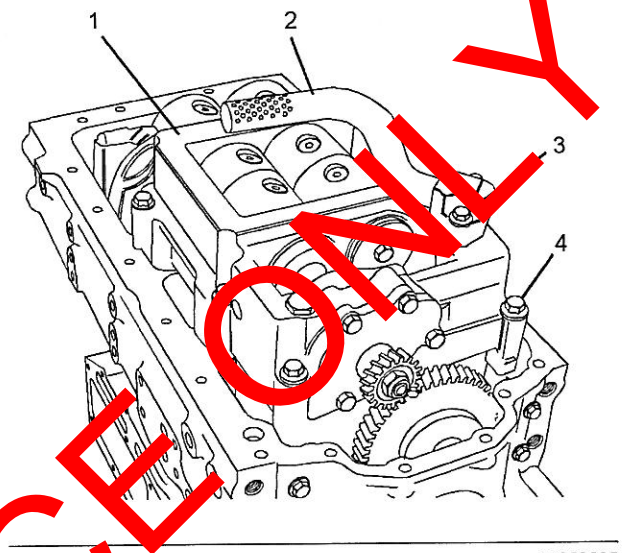



Illustration 275 g01259635

8. Install bolts (4) to balancer (1) finger tight.

9. Remove Tooling (G) and install remaining bolts (4). Tighten the bolts to a torque of 54 N·m (40 lb ft).

10. Remove Tooling (B) and Tooling (C).

11. Install suction pipe (2) and a new gasket to balancer (1).

12. Install bolts (3). Tighten the bolts to a torque to 22 N·m (16 lb ft).

13. Use Tooling (F) in order to check the backlash between gears (10) and (13). Refer to Illustration 273. Refer to Specifications, “Engine Oil Pump”.

14. Use Tooling (F) in order to check the backlash between gear (10) and the crankshaft gear. Refer to Specifications, “Gear Group - Front” for further information.

**End By:**

a. Install the engine oil pan. Refer to Disassembly and Assembly , “Engine Oil Pan - Remove and Install”.

b. Install the front cover. Refer to Disassembly and Assembly, “Front Cover - Remove and Install”.

REFERENCE ONLY

i02933663

# Piston Cooling Jets - Remove and Install

## Removal Procedure

Table 66

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

a. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft in order to gain access to the appropriate piston cooling jet.

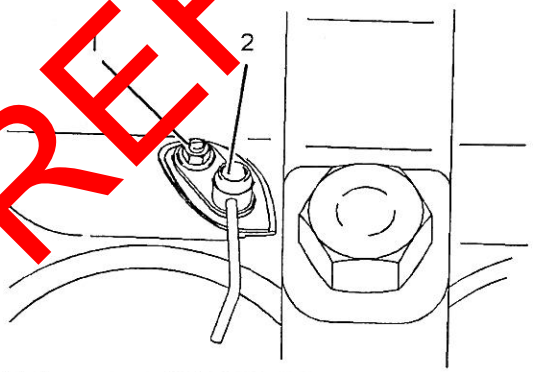



Illustration 276 g01265615
Typical example

2. Remove bolt (1) and piston cooling jet (2) from the cylinder block.

3. Repeat Step 1 and Step 2 for the remaining piston cooling jets.

## Installation Procedure

Table 67

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | |
| | 27610289 | Gear | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

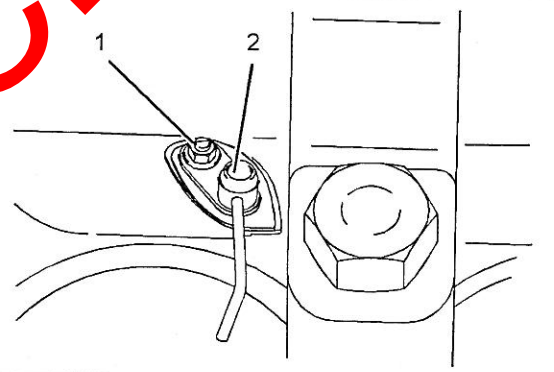



Illustration 277 g01265615

1. Clean the piston cooling jets and inspect the piston cooling jets for damage. Ensure that the valve is free to move within each piston cooling jet. Replace any damaged piston cooling jets.

2. If the crankshaft is installed, use Tooling (A) to rotate the crankshaft in order to access the mounting flange for the piston cooling jet.

3. Position piston cooling jet (2) in the cylinder block. Install bolt (1). Tighten the bolt to a torque of 9 N·m (80 lb in).

4. Repeat Step 2 and Step 3 for the remaining piston cooling jets.

5. If the cylinder head has been removed, It is possible to check the alignment of the piston cooling jets. Refer to Specifications, "Piston Cooling Jet Alignment" for more information.

REFERENCE ONLY

**Note:** It is not possible to check the alignment of the piston cooling jets with the cylinder head in position.

**End By:**

**a.** If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

i02933667

# Pistons and Connecting Rods - Remove

## Removal Procedure

Table 68

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610274 | Ridge Reamer | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

**a.** Remove the cylinder head. Refer to Disassembly and Assembly , "Cylinder Head - Remove".

**b.** If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

**c.** Remove the piston cooling jets. Refer to Disassembly and Assembly , "Piston Cooling Jets - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**1.** Use Tooling (A) to rotate the crankshaft until the crank pin is at the bottom center position.

**2.** Use Tooling (B) to remove the carbon ridge from the top inside surface of the cylinder bore.

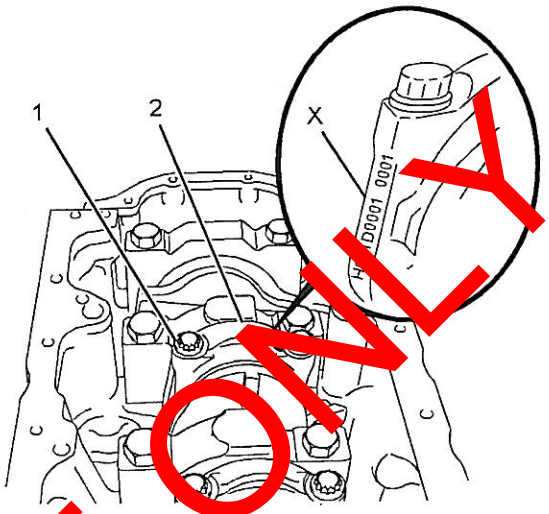



Illustration 278 g01479383

**3.** The connecting rod and the connecting rod cap should have an etched Number (X) on the side. The number on the connecting rod and the connecting rod cap must match. Ensure that the connecting rod and connecting rod cap (2) are marked for the correct location. If necessary, make a temporary mark on the connecting rod and the connecting rod cap in order to identify the cylinder number.

**Note:** Do not stamp the connecting rod assembly. Stamping or punching the connecting rod assembly could cause the connecting rod to fracture.

**4.** Remove bolts (1) and remove connecting rod cap (2) from the connecting rod.

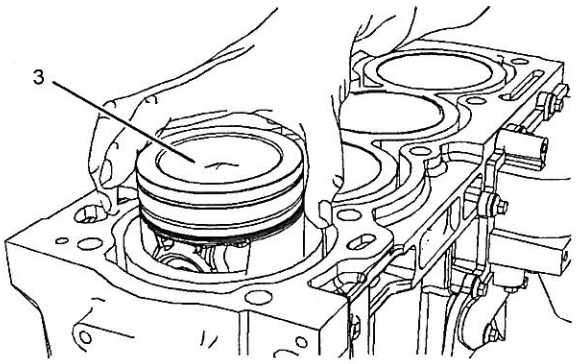



Illustration 279 g01479386
Typical example

**5.** Carefully push piston (3) and the connecting rod assembly out of the cylinder bore. Lift the piston out of the top of the cylinder block.

REFERENCE ONLY

**Note:** Do not push on the fracture split surfaces of the connecting rod as damage may result.

6. Temporarily install connecting rod cap (2) and bolts (1) to the connecting rod when the assembly is out of the engine. Tighten bolts (1) to a torque of 20 N·m (14 lb ft).

**Note:** Fracture split connecting rods should not be left without the connecting rod caps installed. Ensure that the etched number on connecting rod cap matches the etched number on connecting rod. Ensure the correct orientation of the connecting rod cap.

7. Repeat Step 1 through Step 5 for the remaining pistons and connecting rods.

i02933665

# Pistons and Connecting Rods - Disassemble

## Disassembly Procedure

Table 69

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Circlip Pliers | 1 |
| B | - | Piston Ring Expander | 1 |

**Start By:**

a. Remove the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Make a temporary mark on the components of the piston and connecting rod assembly. This will ensure that the components of each piston and connecting rod assembly can be reinstalled in the original cylinder. Mark the underside of the piston on the front pin boss. Do not interchange components.

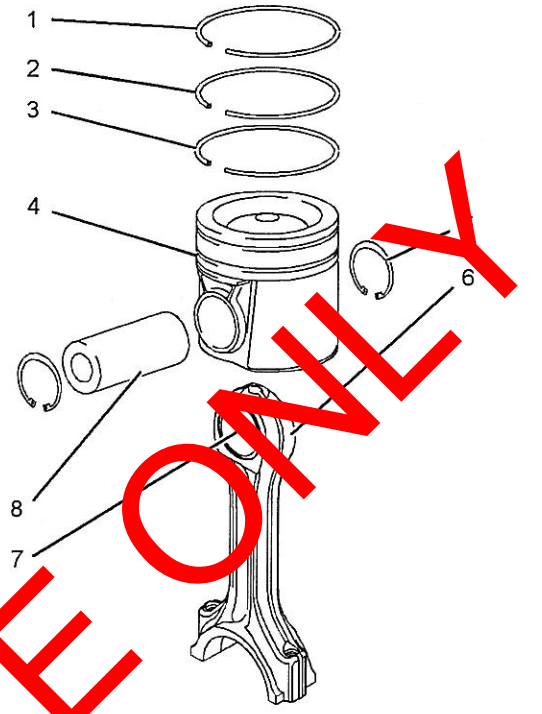



Illustration 280 g01244067

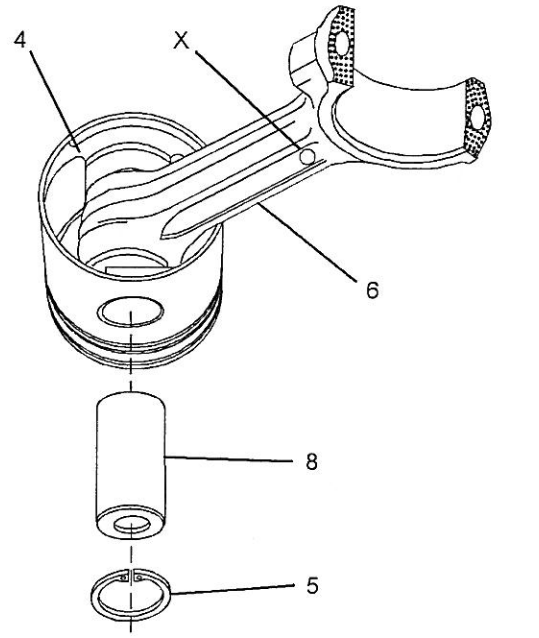



Illustration 281 g01253091
Typical example

2. Place the piston and connecting rod assembly on a suitable surface with the connecting rod upward. Use Tooling (A) in order to remove circlips (5).

REFERENCE ONLY

**Note:** Forged Marks (X) identify the front of the connecting rod assembly. The forged marks should be used for the purposes of orientation.

3. Remove piston pin (8) and connecting rod (6) from piston (4).

**Note:** If the piston pin cannot be removed by hand, heat the piston to a temperature of 45 ± 5 °C (113 ± 9 °F). Do not use a torch to heat the piston. Note the orientation of the connecting rod and the piston.

4. Place the piston on a suitable surface with the crown upward. Use Tooling (B) in order to remove compression rings (1) and (2), and oil control ring (3) from piston (4).

**Note:** Identify the position and orientation of compression rings (1) and (2), and oil control ring (3).

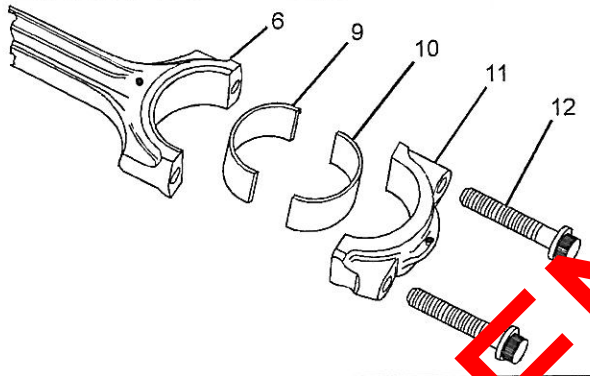



Illustration 282 g0124406

5. Remove bolts (12) and connecting rod cap (11) from connecting rod (6). Discard the bolts.

**Note:** Fracture split connecting rods should not be left without the connecting rod caps installed. After the disassembly procedure for the piston and connecting rod is completed, carry out the assembly procedure and the installation procedure as soon as possible. Refer to Disassembly and Assembly, "Piston and Connecting Rod - Assemble" and Disassembly and Assembly, "Piston and Connecting Rods - Install".

6. Remove the lower half of connecting rod bearing (10) from connecting rod cap (11). Remove the upper half of connecting rod bearing (9) from connecting rod (6). Keep the connecting rod bearings together.

NOTICE
Removal of the piston pin bushing in the connecting rod must be carried out by personnel with the correct training. Also special machinery is required. For more information refer to your authorized Perkins distributor.

7. Inspect the connecting rod for wear or damage. If necessary, replace connecting rod (6) or replace bush (7) for the piston pin.

**Note:** If the connecting rod or the bush for the piston pin are replaced, first identify the height grade of the connecting rod. Refer to Specifications, "Connecting Rods".

8. Repeat Step 1 through Step 7 in order to disassemble the remaining pistons and connecting rods.

i02933664

# Pistons and Connecting Rods - Assemble

## Assembly Procedure

Table 2

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Circlip Pliers | 1 |
| B | - | Piston Ring Expander | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.

REFERENCE ONLY

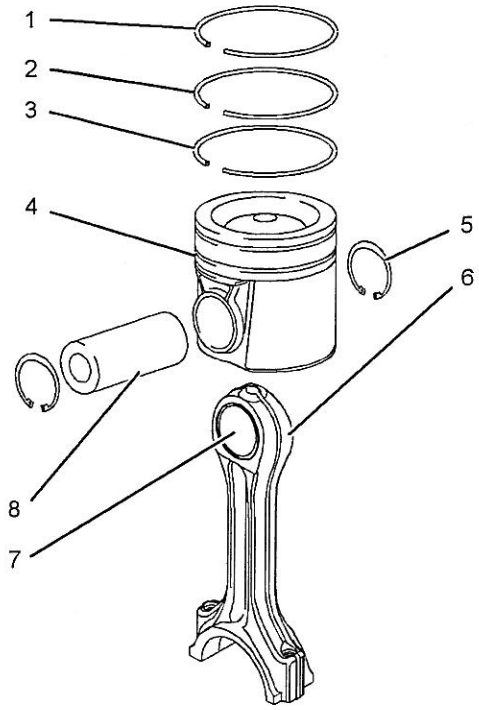



Illustration 283 g01244067

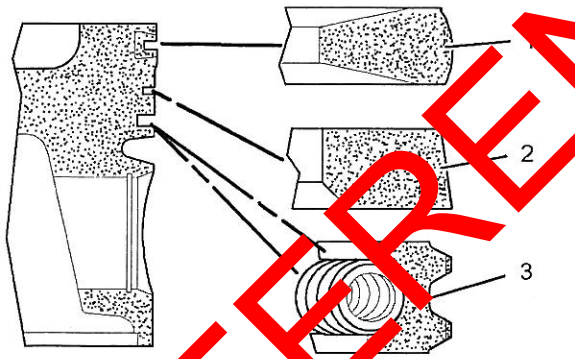



Illustration 284 g01155119

**2.** If the original piston is assembled, follow Step 2.a through Step 2.e in order to install the piston rings.

**a.** Position the spring for oil control ring (3) into the oil ring groove in piston (4). The central wire must be located inside the end of the spring.

**b.** Use Tooling (B) to install oil control ring (3) over the spring.

**Note:** Ensure that the central wire is 180 degrees from the ring gap.

**c.** Use Tooling (B) to install intermediate compression ring (2) into the second groove in piston (4). The word "TOP" must be upward. The chamfer on the inner face must be downward.

**d.** Use Tooling (B) to install top compression ring (1) into the top groove in piston (4). The word "TOP" must be upward.

**e.** Position the piston ring gaps at 120 degrees away from each other.

**Note:** A new piston assembly is supplied with new piston rings.

NOTICE

Removal of the piston pin bushing in the connecting rod must be carried out by personnel with the correct training. Also special machinery is required. For more information refer to your authorized Perkins distributor.

**3.** If the connecting rod assembly or the bush for the piston pin have been replaced, ensure that the height grade of the connecting rod is correct. Refer to Specifications, "Connecting Rods" for further information.

**4.** Lubricate bush (7) and lubricate the bore for the piston pin in piston (4) with clean engine oil.

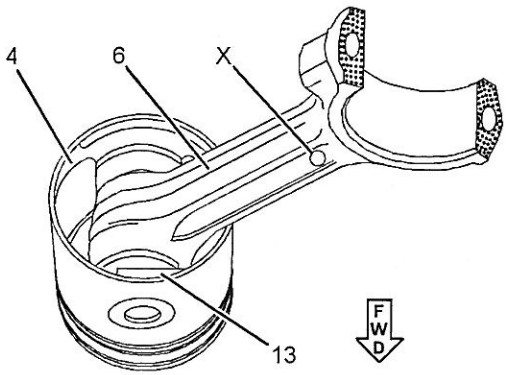



Illustration 285 g01244172

**5.** Place the piston on a suitable surface with the crown downward. Install connecting rod (6) and piston pin (8) to piston (4). Ensure that square boss (13) on the piston, and forged Mark (X) on the connecting rod are in the correct position. See illustration 285.

**Note:** If the piston pin cannot be installed by hand, heat the piston to a temperature of 45° ± 5°C (113° ± 9°F).

**6.** Use Tooling (A) in order to install circlips (5) to the piston pin bore in piston (4).

REFERENCE ONLY

**Note:** Ensure that the circlips are seated in the grooves in the piston.

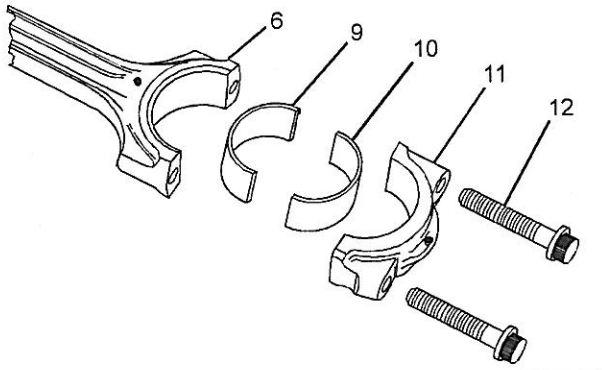



Illustration 286 g01244068

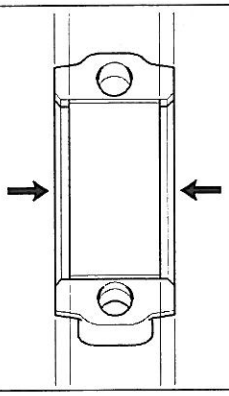


Illustration 287 g01001160

Aligning the connecting rod bearing in the center of the connecting rod

7. Install the upper half of connecting rod bearing (9) to connecting rod (6). Ensure that the connecting rod bearing is centralized in the connecting rod. Refer to Illustration 287.

**Note:** New connecting rod bearings are supplied with an alignment tool. If new connecting rod bearings are installed, use the tool to align the connecting rod bearing in the connecting rod.

8. Install the lower half of connecting rod bearing (10) in connecting rod cap (11). Ensure that the connecting rod bearing is centralized in the connecting rod cap. Refer to Illustration 287.

**Note:** New connecting rod bearings are supplied with an alignment tool. If new connecting rod bearings are installed, use the tool to align the connecting rod bearing in the connecting rod cap.

9. Repeat Step 2 through Step 8 for the remaining piston and connecting rod assemblies.

**Note:** Fracture split connecting rods should not be left without the connecting rod caps installed. After the assembly procedure for the piston and connecting rod is completed, carry out the installation procedure as soon as possible.

**End By:**

a. Install the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Install".

i02933666

# Pistons and Connecting Rods - Install

## Installation Procedure

Table 71

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 21825491 | Piston Ring Compressor | 1 |
| C | 21825607 | Angle gauge | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Discard all used connecting rod bolts.

1. If the connecting rod caps were temporarily installed, remove the connecting rod caps. If necessary, thoroughly clean all of the components.

2. Apply clean engine oil to the cylinder bore, to the piston rings, to the outer surface of the piston and to the connecting rod bearings.

REFERENCE ONLY

**Note:** Install the connecting rod bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil to the connecting rod bearings during final assembly.

3. Use Tooling (A) to rotate the crankshaft until the crankshaft pin is at the bottom center position. Lubricate the crankshaft pin with clean engine oil.

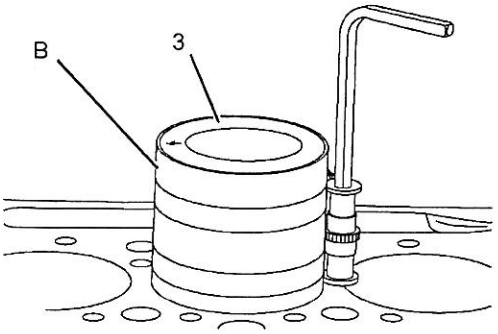



Illustration 288 g01253096
Typical example

4. Ensure that the gaps for the piston rings are at 120 degrees away from each other. Install Tooling (B) onto piston (3).

**Note:** Ensure that Tooling (B) is installed correctly and that the piston can easily slide from the tool. Ensure that the piston and the connecting rod assembly are installed in the correct cylinder. The arrow on the top of the piston must be toward the front of the engine.

5. Carefully push the piston and the connecting rod assembly into the cylinder bore and onto the crankshaft pin.

**Note:** Do not damage the finished surface of the crankshaft pin.

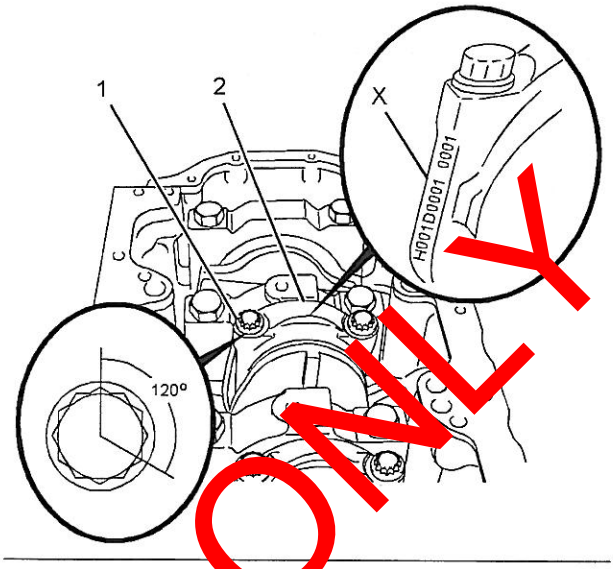



Illustration 289 g01479452
Typical example

6. Install connecting rod cap (2) onto the connecting rod.

**Note:** Ensure that etched Number (X) on the connecting rod cap matches the etched number on the connecting rod. Ensure the correct orientation of connecting rod cap (2).

7. Install new bolts (1) to the connecting rod. Tighten the bolts evenly to a torque of 18 N·m (13 lb ft).

8. Tighten the bolts evenly to a torque of 70 N·m (52 lb ft).

9. Use Tooling (B) to turn the bolts through an additional 120 degrees.

10. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

11. Repeat Step 2 through Step 10 in order to install the remaining pistons and connecting rods.

**Note:** If all pistons and connecting rods require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. **Ensure that both pairs of the pistons and connecting rods are installed before changing from one pair of cylinders to another pair of cylinders.**

12. Check the height of the pistons above the top face of the cylinder block. Refer to Systems Operation, Testing and Adjusting, "Piston Height - Inspect" for the correct procedure.

REFERENCE ONLY

**End By:**

**a.** Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

**b.** If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

**c.** Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

i02933597

# Connecting Rod Bearings - Remove (Connecting rods in position)

## Removal Procedure

Table 72

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Q |
| A(1) | 21825576 | Crankshaft Turning To | 1 |
| A(2) | 27610291 | Barring Device Hou g | 1 |
| | 27610289 | Gear | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

**a.** If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Discard all used connecting rod bolts.

**Note:** If all connecting rod bearings require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. **Ensure that both pairs of the connecting rod bearings are installed before changing from one pair of cylinders to another pair of cylinders.** Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install".

**1.** Use Tooling (A) to rotate the crankshaft until the crank pin is at the bottom center position.

If necessary, remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

**Note:** Removal of the glow plugs aids removal of the connecting rod bearings. It is not essential.

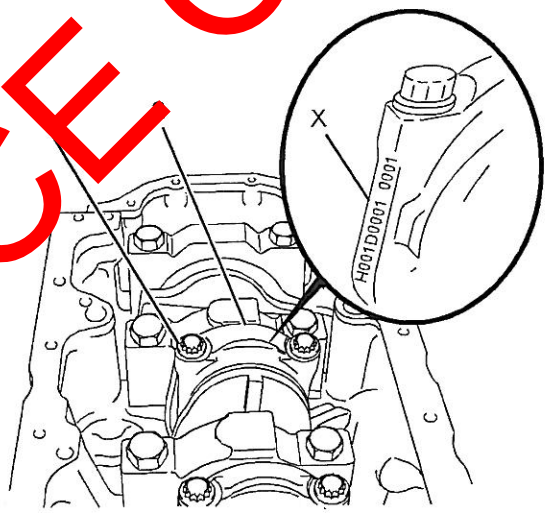



Illustration 290 g01479383

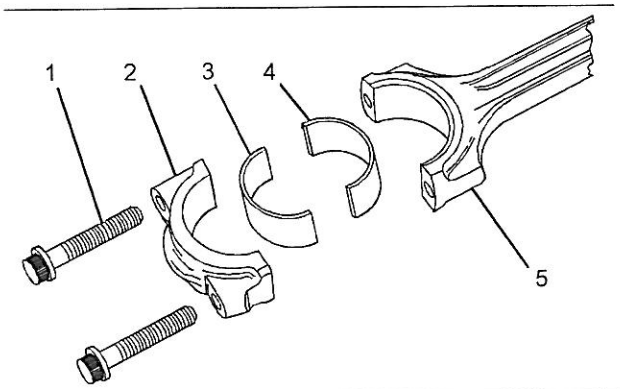



Illustration 291 g01253101

REFERENCE ONLY

2. The connecting rod and the connecting rod cap should have an etched Number (X) on the side. The number on the connecting rod and the connecting rod cap must match. If necessary, make a temporary mark on connecting rod (5) and connecting rod cap (2) in order to identify the cylinder number.

**Note:** Do not punch identification marks onto fracture split connecting rods. Do not stamp identification marks onto fracture split connecting rods.

3. Remove bolts (1) and connecting rod cap (2) from connecting rod (5). Discard the bolts.

4. Remove the lower half of connecting rod bearing (3) from connecting rod cap (2). Keep the connecting rod bearing and the connecting rod cap together.

5. Carefully push the piston and connecting rod assembly into the cylinder bore until connecting rod (5) is clear of the crankshaft. Remove the upper half of connecting rod bearing (4) from connecting rod (5). Keep the bearings together.

**Note:** Do not push on the fracture split surfaces of the connecting rod as damage may result. Do not allow the connecting rod to contact the piston cooling jet.

Fracture split connecting rods should not be left without the connecting rod caps installed. After the removal procedure for the connecting rod bearings is complete, carry out the installation procedure as soon as possible. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install".

i02933596

# Connecting Rod Bearings - Install (Connecting rods in position)

## Installation Procedure

Table 73

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 21825607 | Angle Gauge | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Discard all used connecting rod bolts.

1. Inspect the pins of the crankshaft for damage. If the crankshaft is damaged, replace the crankshaft or recondition the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Remove" and Disassembly and Assembly, "Crankshaft - Install". Ensure that the connecting rod bearings are clean and free from wear or damage. If necessary, replace the connecting rod bearings.

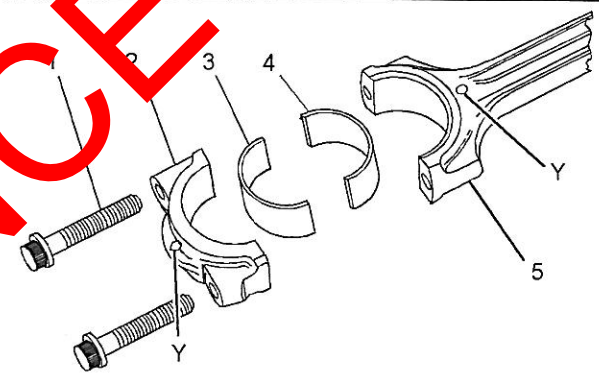



Illustration 292 g01260354

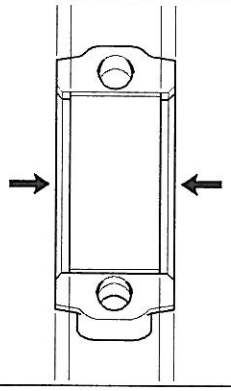


Illustration 293 g01001160
Aligning the bearing in the center of the connecting rod

**Note:** New connecting rod bearings are supplied with an alignment tool. If new bearings are installed, use the tool to align the bearing in the connecting rod.

REFERENCE ONLY

2. Install the upper half of connecting rod bearing (4) to connecting rod (5). Ensure that the bearing is centralized in the connecting rod. Refer to Illustration 293.

   The ends of the bearing must be centered in the connecting rod. The ends of the bearing must be equally positioned in relation to the faces of the connecting rod.

3. Clean the connecting rod cap. Install lower connecting rod bearing (3) to connecting rod cap (2). Ensure that the connecting rod bearing is centralized in the connecting rod cap. Refer to Illustration 293.

   The ends of the lower connecting rod bearing must be centered in the connecting rod cap. The ends of the lower connecting rod bearing must be equally positioned in relation to the faces of the connecting rod cap.

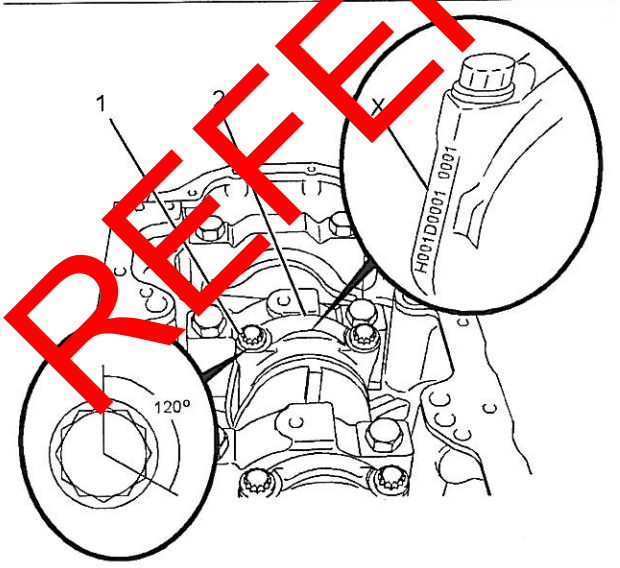
4. Lubricate upper connecting rod bearing (4) with clean engine oil.

5. If necessary, use Tooling (A) in order to rotate the crankshaft until the crankshaft pin is at the bottom dead center position.

6. Carefully pull connecting rod (5) against the crankshaft pin.

**Note:** Do not allow the connecting rod to contact the piston cooling jet.

7. Lubricate the pin of the crankshaft and lubricate lower connecting rod bearing (3) with clean engine oil.




g01479452

Illustration 294
Typical example

8. Install connecting rod cap (2) to connecting rod (5).

**Note:** Ensure that etched Number (X) on connecting rod cap (2) matches etched Number (X) on connecting rod (5). Ensure the correct orientation of the connecting rod cap. The forged Marks (Y) on the connecting rod and the connecting rod cap should be on the same side. Refer to Illustration 292.

9. Install new bolts (1). Tighten the bolts evenly to a torque of 18 N·m (13 lb ft).

**Note:** Do not reuse the old bolts in order to secure the connecting rod cap.

10. Tighten the bolts evenly to a torque of 70 N·m (52 lb ft).

11. Use Tooling (A) to turn the bolts through an additional 120 degrees.

12. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

13. Repeat Step 2 through Step 12 for the remaining connecting rod bearings.

If all connecting rod bearings require replacement the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 with 4 and 2 with 3. **Ensure that both pairs of the connecting rod bearings are installed before changing from one pair of cylinders to another pair of cylinders.**.

14. If the glow plugs were removed, install the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Install".

**End By:**

a. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

REFERENCE ONLY

i02933605

# Crankshaft Main Bearings - Remove and Install (Crankshaft in position)

## Removal Procedure

Table 74

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Start By:**

**a.** If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

**b.** Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove".

**Note:** Either Tooling (A) can be used. Use the tooling that is most suitable.

NOTICE
This procedure must only be used to remove and install the main bearing shells with the crankshaft in position.

The removal procedure and the installation procedure must be completed for each pair of main bearing shells before the next pair of main bearing shells are removed.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

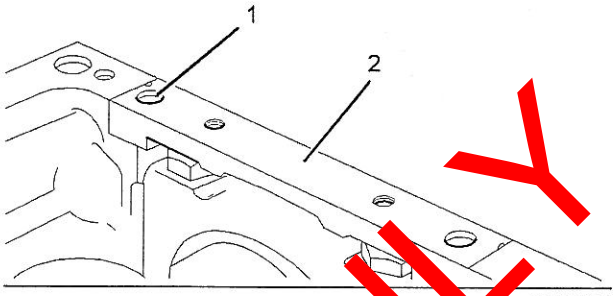



Illustration 295 g01490997
Typical example

**1.** Remove allen head screws (1). Remove bridge piece (2).

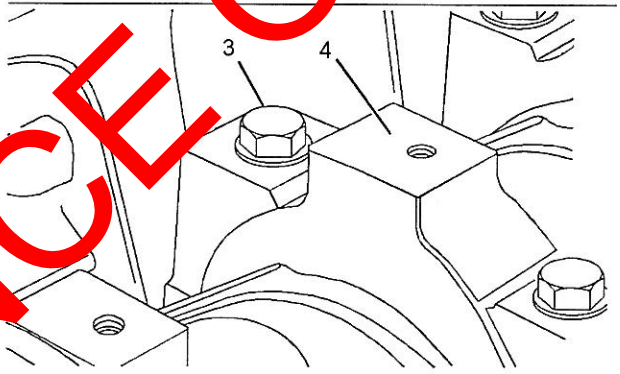



Illustration 296 g01253719
Typical example

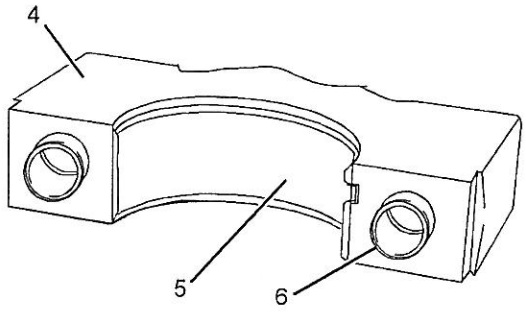



Illustration 297 g01253146
Typical example

**2.** Ensure that the main bearing cap is marked for the correct location and orientation.

**3.** Remove bolts (3). Remove main bearing cap (4) from the cylinder block.

REFERENCE ONLY

4. Remove lower main bearing (5) from main bearing cap (4). Keep the main bearing and the main bearing cap together. Take care not to displace dowels (6).

**Note:** The lower main bearing is a plain bearing that has no oil holes. The dowels may remain in the main bearing cap or in the cylinder block.

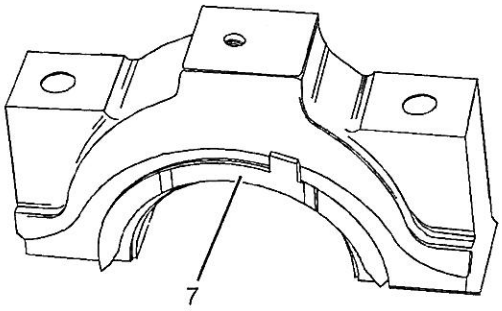



Illustration 298 g01253137
Typical example

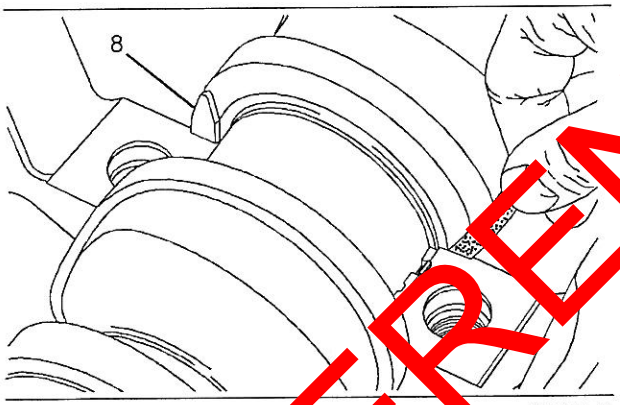



Illustration 299 g01253142
Typical example

5. For number three main bearing cap, remove thrust washers (7).

6. For number three main bearing, remove thrust washers (7) from the cylinder block. In order to remove the thrust washers, push the crankshaft toward the front of the engine or push the crankshaft toward the rear of the engine. Use Tooling (A) in order to rotate the crankshaft. If necessary, use a suitable tool to free the thrust washers.

**Note:** Do not damage the machined surfaces of the crankshaft during removal of the thrust washers.

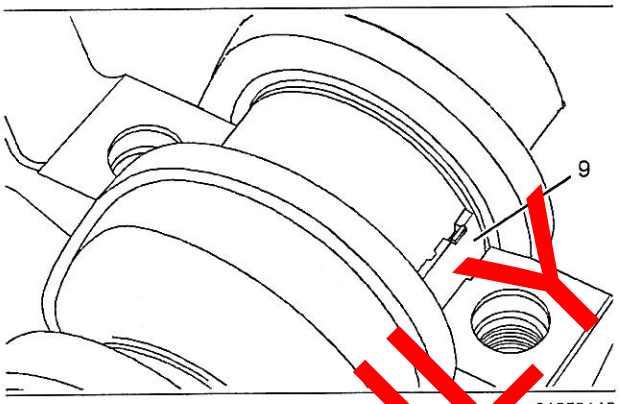



Illustration 300 g01253145

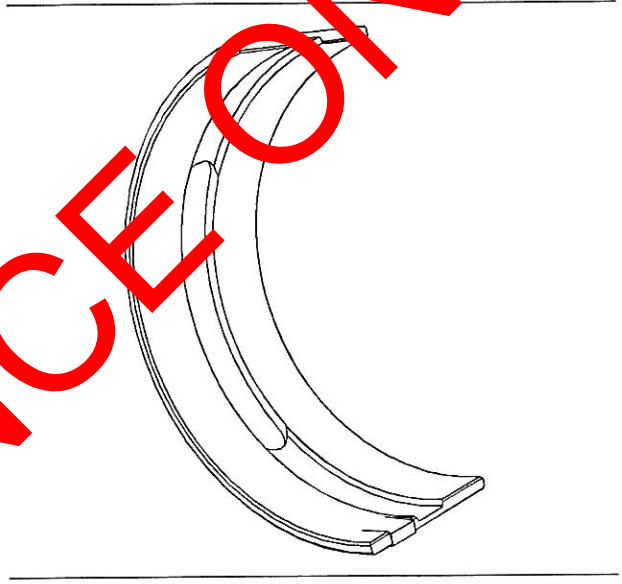


Illustration 301 g01889993
No. 1 Upper Main Bearing

7. Push out upper main bearing (9) with a suitable tool from the side opposite the locating tab. Carefully rotate the crankshaft while you push on the bearing . Remove upper main bearing (9) from the cylinder block. Keep the bearings together.

**Note:** Do not damage the machined surfaces of the crankshaft during removal of the upper main bearing. Number 1 upper main bearing has an oil slot. See Illustration 303. All other upper main bearings have a groove and two oil holes.

REFERENCE ONLY

## Installation Procedure

Table 75

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 21825617 | Dial Indicator Group | 1 |
| C | - | Straight Edge | 1 |
| D | - | 5 mm Allen Socket | 1 |
| E | 21826038 | POWERPART Silicon Rubber Sealant | 1 |

NOTICE
This procedure must only be used to remove and install the main bearing shells with the crankshaft in position.

The removal procedure and the installation procedure must be completed for each pair of main bearing shells before the next pair of main bearing shells are removed.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the main bearings are clean and free from wear or damage. If necessary, replace the main bearings.

2. Clean the journals of the crankshaft. Inspect the journals of the crankshaft for damage. If necessary, replace the crankshaft or recondition the crankshaft.

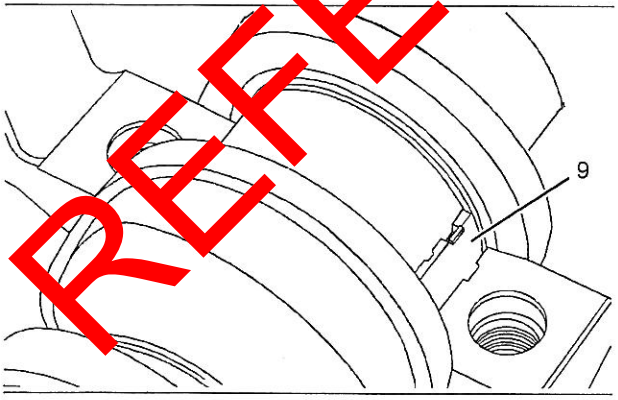



Illustration 302 g01253145
Typical example

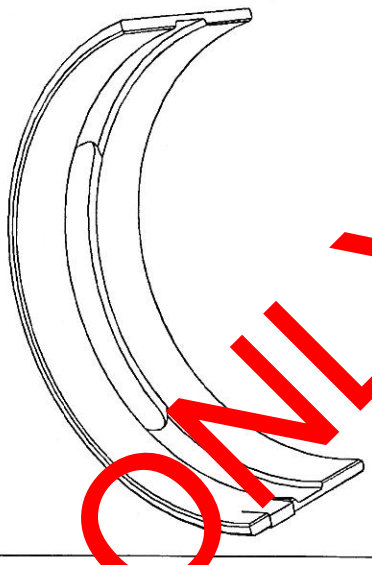


Illustration 303 g01889993
No. 1 Upper Main Bearing

3. Lubricate the crankshaft journal and upper main bearing (9) with clean engine oil. Slide upper main bearing (9) into position between the crankshaft journal and the cylinder block. Ensure that the locating tab for the upper main bearing is correctly seated in the slot in the cylinder block.

**Note:** Number 1 upper main bearing has an oil slot. See Illustration 303. All other upper main bearings have a groove and two oil holes.

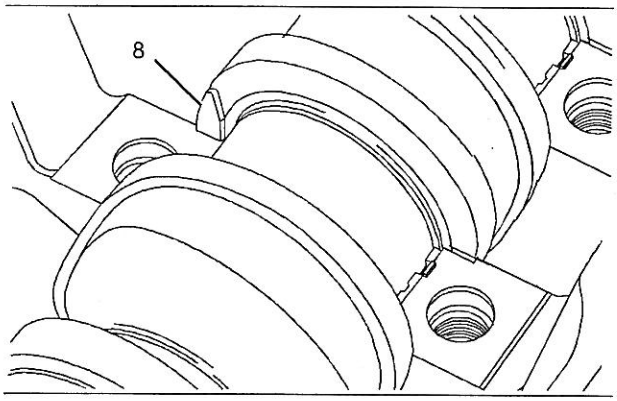



Illustration 304 g01261200
Typical example

4. For number three main bearing, ensure that thrust washers (8) are clean and free from wear or damage. If necessary, replace the thrust washers. Lubricate thrust washers (8) with clean engine oil. Slide the thrust washers into position between the crankshaft and the cylinder block. The grooves in the thrust washers must be located against the crankshaft.

REFERENCE ONLY

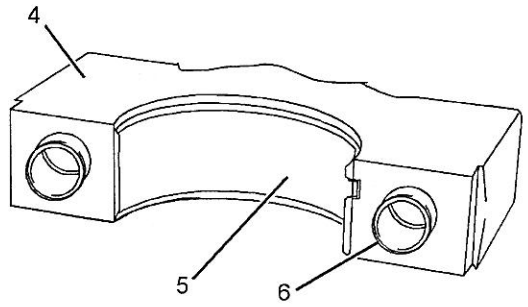



Illustration 305 g01253146
Typical example

**5.** Install lower main bearing (5) into main bearing cap (4). Ensure that the locating tab for the lower main bearing is correctly seated into the slot in the bearing cap.

**Note:** The lower main bearing is a plain bearing that has no oil holes.

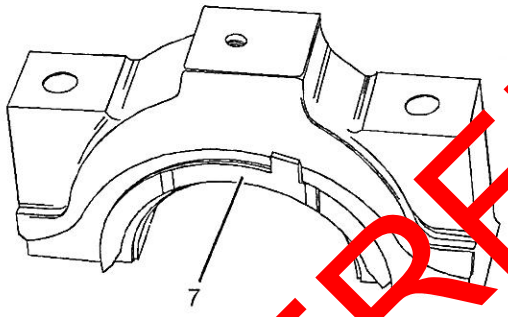



Illustration 306 g01253137
Typical example

**6.** For number three main bearing cap, ensure that thrust washers (7) are clean and free from wear or damage. If necessary, replace the thrust washers. Lubricate the thrust washers (7) with clean engine oil. Place the thrust washers into position on the main bearing cap. Ensure that the locating tab is correctly seated in the main bearing cap.

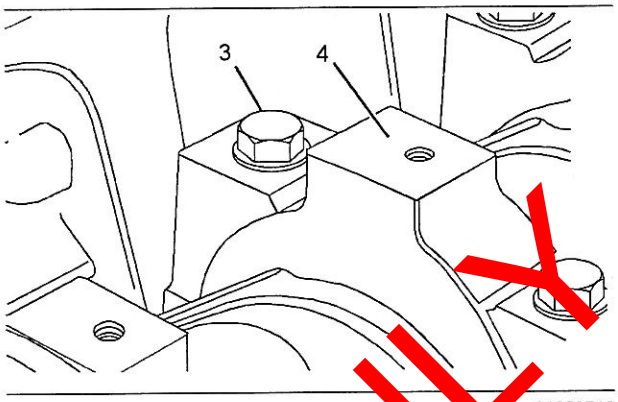



Illustration 307 g01253719
Typical example

**7.** Lubricate the crankshaft journal and the lower main bearing with clean engine oil. Install main bearing cap (4) to the cylinder block.

**Note:** Ensure the correct orientation of the main bearing cap. The locating tab for the upper and the lower bearing should be on the same side of the engine.

**8.** Lubricate the threads of bolts (3) with clean engine oil. Lubricate the underside of the heads of the bolts with clean engine oil.

Install bolts (3) to main bearing cap (4). Evenly tighten the bolts in order to pull cap (5) into position. Ensure that the cap is correctly seated.

**Note:** Do not tap the main bearing cap into position as the bearing may be dislodged.

**10.** Tighten bolts (3) to a torque of 245 N·m (180 lb ft).

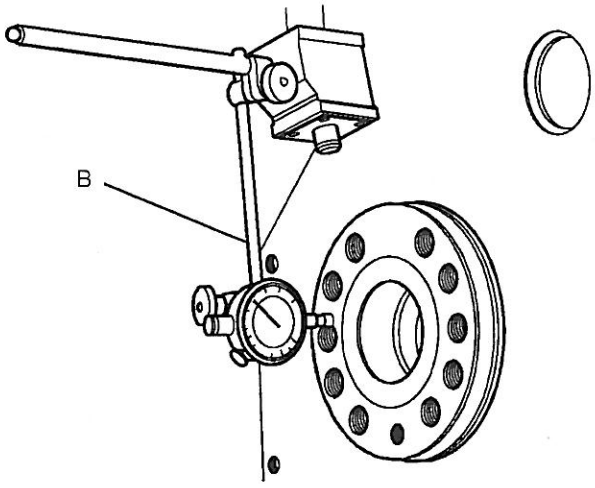



Illustration 308 g01253186
Typical example

REFERENCE ONLY

11. Check the crankshaft end play. Push the crankshaft toward the front of the engine. Install Tooling (B) to the cylinder block and the rear face of the crankshaft. Push the crankshaft toward the rear of the engine. Use Tooling (B) to measure the crankshaft end play. The permissible crankshaft end play is 0.17 to 0.41 mm (0.007 to 0.016 inch).

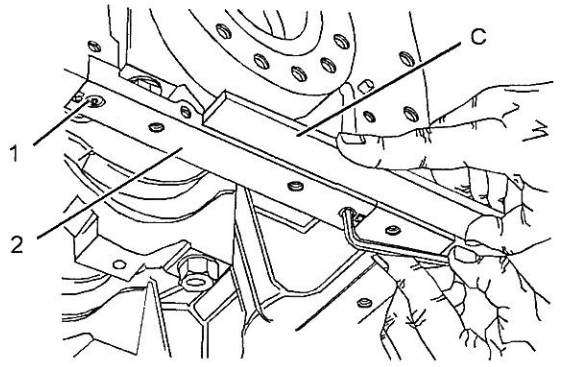



Illustration 309 g01253836
Typical example

12. Follow Step 12.a through Step 12.d in order to install the bridge piece.

    a. Ensure that the recess in the cylinder block and the bridge piece are clean, dry and free from old sealant.

    b. Install bridge piece (2) and allen head screws (1). Tighten the allen head screws finger tight.

    c. Use Tooling (C) in order to align the rear face of the bridge piece with the rear face of the cylinder block.

    d. Use Tooling (D) to tighten allen head screws (1) to a torque of 1[illegible] N·m (12 lb ft).

13. Install the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

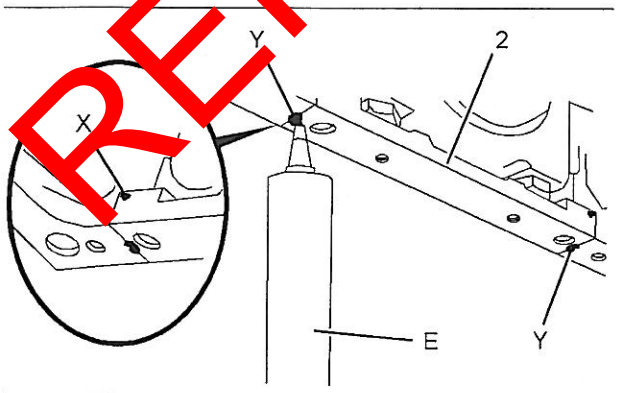



Illustration 310 g01344584
Typical example

14. Apply Tooling (E) to Cavities (Y) in bridge piece (2). Continue to apply Tooling (E) until sealant extrudes from Cavities (X).

**Note:** If the oil pan will not be installed immediately, ensure that the face of the bridge piece and the cylinder block are left free of sealant.

**End By:**

a. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

i02933602

# Crankshaft - Remove

## Removal Procedure

Table 76

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Lifting Strap | 1 |

**Start By:**

a. Remove the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove".

b. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".

c. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove".

d. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

NOTICE
If the crankshaft has been reground or if the crankshaft has been replaced, the height of the piston above the cylinder block must be inspected. It is necessary to remove the cylinder head in order to inspect the height of the piston above the cylinder block.

REFERENCE ONLY

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. The engine should be mounted on a suitable stand and placed in the inverted position.

2. If necessary, remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove". Remove the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Remove".

   If the cylinder head, the pistons and the connecting rods have not been removed, remove the connecting rod caps. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Remove".

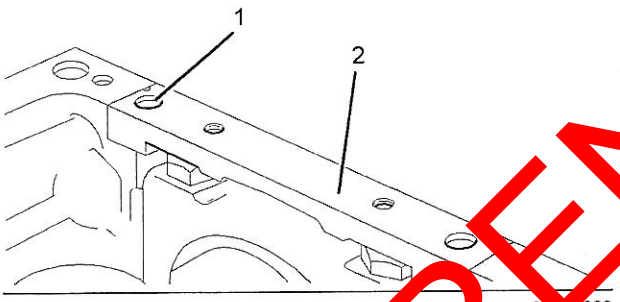



Illustration 311 g01[illegible]628
Typical example

3. Remove allen head screws (1). Remove bridge piece (2).

4. Ensure that the main bearing caps are marked for the location and orientation.

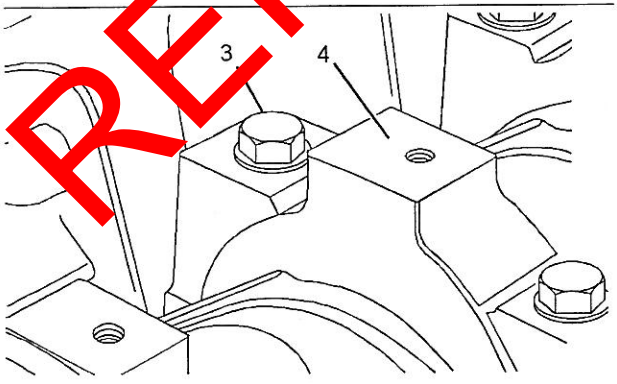



Illustration 312 g01253719
Typical example

5. Remove bolts (3) and main bearing caps (4) from the cylinder block.

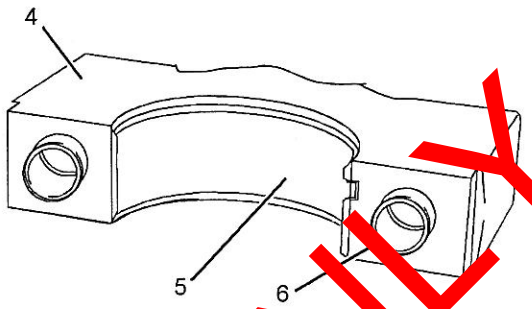



Illustration 313 g01253146
Typical example

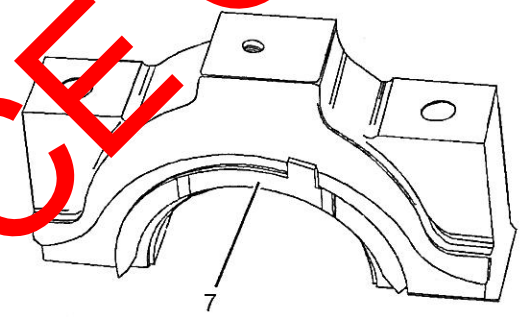



Illustration 314 g01253137
Typical example

6. Remove lower main bearings (5) from main bearing caps (4). Take care not to displace dowels (6). For number three main bearing cap, remove thrust washers (7). Keep the lower main bearings and the thrust washers with the respective main bearing caps.

**Note:** The lower main bearings are plain bearings that have no oil holes. The dowels may remain in the main bearing cap or in the cylinder block.

REFERENCE ONLY

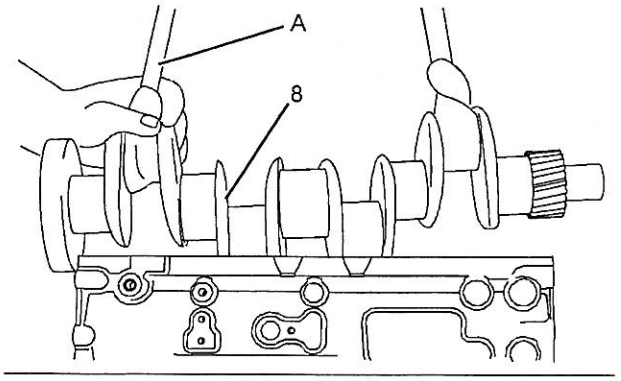



Illustration 315 g01254099
Typical example

7. Attach Tooling (A) and a suitable lifting device to crankshaft (8). Carefully lift the crankshaft out of the cylinder block. The weight of the crankshaft is approximately 30 kg (66 lb).

**Note:** Do not damage any of the finished surfaces on the crankshaft. When the crankshaft is removed from the engine, the crankshaft must be supported on a suitable stand in order to prevent damage to the crankshaft timing ring.

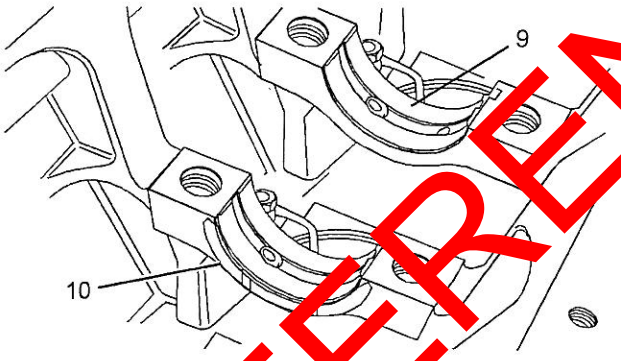



Illustration 316 g01254104
Typical example

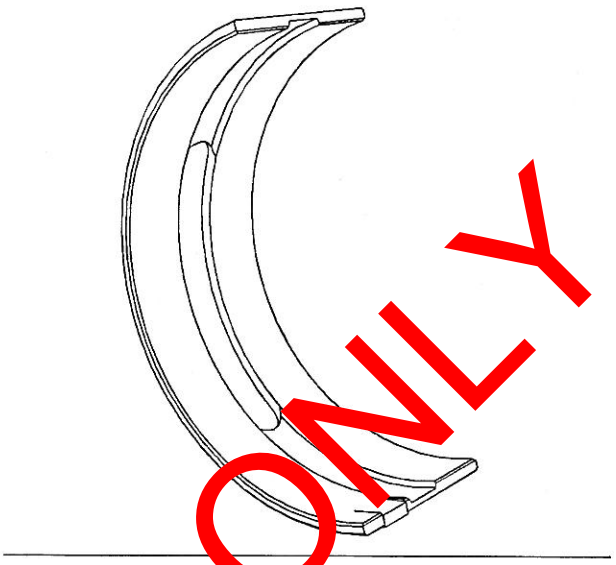


Illustration 317 g01889993
No. 1 Upper Main Bearing

8. Remove upper main bearings (9) from the cylinder block. Keep the upper main bearings with the respective main bearing caps.

**Note:** Number 1 upper main bearing has an oil slot. See Illustration 317. All other upper main bearings have a groove and two oil holes.

9. Remove thrust washers (10) from number three main bearing in the cylinder block.

10. If necessary, remove the crankshaft timing ring. Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install".

11. If necessary, remove the crankshaft gear. Refer to Disassembly and Assembly, "Crankshaft Gear - Remove and Install".

REFERENCE ONLY

i02933601

# Crankshaft - Install

## Installation Procedure

Table 77

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Lifting Strap | 1 |
| B | 21825617 | Dial Indicator Group | 1 |
| C | - | Straight Edge | 1 |
| D | - | 5 mm Allen Socket | 1 |
| E | 21826038 | POWERPART Silicon Rubber Sealant | - |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
If the crankshaft has been reground or if the crankshaft has been replaced, the height of the piston above the cylinder block must be inspected. It is necessary to remove the cylinder head in order to inspect the height of the piston above the cylinder block.

NOTICE
If the crankshaft has been reground or the crankshaft has been replaced, ensure that the engine oil system is free from debris and contaminants.

1. Clean the crankshaft and inspect the crankshaft for wear or damage. Refer to Specifications, "Crankshaft" for more information. If necessary, replace the crankshaft or recondition the crankshaft.

2. If necessary, install the crankshaft gear. Refer to Disassembly and Assembly, "Crankshaft Gear - Remove and Install".

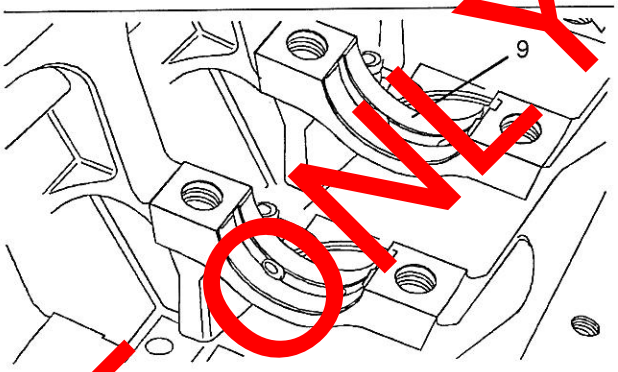
3. If necessary, install a new crankshaft timing ring. Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install".

**Note:** The engine should be mounted on a suitable stand and placed in the inverted position.

4. Ensure that the parent bores for the crankshaft bearings in the cylinder block are clean. Ensure that the threads for the bearing bolts in the cylinder block are clean and free from damage.

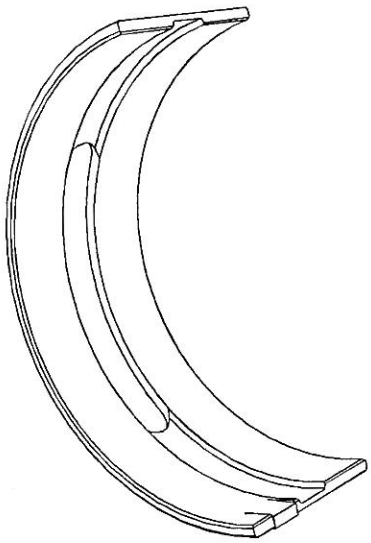
5. Clean the crankshaft bearings and the thrust washers. Inspect the bearings and the thrust washers for wear or damage. If necessary, replace the bearings and the thrust washers.

**Note:** If the crankshaft bearings are replaced, check whether oversize bearings were previously installed. If the thrust washers are replaced, check whether oversize thrust washers were previously installed.




g01253240

Illustration 318
Typical example



g01889993

Illustration 319
No. 1 Upper Main Bearing

6. Install upper bearings (9) to the cylinder block. Ensure that the locating tabs for the upper bearings are seated in the slots in the cylinder block.

**Note:** Number 1 upper main bearing has an oil slot. See Illustration 319. All other upper bearings have a groove and two oil holes.

7. Lubricate upper bearings (9) with clean engine oil.

REFERENCE ONLY

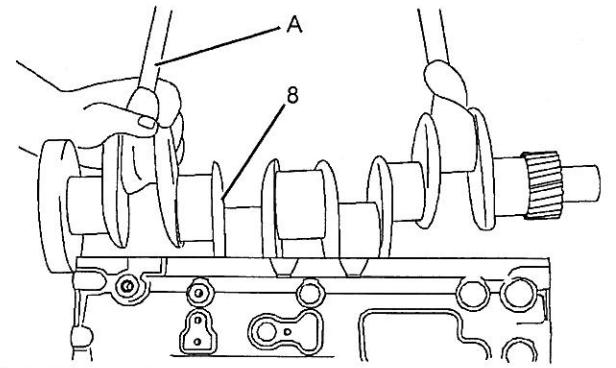



Illustration 320 g01254099
Typical example

8. Attach Tooling (A) and a suitable lifting device to crankshaft (8). Carefully lift the crankshaft into the cylinder block. The weight of the crankshaft is approximately 30 kg (66 lb). Remove Tooling (A).

**Note:** Do not damage any of the finished surfaces on the crankshaft. Do not damage the bearing.

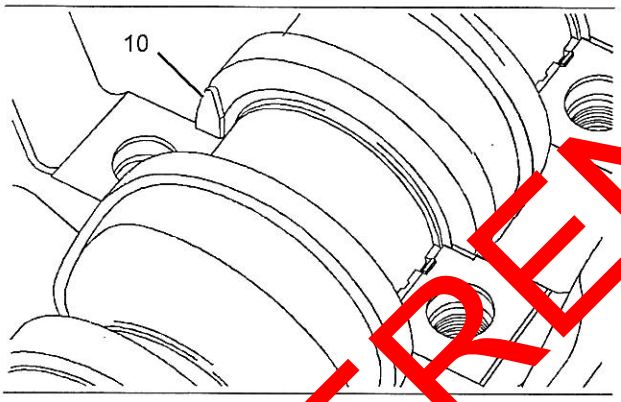



Illustration 321 g01254100
Typical example

9. For number three bearing, ensure that thrust washers (10) are clean and free from wear or damage. If necessary, replace the thrust washers. Lubricate thrust washers (10) with clean engine oil. Slide the thrust washers into position between the crankshaft and the cylinder block.

**Note:** The grooves in the thrust washers must be located against the crankshaft.

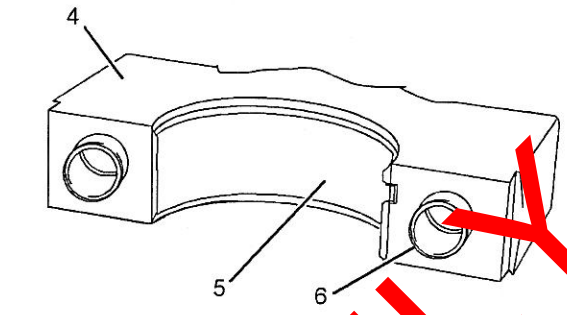



Illustration 322 g01253146

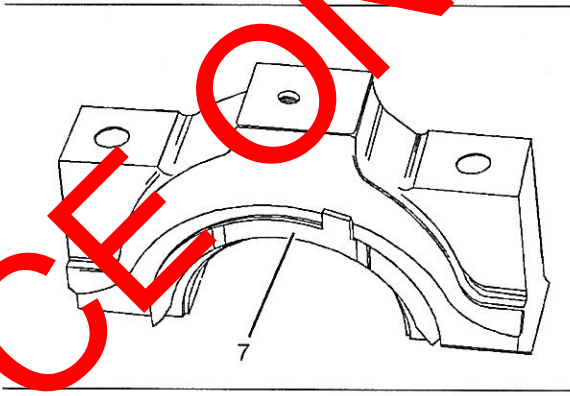



Illustration 323 g01253137

10. Install lower bearings (5) into bearing caps (4). Ensure that the locating tabs for the lower bearings are correctly seated into the slots in the bearing caps. For number three bearing cap, ensure that thrust washers (7) are clean and free from wear or damage. If necessary, replace both the thrust washers. Lubricate thrust washers (7) with clean engine oil. Place the thrust washers into position on the bearing cap. Ensure that the locating tab is correctly seated in the bearing cap.

**Note:** The lower bearing is a plain bearing that has no oil holes.

11. Lubricate lower bearings (5) and lubricate the journals of crankshaft (8) with clean engine oil. Install bearing caps (4) to the cylinder block.

**Note:** Ensure the correct location and orientation of the bearing caps. The locating tabs for the upper and the lower bearings should be on the same side of the engine.

REFERENCE ONLY

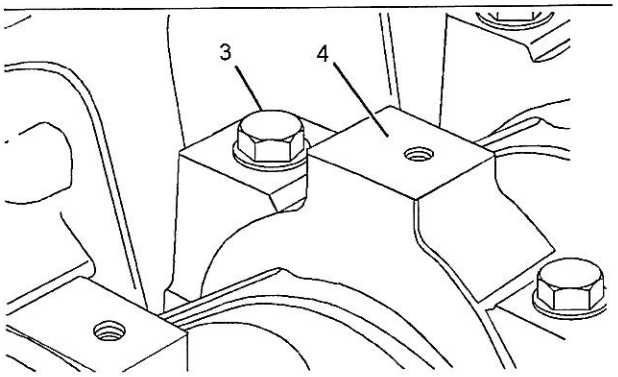



Illustration 324 g01253719

**12.** Lubricate the threads of bolts (3) with clean engine oil. Lubricate the underside of the heads of the bolts with clean engine oil.

**13.** Install bolts (3) to bearing caps (4). Evenly tighten the bolts in order to pull the caps into position. Ensure that the caps are correctly seated.

**Note:** Do not tap the bearing caps into position as the bearing may be dislodged.

**14.** Tighten bolts (3) to a torque of 245 N·m (180 lb ft).

**15.** Rotate the crankshaft in order to ensure that there is no binding.

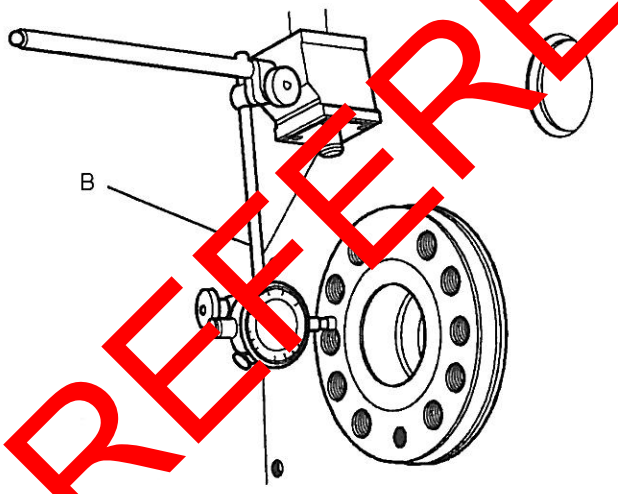



Illustration 325 g01253186
Typical example

**16.** Check the crankshaft end play. Push the crankshaft toward the front of the engine. Install Tooling (B) to the cylinder block and the rear face of the crankshaft. Push the crankshaft toward the rear of the engine. Use Tooling (B) to measure the crankshaft end play. The permissible crankshaft end play is 0.17 to 0.41 mm (0.007 to 0.016 inch).

**17.** If the crankshaft has been replaced or the crankshaft has been reconditioned, inspect the height of the piston above the cylinder block. Refer to Systems Operation, Testing and Adjusting, "Piston Height - Inspect" for more information.

If the crankshaft has not been replaced or the crankshaft has not been reconditioned, install the connecting rod caps. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install".

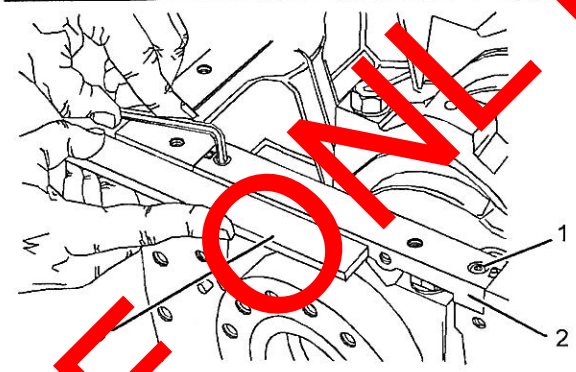



Illustration 326 g01254102
Typical example

**18.** Follow Step 18.a through Step18.d in order to install the bridge piece.

**a.** Ensure that the cylinder block and the bridge piece are clean, dry and free from old sealant.

**b.** Install bridge piece (2) and allen head screws (1). Tighten the allen head screws finger tight.

**c.** Use Tooling (C) in order to align the rear face of the bridge piece with the rear face of the cylinder block.

**d.** Use Tooling (D) in order to tighten the allen head screws to a torque of 16 N·m (12 lb ft).

**19.** Install the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

REFERENCE ONLY

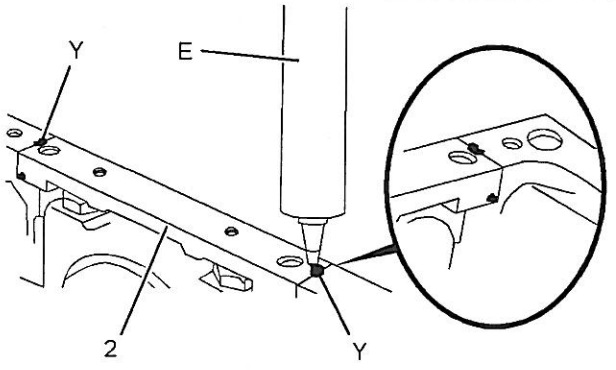



Illustration 327 g01344593

Typical example

**20.** Apply Tooling (E) to Cavities (Y) in the bridge piece (2). Continue to apply Tooling (E) until sealant extrudes from Cavities (X).

**Note:** If the oil pan will not be installed immediately, ensure that the face of the bridge piece and the cylinder block are left free of sealant.

**End By:**

**a.** If necessary, install the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Install".

**b.** If the engine has a balancer, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install". If the engine does not have a balancer, install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

**c.** Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

**d.** If necessary, install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

**e.** Install the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install".

i02933611

# Crankshaft Timing Ring - Remove and Install

## Removal Procedure

**Start By:**

**a.** Remove the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Remove".

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

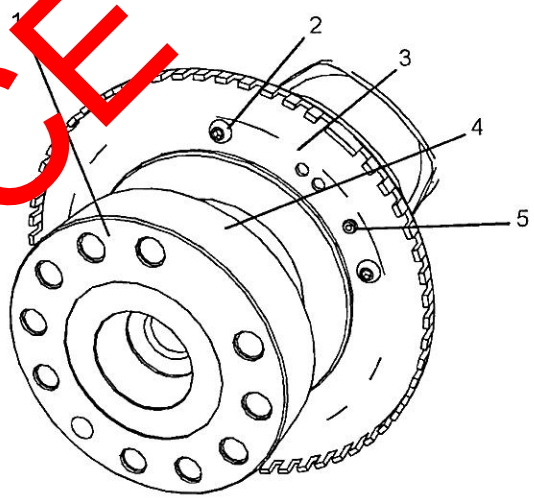



Illustration 328 g01254108

**1.** Support crankshaft (1) on a suitable stand.

**2.** Remove allen head screws (2) from crankshaft timing ring (3). Do not reuse the allen head screws.

**3.** Carefully remove crankshaft timing ring (3) from crankshaft (1). Do not reuse the crankshaft timing ring.

**Note:** Ensure that seal surface (4) of the crankshaft is not damaged when the crankshaft timing ring is removed.

**Note:** Do not remove dowel (5) from crankshaft (1) unless the dowel is damaged.

REFERENCE ONLY

## Installation Procedure

Table 78

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | 4 mm Allen Socket | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Support crankshaft (1) on a suitable stand.
2. Ensure that the flange for the crankshaft timing ring on the crankshaft is clean and free from damage.

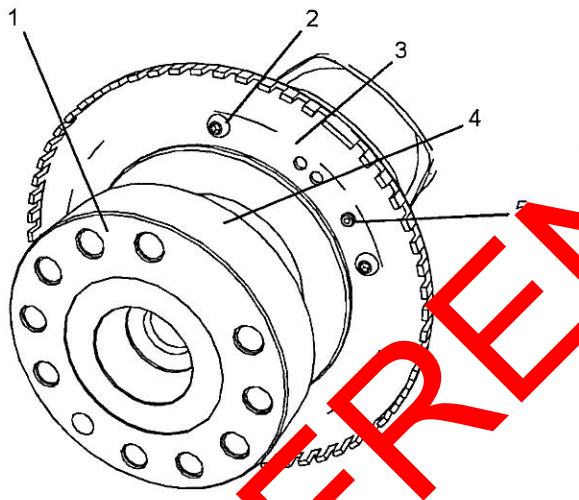



Illustration 329 g01254108

3. If dowel (5) was removed, install a new dowel to crankshaft (1).
4. Position crankshaft timing ring (3) onto the crankshaft with the teeth toward rear seal surface (4). Align the hole in crankshaft timing ring (3) with dowel (5). Carefully install crankshaft timing ring (3) to crankshaft (1).

**Note:** Ensure that seal surface (4) on the crankshaft is not damaged when the crankshaft timing ring is installed.

5. Use Tooling (A) to install new allen head screws (2). Tighten the allen head screws to a torque of 9 N·m (80 lb in).

**End By:**

a. Install the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Install ".

i02933604

# Crankshaft Gear - Remove and Install

## Removal Procedure

Table 79

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Bearing Puller | 1 |
| | - | Puller | 1 |
| | - | Crossblock | 1 |
| | - | Puller Leg | 2 |

**Start By:**

a. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".
b. If the engine is equipped with a balancer, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove". If the engine is not equipped with a balancer, remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The crankshaft gear may be a sliding fit on the crankshaft or an interference fit on the crankshaft.

REFERENCE ONLY

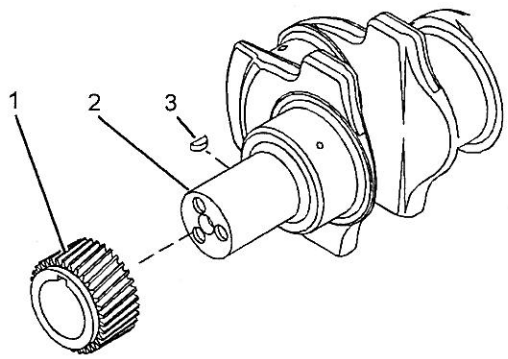



Illustration 330 g01367358
Typical example

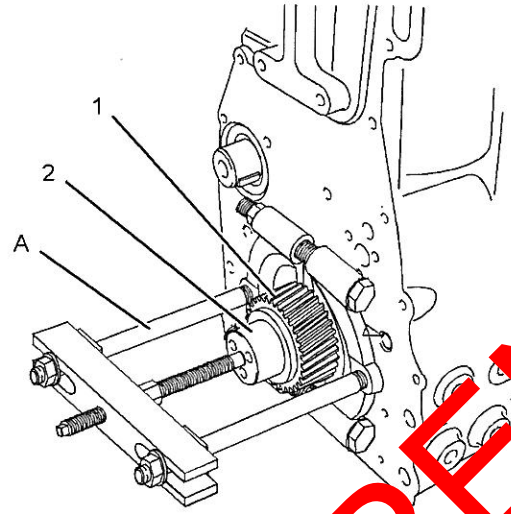



Illustration 331 g01270549
Typical example

1. If the crankshaft gear is a sliding fit on the crankshaft, remove crankshaft gear (1) from crankshaft (2).

   If the crankshaft gear is an interference fit on the crankshaft, use Tooling (A) in order to remove crankshaft gear (1) from crankshaft (2).

2. If necessary, remove key (3) from crankshaft (2).

**Note:** Do not remove the key from the crankshaft unless the key is damaged.

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.

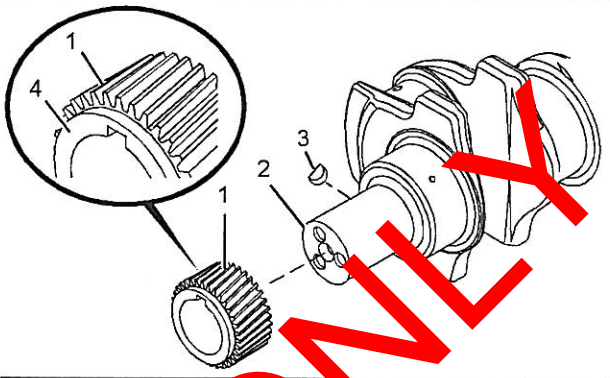



Illustration 332 g01367359
Typical example

2. If necessary, install a new key (3) to crankshaft (2).

**Note:** The crankshaft gear may be a sliding fit on the crankshaft or an interference fit on the crankshaft.

**⚠ WARNING**

**Hot parts or hot components can cause burns or personal injury. Do not allow hot parts or components to contact your skin. Use protective clothing or protective equipment to protect your skin.**

3. If the crankshaft gear is a sliding fit on the crankshaft, align the keyway in crankshaft gear (1) with key (3) in the crankshaft. Install crankshaft gear (1) to crankshaft (2).

   If the crankshaft gear is an interference fit on the crankshaft, heat crankshaft gear (1) in an oven to 150° ± 50°C (302° ± 90°F). Align the keyway in crankshaft gear (1) with key (3) in the crankshaft. Install crankshaft gear (1) to crankshaft (2).

   Ensure that shoulder (4) on crankshaft gear (1) is toward the front of the engine.

**End By:**

a. Install the front housing. Refer to Disassembly and Assembly, “Housing (Front) - Install”.

b. If the engine is equipped with a balancer, install the balancer. Refer to Disassembly and Assembly, “Balancer - Install”. If the engine is not equipped with a balancer, install the engine oil pump. Refer to Disassembly and Assembly, “Engine Oil Pump - Remove and Install”.

REFERENCE ONLY

i02748526

# Bearing Clearance - Check

## Measurement Procedure

Table 80

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Plastic Gauge (Green) 0.025 to 0.076 mm (0.001 to 0.003 inch) | 1 |
| | - | Plastic Gauge (Red) 0.051 to 0.152 mm (0.002 to 0.006 inch) | 1 |
| | - | Plastic Gauge (Blue) 0.102 to 0.229 mm (0.004 to 0.009 inch) | 1 |
| | - | Plastic Gauge (Yellow) 0.230 to 0.510 mm (0.009 to 0.020 inch) | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten component life.

**Note:** Perkins does not recommend the checking of the actual clearances of the bearing shells particularly on small engines. This is because of the possibility of obtaining inaccurate results and of damaging the bearing shell or the journal surfaces. Each Perkins bearing shell is quality checked for specific wall thickness.

**Note:** The measurements should be within specifications and the correct bearings should be used. If the crankshaft journals and the bores for the block and the rods were measured during disassembly, no further checks are necessary. However, if the technician still wants to measure the bearing clearances, Tooling (A) is an acceptable method. Tooling (A) is less accurate on journals with small diameters if clearances are less than 0.10 mm (0.004 inch).

NOTICE
Lead wire, shim stock or a dial bore gauge can damage the bearing surfaces.

The technician must be very careful to use Tooling (A) correctly. The following points must be remembered:

- Ensure that the backs of the bearings and the bores are clean and dry.
- Ensure that the bearing locking tabs are properly seated in the tab grooves.
- The crankshaft must be free of oil at the contact points of Tooling (A).

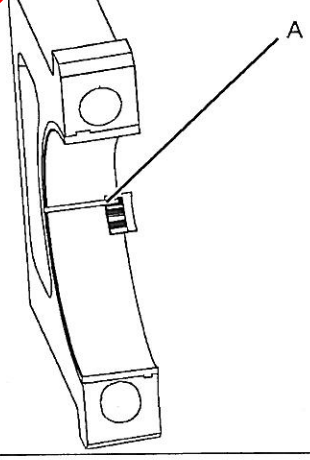
1. Put a piece of Tooling (A) on the crown of the bearing that is in the cap.

**Note:** Do not allow Tooling (A) to extend over the edge of the bearing.

2. Use the correct torque-turn specifications in order to install the bearing cap. Do not use an impact wrench. Be careful not to dislodge the bearing when the cap is installed.

**Note:** Do not turn the crankshaft when Tooling (A) is installed.

3. Carefully remove the cap but do not remove Tooling (A). Measure the width of Tooling (A) while Tooling (A) is in the bearing cap or on the crankshaft journal. Refer to Illustration 333.




g01152855
Illustration 333
Typical Example

4. Remove all of Tooling (A) before you install the bearing cap.

**Note:** When Tooling (A) is used, the readings can sometimes be unclear. For example, all parts of Tooling (A) are not the same width. Measure the major width in order to ensure that the parts are within the specification range. Refer to Specifications Manual, “Connecting Rod Bearing Journal” and Specifications Manual, “Main Bearing Journal” for the correct clearances.

REFERENCE ONLY

i02933606

# Crankshaft Position Sensor - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

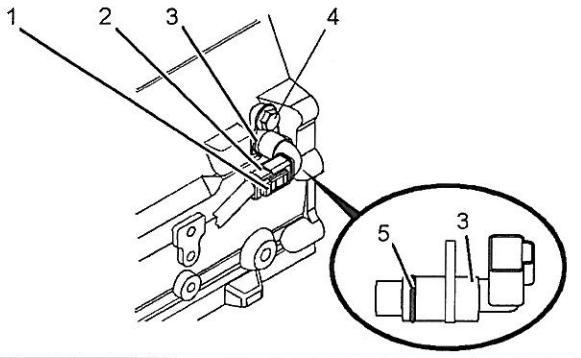



Illustration 334 g01479572
Typical example

1. Slide locking tab (1) into the unlocked position.
2. Disconnect harness assembly (2) from position sensor (3).
3. Remove bolt (4).
4. Carefully remove position sensor (3) from the cylinder block.

**Note:** Do not use a lever to remove the position sensor from the cylinder block.

5. Remove O-ring seal (5) from position sensor (3).

## Installation Procedure

Table 1

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21820221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

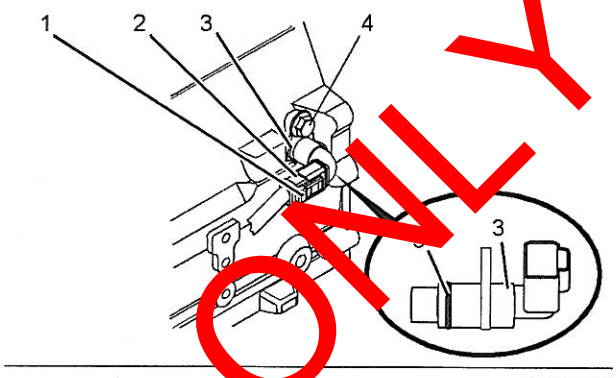



Illustration 335 g01479572
Typical example

1. Install a new O-ring seal (5) to the groove in position sensor (3). Lubricate the new O-ring seal with Tooling (A).
2. Align the hole in position sensor (3) with the hole in the cylinder block. Install the position sensor to the cylinder block.

**Note:** Do not use bolt (4) to pull the position sensor into position against the cylinder block.

3. Install bolt (4). Tighten the bolt to a torque of 22 N·m (16 lb ft).
4. Connect harness assembly (2) to position sensor (3).
5. Slide locking tab (1) into the locked position.

i02933668

# Position Sensor (Fuel Injection Pump) - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

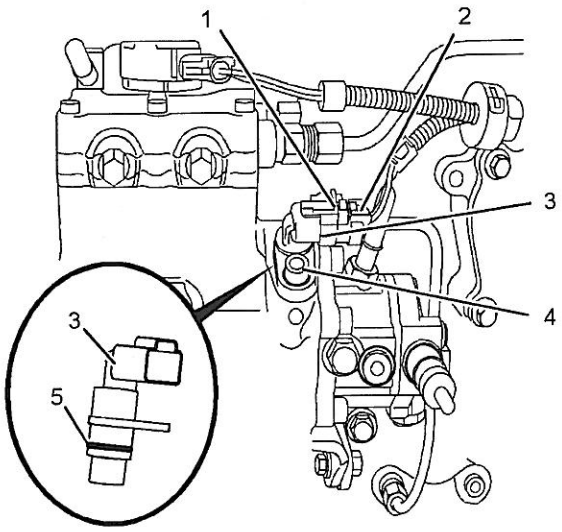



Illustration 336 g01480052
Typical example

1. Slide locking tab (1) into the unlocked position.
2. Disconnect harness assembly (2) from position sensor (3).
3. Remove bolt (4).
4. Carefully remove position sensor (3) from the fuel injection pump.

**Note:** Do not use a lever to remove the position sensor from the fuel injection pump.

5. Plug the hole for the position sensor in the fuel injection pump with a new plug.
6. Remove O-ring seal (5) from position sensor (3).

## Installation Procedure

Table 82

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 1220221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

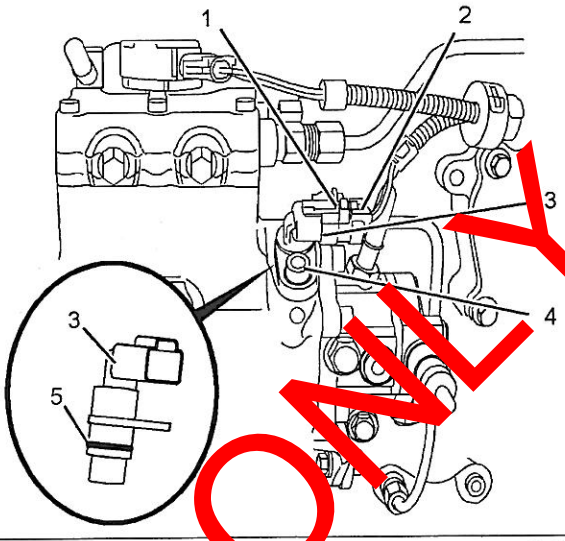



Illustration 337 g01480052
Typical example

1. Install a new O-ring seal (5) to the groove in position sensor (3). Lubricate the new O-ring seal with Tooling (A).
2. Remove the plug from the hole in the fuel injection pump for the position sensor.
3. Align the hole in position sensor (3) with the hole in the fuel injection pump. Install the position sensor to the fuel injection pump.

**Note:** Do not use bolt (4) to pull the position sensor into position against the fuel injection pump.

4. Install bolt (4). Tighten the bolt to a torque of 22 N·m (16 lb ft).
5. Connect harness assembly (2) to position sensor (3).
6. Slide locking tab (1) into the locked position.

i02933598

# Coolant Temperature Sensor - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system, to a level below the coolant temperature sensor, into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

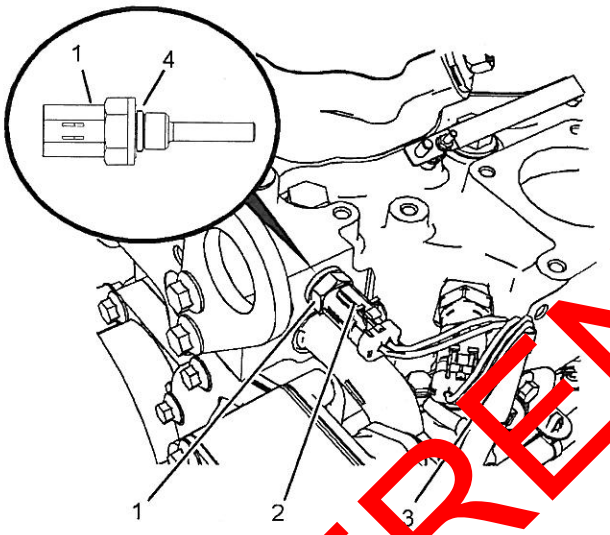



Illustration 338 g01480094
Typical example

2. Slide locking tab (2) into the unlocked position.

3. Disconnect harness assembly (3) from coolant temperature sensor (1).

**Note:** The coolant temperature sensor has a two-wire plug.

4. Use a deep socket to remove coolant temperature sensor (1) from the cylinder head.

**Note:** If necessary, remove the bracket for the harness assembly from the bypass tube.

5. Remove O-ring seal (4) from coolant temperature sensor (1).

## Installation Procedure

Table 83

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21820221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

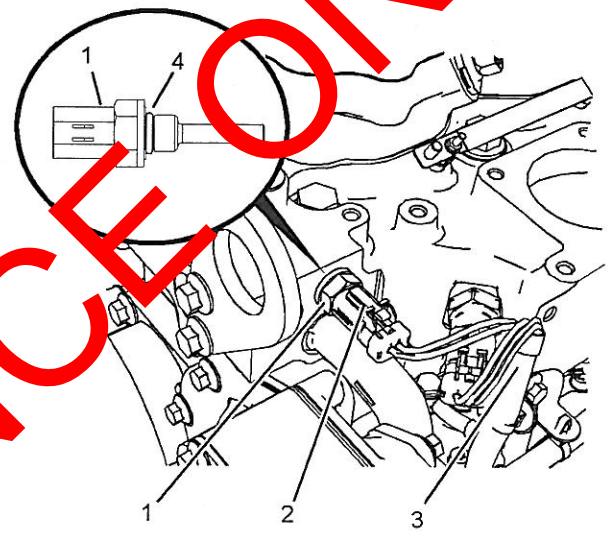



Illustration 339 g01480094
Typical example

1. Install a new O-ring seal (4) to the groove in coolant temperature sensor (1). Lubricate the new O-ring seal with Tooling (A).

2. Use a deep socket in order to install coolant temperature sensor (1) to the cylinder head. Tighten the coolant temperature sensor to a torque of 20 N·m (15 lb ft).

3. Connect harness assembly (3) to coolant temperature sensor (1).

**Note:** If necessary, install the bracket for the harness assembly to the bypass tube.

4. Slide locking tab (2) into the locked position.

5. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check" and refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.

REFERENCE ONLY

i02933624

# Engine Oil Pressure Sensor - Remove and Install

## Removal Procedure

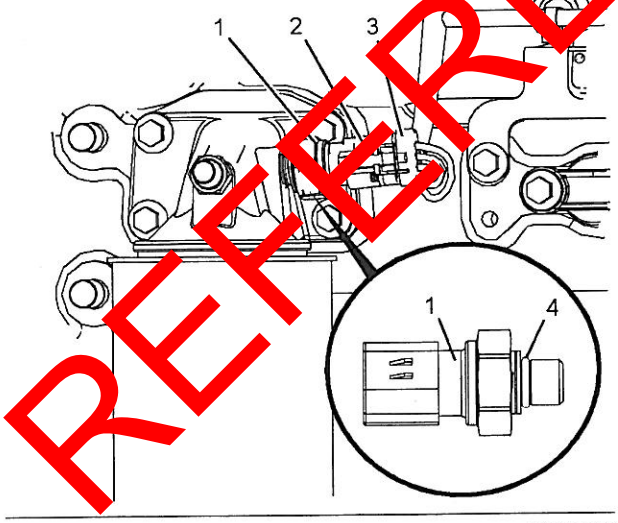
NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** The engine oil pressure sensor may be located in the cylinder block, on a plate or in the engine oil filter base. Ensure that the engine oil pressure sensor is installed in the correct position.




g01480133

Illustration 340
Typical example

1. Slide locking tab (2) into the unlocked position.
2. Disconnect harness assembly (3) from engine oil pressure sensor (1).
3. If necessary, remove the engine oil filter in order to gain access to engine oil pressure sensor (1). Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".
4. If necessary, remove the dipstick tube in order to gain access to engine oil pressure sensor (1). Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".
5. Use a deep socket to remove engine oil pressure sensor (1).
6. Remove O-ring seal (4) from engine oil pressure sensor (1).

## Installation Procedure

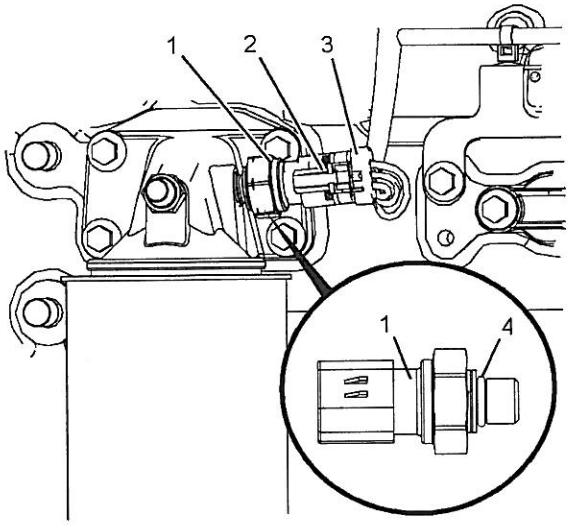
Table 84

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21820221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The engine oil pressure sensor may be located in the cylinder block, on a blanking plate or in the engine oil filter base. Ensure that the engine oil pressure sensor is installed in the correct position.




g01480133

Illustration 341
Typical example

REFERENCE ONLY

1. Install a new O-ring seal (4) to the groove in engine oil pressure sensor (1). Lubricate the new O-ring seal with Tooling (A).

2. Use a deep socket to install engine oil pressure sensor (1). Tighten the engine oil pressure sensor to a torque of 10 N·m (89 lb in).

3. If necessary, install the engine oil filter. Refer to Operation and Maintenance Manual, "Engine Oil and Filter Change".

4. If necessary, install the dipstick tube. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

5. Connect harness assembly (3) to engine oil pressure sensor (1).

6. Slide locking tab (2) into the locked position.

7. If necessary, fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check".

i02933645

# Fuel Pressure Sensor - Remove and Install

## Removal Procedure

Table 85

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Seal Pick | 1 |

**WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

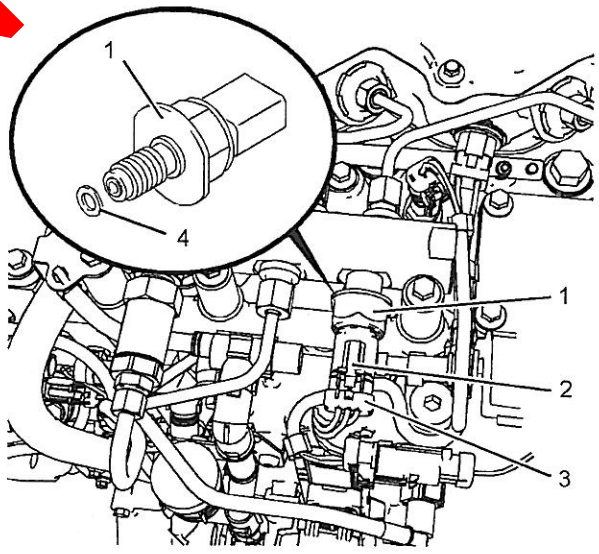



Illustration 342 g01459748
Typical example

1. Slide locking tab (2) into the unlocked position.

2. Disconnect harness assembly (3) from fuel pressure sensor (1).

3. Use a deep socket to remove fuel pressure sensor (1) from the fuel manifold.

REFERENCE ONLY

**Note:** After the engine has stopped, allow the pressure to dissipate for 60 seconds before removing the fuel pressure sensor.

4. If necessary, use Tooling (A) in order to remove sealing washer (4) from the fuel manifold.

**Note:** Do not damage the seat for the washer in the fuel manifold. Ensure that no debris enters the fuel manifold during the removal of the sealing washer.

5. Plug the open port in the fuel manifold immediately with a new plug.

## Installation Procedure

Table 86

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 21825607 | Angle gauge | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

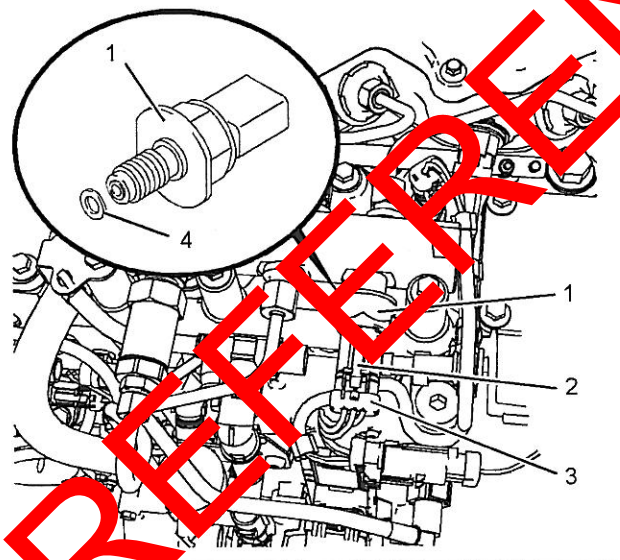



Illustration 343 g01459748
Typical example

1. Position a new sealing washer (4) onto fuel pressure sensor (1).

2. Remove the plug from the fuel manifold.

3. Install fuel pressure sensor (1) to the fuel manifold. Use a deep socket to tighten the fuel pressure sensor to a torque of 5 N·m (44 lb in). Use Tooling (B) to turn the fuel pressure sensor through an additional 120 degrees.

4. Connect harness assembly (3) to fuel pressure sensor (1).

5. Slide locking tab (2) into the locked position.

6. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933592

# Boost Pressure Sensor - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The boost pressure sensor may be located on the secondary fuel filter base or in the cylinder head.

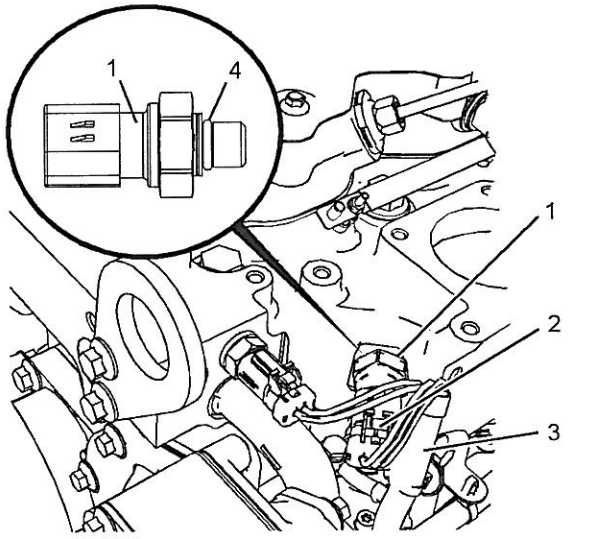



Illustration 344 g01480192
Typical example

1. Slide locking tab (2) into the unlocked position.

2. Disconnect harness assembly (3) from boost pressure sensor (1).

REFERENCE ONLY

**Note:** The boost pressure sensor has a three-wire plug.

3. Use a deep socket to remove boost pressure sensor (1).

**Note:** If necessary, remove the bracket for the harness assembly from the bypass tube.

4. Remove O-ring seal (4) from boost pressure sensor (1).

## Installation Procedure

Table 87

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | 21820221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The boost pressure sensor may be located on the secondary fuel filter base or in the cylinder head.




Illustration 345 g01480192
Typical example

1. Install a new O-ring seal (4) to the groove in boost pressure sensor (1). Lubricate the new O-ring seal with Tooling (A).

2. Use a deep socket to install boost pressure sensor (1). Tighten the boost pressure sensor to a torque of 10 N·m (89 lb in).

**Note:** If necessary, install the bracket for the harness assembly to the bypass tube.

3. Connect harness assembly (3) to boost pressure sensor (1).

4. Slide locking tab (2) into the locked position.

i02933659

# Inlet Air Temperature Sensor - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

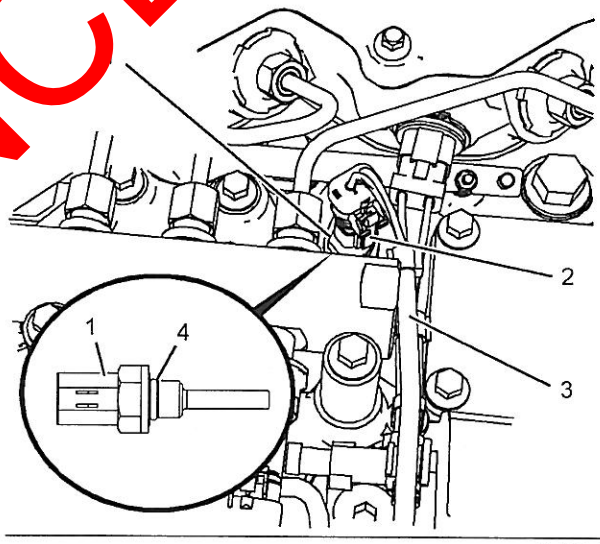



Illustration 346 g01480292
Typical example

1. Slide locking tab (2) into the unlocked position.

2. Disconnect harness assembly (3) from inlet air pressure sensor (1).

**Note:** The inlet air temperature sensor has a two wire plug.

3. Use a deep socket in order to remove inlet air temperature sensor (1) from the cylinder head.

4. Remove O-ring seal (4) from inlet air temperature sensor (1).

REFERENCE ONLY

## Installation Procedure

Table 88

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21820221 | POWERPART Rubber Grease | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

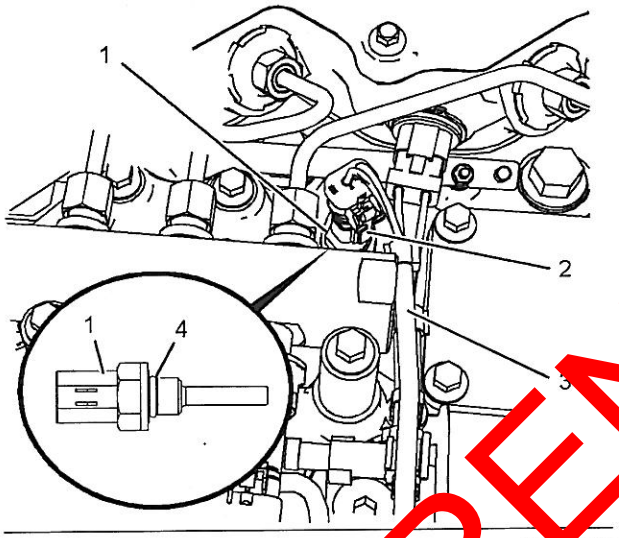



Illustration 347 g01[illegible]0292
Typical example

1. Install a new O-ring seal (4) to the groove in inlet air temperature sensor (1). Lubricate the new O-ring seal with cooling (A).
2. Install inlet air temperature sensor (1) to the cylinder head. Use a deep socket in order to tighten the inlet air temperature sensor to a torque of 20 N·m (15 lb ft).
3. Connect harness assembly (3) to inlet air temperature sensor (1).
4. Slide locking tab (2) into the locked position.

i02933653

# Glow Plugs - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the battery disconnect switch to the OFF position.

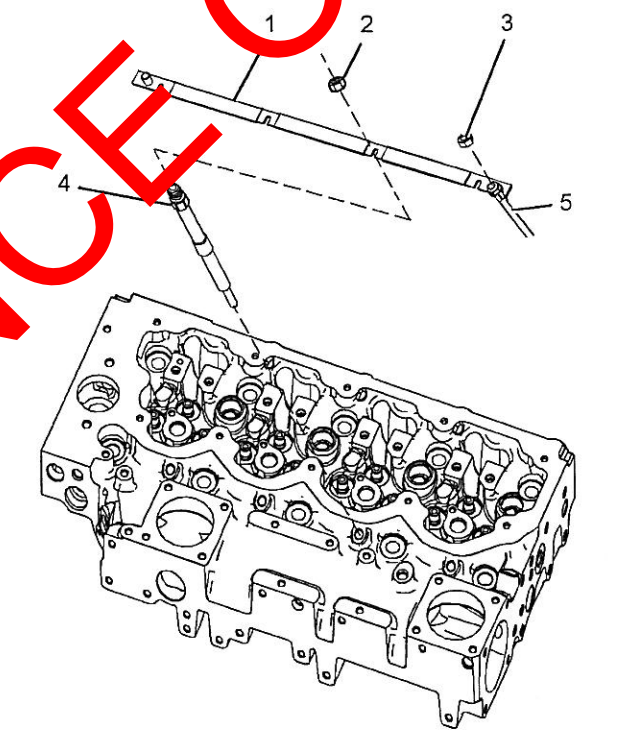



Illustration 348 g01245944
Typical example

2. Remove nut (3) and disconnect wire (5) from bus bar (1).

**Note:** The wire may be connected to either end of the bus bar. Note the position of the wire.

3. Remove nuts (2) that secure bus bar (1) to glow plugs (4).
4. Remove bus bar (1) from glow plugs (4).
5. Remove glow plugs (4) from the cylinder head.

REFERENCE ONLY

## Installation Procedure

Table 89

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610296 | Torque Wrench | 1 |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the threads of the glow plugs are clean and free from damage. Replace any damaged glow plugs.

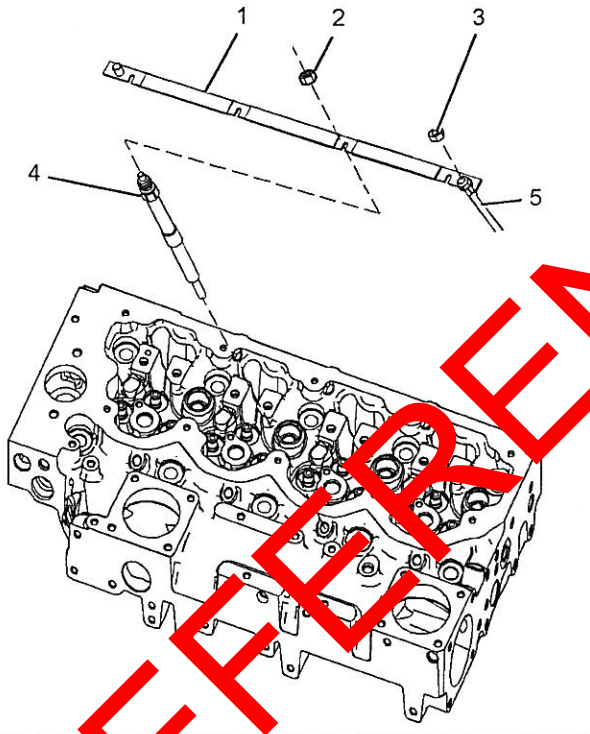



Illustration 349 g01245944
Typical example

2. Install glow plugs (4) into the cylinder head. Tighten the glow plugs to a torque of 15 N·m (132 lb in).

3. Position bus bar (1) onto glow plugs (4). Install nuts (2) onto the glow plugs. Use Tooling (A) in order to tighten the nuts to a torque of 2 N·m (17 lb in).

4. Connect wire (5) to the stud on bus bar (1).

**Note:** The wire may be connected to either end of the bus bar. Ensure that the wire is installed in the correct position.

5. Install nut (3) to the stud on bus bar (1). Tighten the nut to a torque of 6 N·m (53 lb in).

6. Turn the battery disconnect switch to the ON position.

i02[illegible]3675

# V-Belts - Remove and Install (Engines Without an Automatic Belt Tensioner)

## Removal Procedure

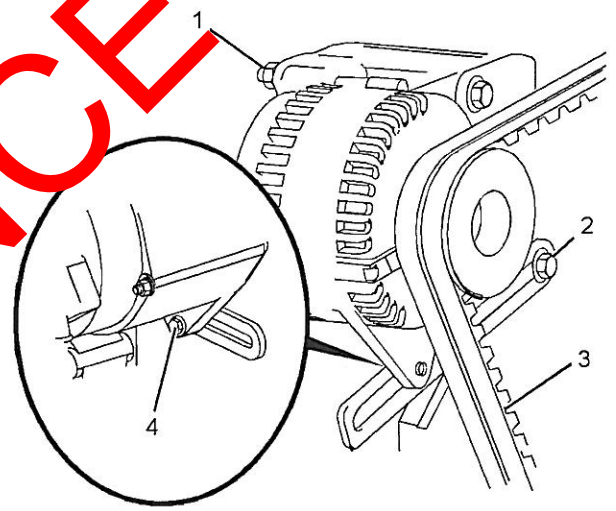



Illustration 350 g01401773
Typical example

1. If the engine is equipped with fan guards, remove the fan guards.

2. Loosen nut (1), bolt (2) and bolt (4). Slide the alternator toward the engine.

3. Remove V-belts (3).

**Note:** Mark the position and direction of rotation if the V-belts will be reused. Never replace single V-belts. Always replace V-belts as a pair.

REFERENCE ONLY

## Installation Procedure

Table 90

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Belt Tension Gauge | 1 |

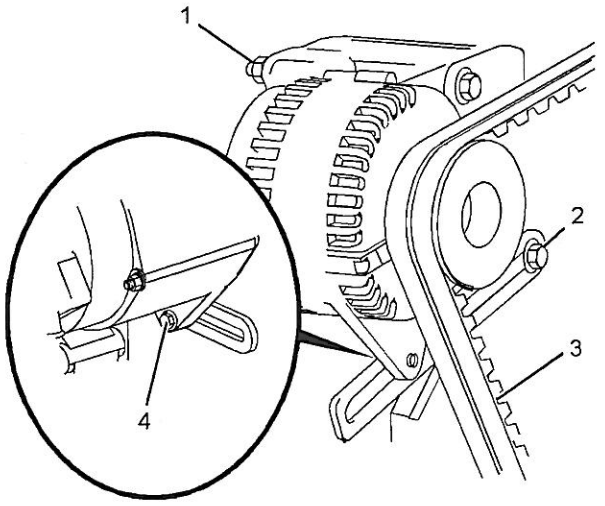



Illustration 351 g01401773
Typical example

1. Install V-belts (3) onto the correct pulleys.

**Note:** Used V-belts should be installed in the original position and direction of rotation.

2. Adjust the tension on the V-belts by moving the alternator away from the engine. Use Tooling (A) in order to achieve the correct belt tension. Refer to Specifications, "Belt Tension Chart" for more information. Tighten bolt (1) to a torque of 22 N·m (16 lb ft).

3. Tighten bolt (2) to a torque of 44 N·m (32 lb ft).

4. Tighten nut (4) to a torque of 22 N·m (16 lb ft).

5. If the engine is equipped with fan guards, install the fan guards.

i02933589

# Alternator Belt - Remove and Install (Engines With an Automatic Belt Tensioner)

## Removal Procedure

Table 91

| Required Tool | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | - | Locking Pin Ø mm x 85 mm | 1 |

1. If the engine is equipped with fan guards, remove the fan guards.

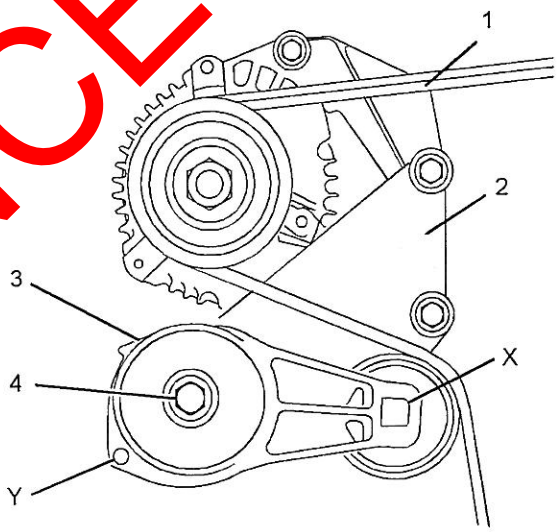



Illustration 352 g01260739
Typical example

2. Install a suitable square drive tool into Hole (X) in tensioner (3). From the front of the engine, turn the tool in a clockwise direction.

3. Insert Tooling (A) into Hole (Y). Release the pressure on the square drive tool.

4. Remove alternator belt (1).

**Note:** Mark the direction of rotation if the belt will be reused.

5. From the front of the engine, turn the square drive tool in a clockwise direction. Release the pressure on Tooling (A). Remove Tooling (A) from Hole (Y).

REFERENCE ONLY

6. Release the pressure on the square drive tool and remove the tool from Hole (X).

7. If necessary, follow Step 7.a and Step 7.b in order to remove tensioner (3) from mounting bracket (2).

   a. Remove bolt (4) that secures tensioner (3) to mounting bracket (2).

   b. Remove tensioner (3) from mounting bracket (2).

## Installation Procedure

Table 92

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| A | - | Locking Pin<br>Ø 8mm by 85 mm | 1 |

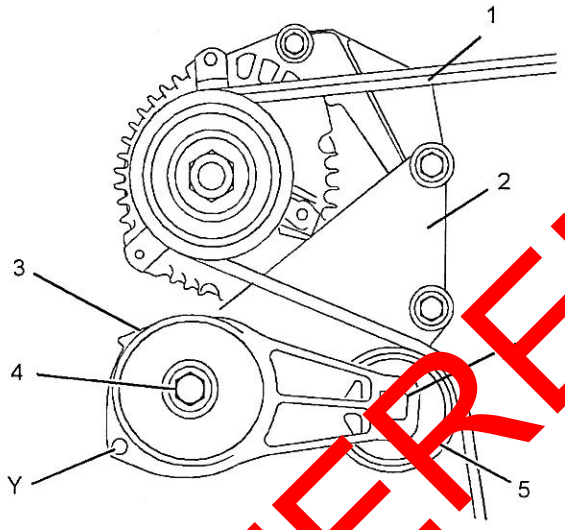



Illustration 353 g01270907

Typical example

1. If the tensioner was previously removed, follow Step 1.a through Step 1.c in order to install the tensioner.

   a. Align the dowel in the back of tensioner (3) with the hole in mounting bracket (2).

   b. Install tensioner (3) to mounting bracket (2).

   c. Install bolt (4). Tighten the bolt to a torque of 44 N·m (32 lb ft).

2. Install a suitable square drive tool into Hole (X) in tensioner (1). From the front of the engine, turn the tool in a clockwise direction.

3. Insert Tooling (A) into Hole (Y). Release the pressure on the square drive tool.

4. Install alternator belt (1). Ensure that the alternator belt is centered on pulley (5). A used alternator belt should be installed in the original direction of rotation.

**Note:** The ribs on the alternator belt must be located into the ribs of all pulleys.

5. From the front of the engine, turn the square drive tool in a clockwise direction. Release the pressure on Tooling (A). Remove Tooling (A) from Hole (Y).

6. Release the pressure on the square drive tool until the alternator belt is tensioned. Remove the tool from Hole (X).

**Note:** The tensioner should be at the nominal position.

7. If the engine is equipped with fan guards, install the fan guards.

i02933630

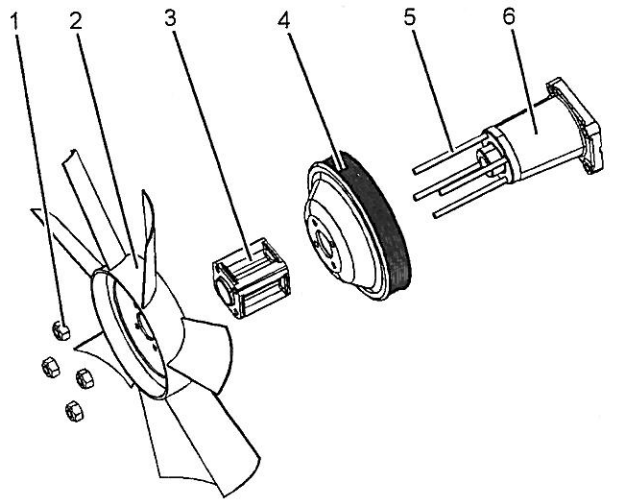
# Fan - Remove and Install

## Removal Procedure

**Start By:**

a. If the engine is equipped with an automatic belt tensioner, remove the Alternator Belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install". If the engine is not equipped with an automatic belt tensioner, remove the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

REFERENCE ONLY




g01270917

Illustration 354
Typical example

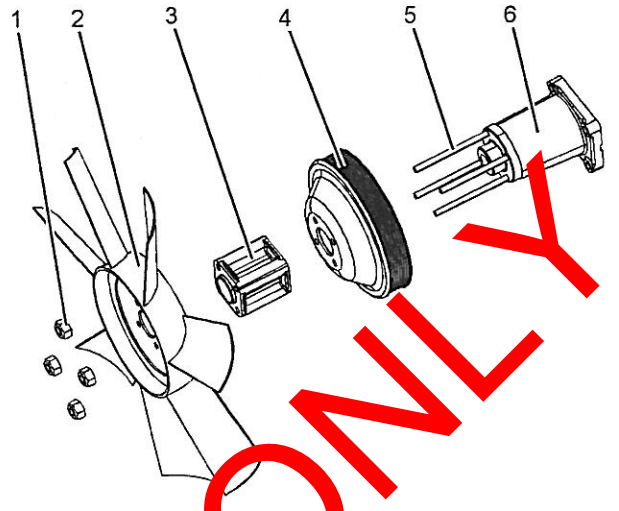
1. Remove locking nuts (1).
2. Remove fan (2).

**Note:** Note the orientation of the fan.

3. Remove fan adapter (3).
4. Remove fan pulley (4).
5. If necessary, remove studs (5) from fan drive (6).

## Installation Procedure

1. Ensure that all the components are free from wear or damage. If necessary, replace any components that are worn or damaged.




g01270917

Illustration 355
Typical example

2. If necessary, install studs (5) to fan drive (6).
3. Install fan pulley (4).
4. Install fan adapter (3).
5. Install fan (2).

**Note:** Ensure that the fan is correctly oriented.

6. Inspect the condition of locking nuts (1). If necessary, replace the locking nuts. Install locking nuts (1) and tighten to a torque of 22 N·m (16 lb ft).

**End By:**

a. If the engine is equipped with an automatic belt tensioner, install the Alternator Belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install". If the engine is not equipped with an automatic belt tensioner, install the V-Belts. Refer to Disassembly and Assembly, "V-Belts - Remove and Install".

i02933631

# Fan Drive - Remove and Install

## Removal Procedure

**Start By:**

a. Remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

REFERENCE ONLY

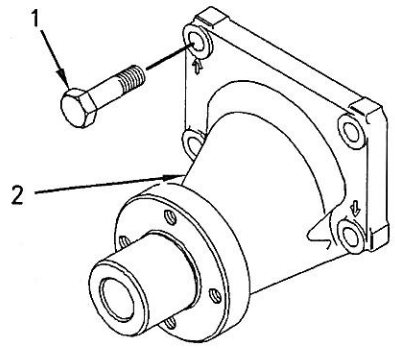



Illustration 356 g00944500
Typical example

1. Remove bolts (1) from fan drive (2).

**Note:** Identify the orientation and the position of the fan drive.

2. Remove fan drive (2).

## Installation Procedure

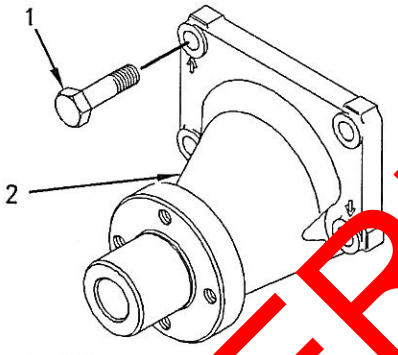



Illustration 357 g00944500
Typical example

1. Check the fan drive for wear or damage. The fan drive is not a serviceable item. If the fan drive is worn or damaged, replace the fan drive.

2. Install fan drive (2).

**Note:** Ensure the correct orientation of the fan drive.

3. Install bolts (1). Tighten the bolts to a torque of 44 N·m (32 lb ft).

**End By:**

a. Install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

i02933616

# Electronic Control Module - Remove and Install

## Removal Procedure

NOTICE
**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

**Note:** Some engines do not have a fuel supply to the electronic control module.

1. Turn the battery disconnect switch to the OFF position.

2. If the electronic control module is equipped with a fuel supply, turn the fuel supply to the OFF position.

REFERENCE ONLY

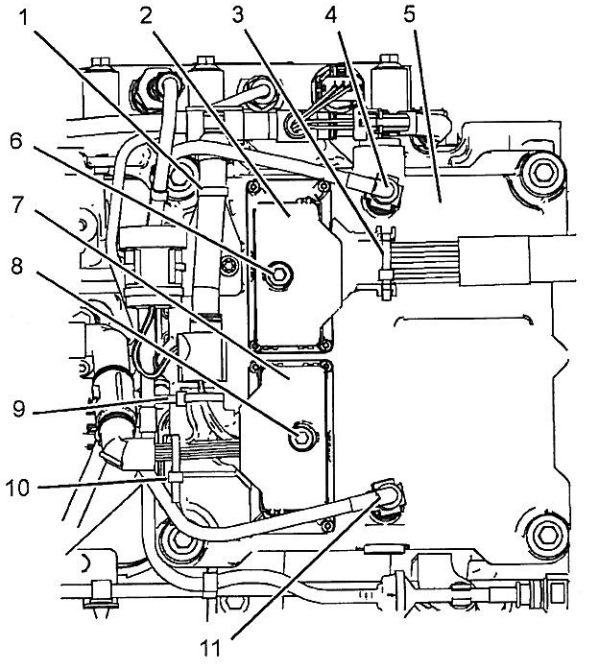



Illustration 358 g01271315
Typical example

3. Cut cable strap (3). Unscrew bolt (6) that secures machine wiring harness (2) to electronic control module (5). Disconnect the machine wiring harness from the electronic control module.

4. Cut cable straps (1), (9) and (10). Unscrew bolt (8) that secures engine harness (7) to electronic control module (5). Disconnect the engine harness from the electronic control module.

5. If the electronic control module is equipped with a fuel supply, disconnect plastic tube assembly (4) and plastic tube assembly (11).

**Note:** If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are plugged.

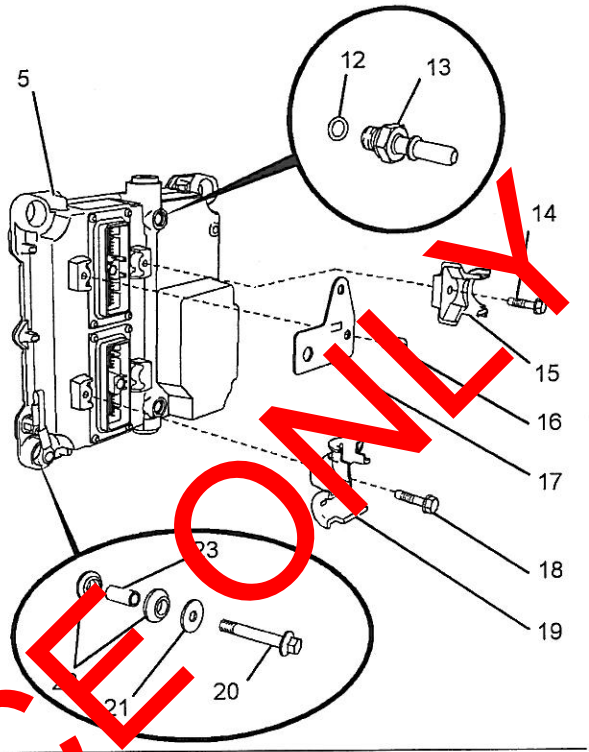



Illustration 359 g01807973
Typical example

6. Remove bolts (20) and remove the assembly of the electronic control module. Note the position of any brackets that are secured by bolts (20). Note the orientation of the electronic control module.

7. Remove bolts (20) and remove washers (18) from electronic control module (5). Note the position of the ground strap for the electronic control module.

8. If necessary, follow Step 8.a through Step 8.e in order to disassemble the electronic control module.

   a. Remove isolation mounts (22) and spacers (23).

   b. Remove connectors (13). Remove O-ring seals (12) from the connectors.

   c. Remove bolt (18) and remove bracket (19) for the engine wiring harness. Note the orientation of the bracket.

   d. Loosen bolt (16) and remove bracket (17) from the engine wiring harness. Note the orientation of the bracket.

   e. Remove bolt (14) and remove bracket (15) for the machine wiring harness. Note the orientation of the bracket.

REFERENCE ONLY

## Installation Procedure

Table 93

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610296 | Torque Wrench | 1 |

1. If a replacement electronic control module is installed, the module must be programmed with the correct information. Refer to Troubleshooting, "Replacing the ECM" and refer to Troubleshooting, "Flash Programming" for the correct procedure.

2. Ensure that the electronic control module is clean and free from damage. If necessary, replace the electronic control module.

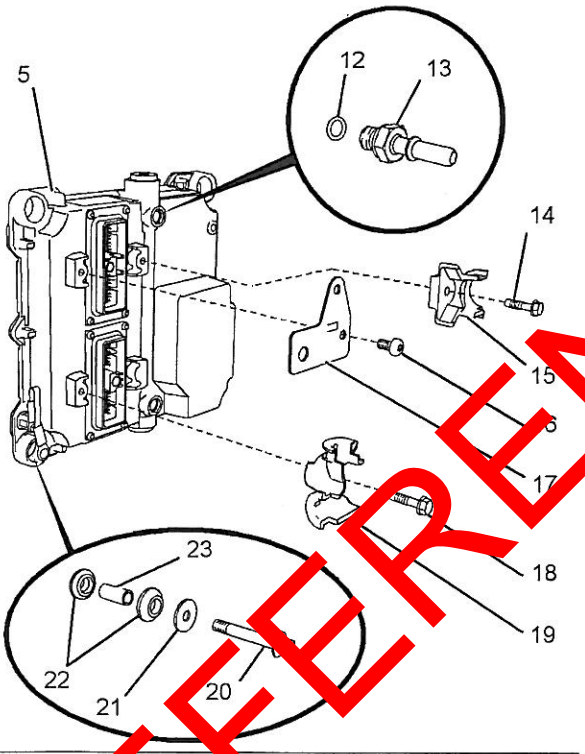



Illustration 36 g01807973
Typical exam

3. If nec ssary, ollow Step 3.a through Step 3.e in orde to assemble the electronic control module.

   a. Install new O-ring seals (12) to connectors (13). Install connectors (13) to electronic control module (5). Tighten the connectors to a torque of 18 N·m (13 lb ft).

   b. Position bracket (17) on electronic control module (5). Ensure that the bracket is correctly oriented. Install torx screw (16). Tighten the torx screw to a torque of 7 N·m (62 lb in).

   c. Position bracket (19) on electronic control module (5). Ensure that the bracket is correctly oriented. Install bolt (18). Tighten the bolt to a torque of 9 N·m (80 lb in).

   d. Position bracket (15) for the machine wiring harness on electronic control module (5). Ensure that the bracket is correctly oriented and install bolt (14). Tighten the bolt to a torque of 9 N·m (80 lb in).

   e. Install isolation mounts (22) and spacers (23) to electronic control module (5).

4. Install washers (21) and bolts (20) to electronic control module (5).

**Note:** Ensure that the ground strap for the electronic control module is clamped between the washer and the appropriate bolt.

5. Install the assembly of the electronic control module to the mounting bracket . Ensure that all brackets that are secured by bolts (20) are installed in the correct position. Tighten bolts (20) to a torque of 22 N·m (16 lb ft).

**Note:** Ensure that the electronic control module is correctly oriented. Ensure that the ground strap is not pinched as the bolt is tightened.

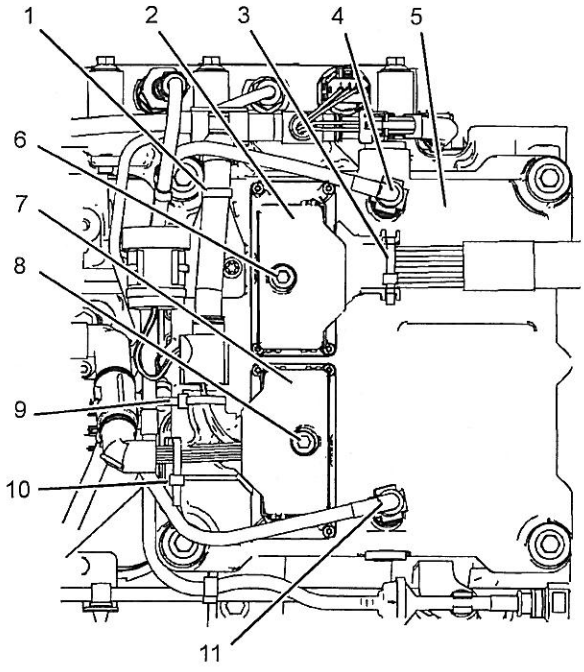



Illustration 361 g01271315
Typical example

REFERENCE ONLY

6. If the electronic control module is equipped with a fuel supply, connect plastic tube assembly (4) and tube assembly (11) to electronic control module (5).

**Note:** If the tube assemblies have quick fit connections, ensure that the connections are clean before the tube assemblies are connected.

7. Connect engine wiring harness (7) to electronic control module (5). Use Tooling (A) to tighten bolt (8) to a torque of 5 N·m (44 lb in). If the engine is equipped with a diagnostic connection, install the diagnostic connection to the support clip.

**Note:** Care must be taken in order to avoid damage to the connector pins during installation of the harness.

8. Position the assembly of the engine wiring harness onto bracket (15), bracket (17) and bracket (19). Use new cable straps (1), (9) and (10) in order to secure the harness assembly to the brackets.

9. Connect machine wiring harness (2) to electronic control module (5). Use Tooling (A) to tighten bolt (6) to a torque of 5 N·m (44 lb in).

**Note:** Care must be taken in order to avoid damage to the connector pins during installation of the harness.

10. Use a new cable strap (3) in order to secure the machine wiring harness (2).

11. If the electronic control module is equipped with a fuel supply, turn the fuel supply to ON position.

12. Turn the battery disconnect switch to the ON position.

13. If the electronic control module is equipped with a fuel supply, remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

i02933614

# ECM Mounting Bracket - Remove and Install

## Removal Procedure

**Start By:**

a. Remove the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

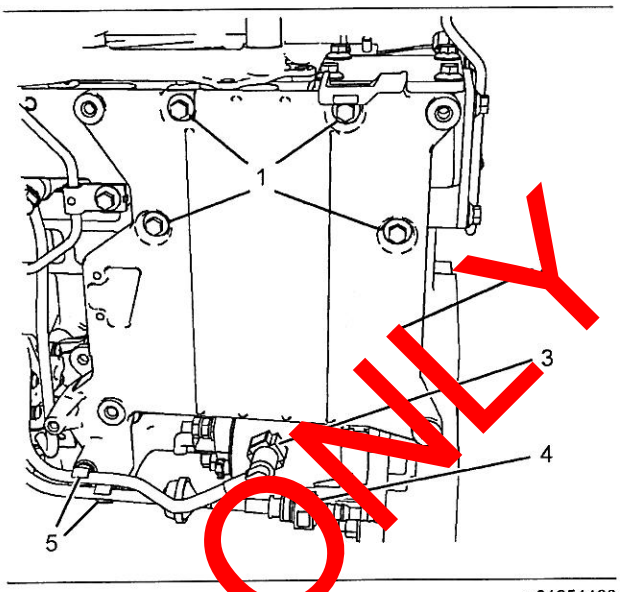



Illustration 2
Typical example
g01254468

1. Remove plastic tube assembly (3) and assembly (4) from clips (5).

2. Cut the cable strap and position the engine wiring harness away from mounting bracket (2).

3. Remove bolts (1) and remove mounting bracket (2) from the cylinder head.

4. If necessary, remove clips (5) from mounting bracket (2).

## Installation Procedure

1. Ensure that the mounting bracket for the electronic control module is clean and free from damage. If necessary, replace the mounting bracket.

REFERENCE ONLY

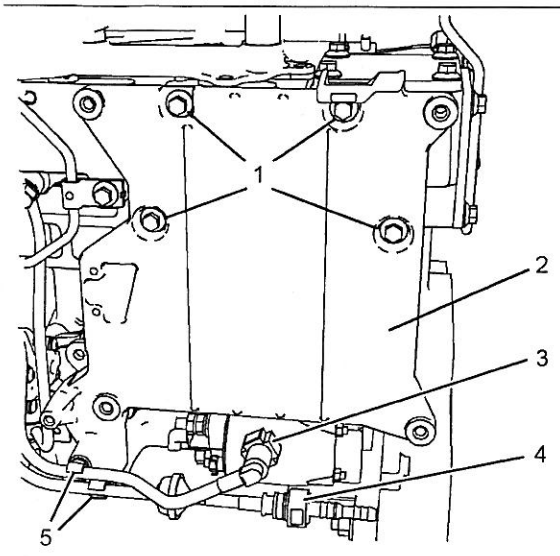



Illustration 363 g01254468
Typical example

2. If necessary, install clips (5) to mounting bracket (2).

3. Position mounting bracket (2) against the cylinder head. Install bolts (1). Tighten the bolts to a torque of 22 N·m (16 lb ft).

4. Position the engine wiring harness against mounting bracket (2). Secure the engine wiring harness with a new cable strap.

5. Install plastic tube assembly (3) and tube assembly (4) to clips (5).

**End By:**

a. Install the electronic control module. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".

i02933588

# Alternator - Remove (Engines Without an Automatic Belt Tensioner)

## Removal Procedure

**Start By:**

a. Remove the V-belts. Refer to Disassembly and Assembly, "V-belts - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the battery disconnect switch to the OFF position.

2. Make temporary identification marks on the connections of the harness assembly.

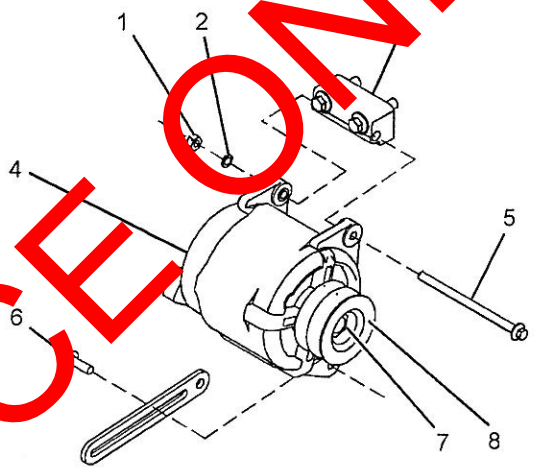



Illustration 364 g01255718
Typical Example

3. Disconnect the harness assembly from alternator (4).

4. Remove bolt (6) from alternator (4).

5. Remove nut (1) and washer (2). Remove bolt (5) from alternator (4). Remove alternator (4) from alternator bracket (3).

6. If necessary, remove pulley (8) from alternator (4). Follow Step 6.a and Step 6.b for the method in order to remove the pulley from the alternator.

**Note:** This method may not be suitable for some configurations of pulley.

a. Hold the shaft of alternator (4) with an allen wrench. Use a cranked ring spanner (box wrench) in order to loosen nut (7).

b. Remove nut (7) and pulley (8) from alternator (4).

REFERENCE ONLY

i02933586

# Alternator - Remove (Engines With an Automatic Belt Tensioner)

## Removal Procedure

**Start By:**

**a.** Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**1.** Turn the battery disconnect switch to the OFF position.

**2.** Make temporary identification marks on the connections of the harness assembly.

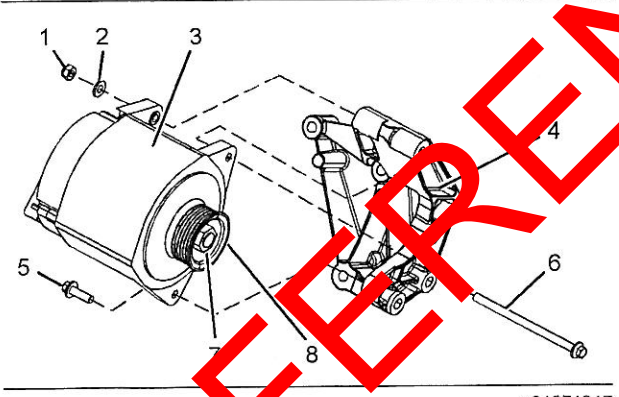



Illustration 365 g01271317
Typical example

**3.** Disconnect the harness assembly from alternator (3).

**4.** Remove bolt (5) from alternator (3).

**5.** Remove nut (1) and washer (2). Remove bolt (6) from alternator (3). Remove the alternator from alternator bracket (4).

**6.** If necessary, follow Step 6.a and Step 6.b in order to remove pulley (8) from alternator (1).

**a.** Hold the shaft of alternator (3) with an allen wrench. Use a cranked ring spanner (box wrench) in order to loosen nut (7).

**b.** Remove nut (7) and pulley (8) from alternator (3).

i02933587

# Alternator - Install (Engines Without an Automatic Belt Tensioner)

## Installation Procedure

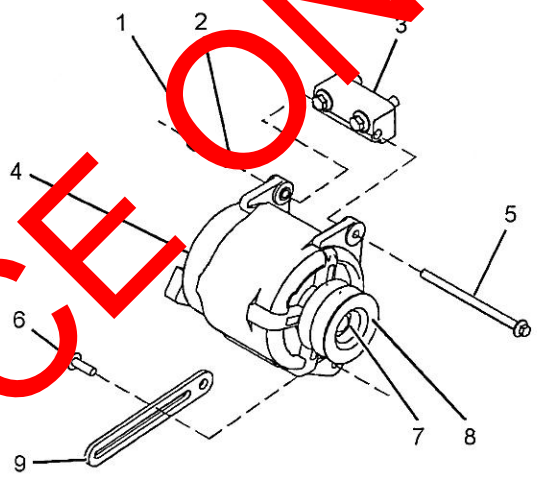



Illustration 366 g01263045
Typical example

**1.** If necessary, install the pulley to the alternator. Follow Step 1.a and Step 1.b in order to install the pulley to the alternator.

**Note:** This method may not be suitable for some configurations of pulley.

**a.** Install pulley (8) and nut (7) to the shaft of alternator (4).

**b.** Hold the shaft of the alternator with an allen wrench. Use a cranked ring spanner (box wrench) in order to tighten nut (7). Tighten the nut to a torque of 80 N·m (59 lb ft).

**2.** Install alternator (4) to bracket (3) and install bolt (5) to alternator (4).

**3.** Install washer (2) and nut (1) to bolt (5) finger tight.

**4.** Install bolt (6) through adjusting link (9) to alternator (4) finger tight.

REFERENCE ONLY

5. Install the V-belts. Refer to Disassembly and assembly, "V-belts - Remove and Install" for the correct procedure.

6. Tighten nut (1) and bolt (6) to a torque of 22 N·m (16 lb ft).

7. Connect the wiring harness assembly to alternator (4).

8. Turn the battery disconnect switch to the ON position.

i02933585

# Alternator - Install (Engines With an Automatic Belt Tensioner)

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

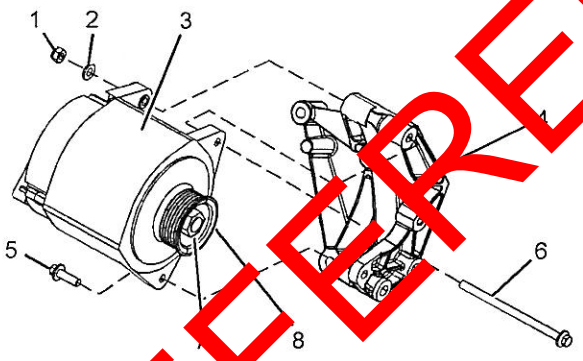



Illustration 36 g01271317
Typical exam e

1. If necessary, install pulley (8) and nut (7) to alternator (3). Hold the shaft of the alternator with an Allen wrench. Use a cranked ring spanner (box wrench) in order to tighten nut (7).

**Note:** Different types of alternator have different sizes of nut. Ensure that the correct torque value is used for the nut.

Tighten M16 and M17 nuts to a torque of 80 N·m (59 lb ft). Tighten 5/8 inch - 18 UNF nuts to a torque of 102 N·m (75 lb ft).

2. Position alternator (3) on alternator mounting bracket (4).

3. Install bolt (6) to alternator (3). Install washer (2) and nut (1) to bolt (6).

4. Install bolt (5) to alternator (3).

5. Tighten nut (1) and bolt (5) to a torque of 22 N·m (16 lb ft).

6. Connect the wiring harness assembly to alternator (3).

7. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

8. Turn the battery disconnect switch to the ON position.

i02933615

# Electric Starting Motor - Remove and Install

## Removal Procedure

**⚠ WARNING**

**Accidental engine starting can cause injury or death to personnel working on the equipment.**

**To avoid accidental engine starting, disconnect the battery cable from the negative (−) battery terminal. Completely tape all metal surfaces of the disconnected battery cable end in order to prevent contact with other metal surfaces which could activate the engine electrical system.**

**Place a Do Not Operate tag at the Start/Stop switch location to inform personnel that the equipment is being worked on.**

1. Turn the battery disconnect switch to the OFF position.

2. If necessary, remove the hose for the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

3. Make temporary identification marks on the harness assemblies that are connected to the electric starting motor and to the solenoid.

REFERENCE ONLY

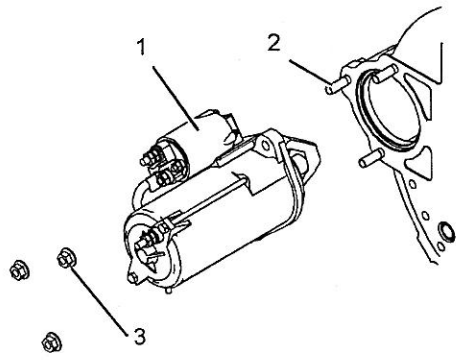



Illustration 368 g01261155
Typical example

4. Disconnect the harness assemblies from the electric starting motor and from the solenoid.

5. Remove nuts (3) from electric starting motor (1).

**Note:** Support the weight of the electric starting motor as the nuts are removed.

6. Remove electric starting motor (1).

7. If necessary, remove studs (2).

## Installation Procedure

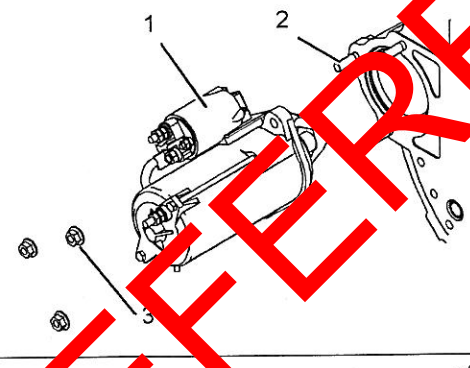



Illustration 369 g01261155
Typical example

1. If necessary, install studs (2).

2. Align electric starting motor (1) to studs (2). Install the electric starting motor.

3. Install nuts (3).

   Tighten M10 nuts to a torque of 44 N·m (32 lb ft).

   Tighten M12 nuts to a torque of 78 N·m (57 lb ft).

4. Connect the harness assemblies to the electric starting motor and the solenoid.

5. If necessary, install the hose for the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".

6. Turn the battery disconnect switch to the ON position.

2933584

# Air Compressor - Remove and Install

## Removal Procedure

Table 94

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A(1) | 21825576 | Crankshaft Turning Tool | 1 |
| A(2) | 27610291 | Barring Device Housing | 1 |
| | 27610289 | Gear | 1 |
| B | 27610211 | Crankshaft Timing Pin | 1 |
| C | - | Puller (Three Leg) | 1 |

(1) This Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Put identification marks on all hoses, on all hose assemblies and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

REFERENCE ONLY

**⚠ WARNING**

**Do not disconnect the air lines until the air pressure in the system is at zero. If hose is disconnected under pressure it can cause personal injury.**

1. Release the pressure from the air system.
2. Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.
3. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".
4. If the engine is equipped with a hydraulic pump on the rear of the air compressor, remove the hydraulic pump.
5. Use Tooling (A) in order to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Centre Position for No.1 Piston".

**Note:** The air compressor must be timed with the engine in order to minimize engine vibration.

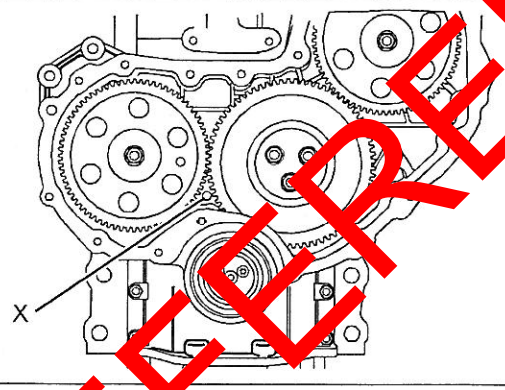



Illustration 370 g01272266
Typical example

6. Install Tooling (B) through Hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft.

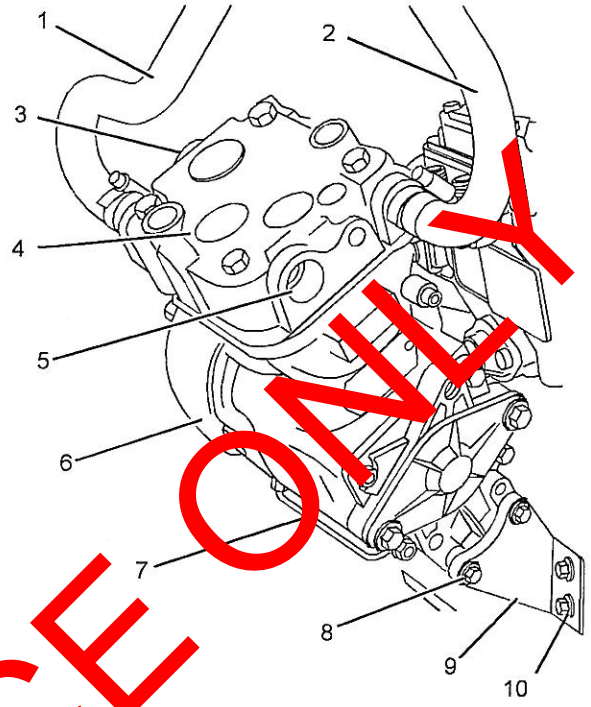



Illustration 371 g01250794
Typical example

7. Disconnect coolant hoses (1) and (2) from air compressor (4).
8. Disconnect the air lines from ports (3) and (5).
9. Remove tube assembly (7) from air compressor (4) and from the cylinder block.
10. Remove bolts (8) and (10) from support bracket (9) and remove the support bracket.

REFERENCE ONLY

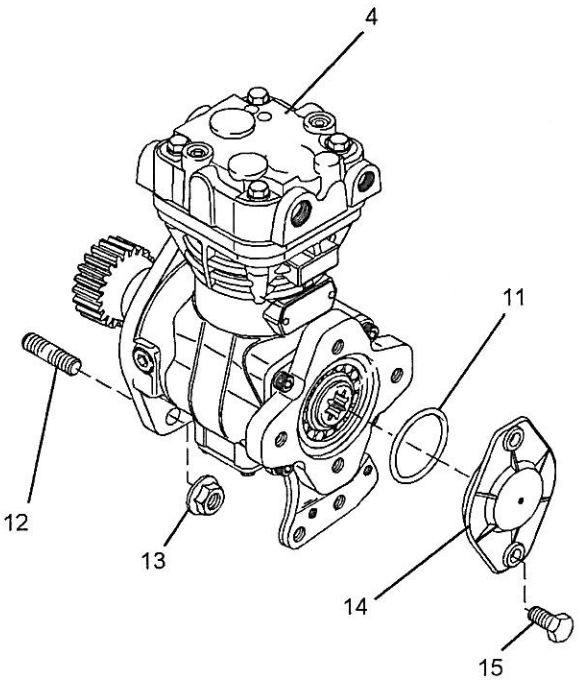



Illustration 372 g01250816
Typical example

**11.** Support air compressor (4). Remove nuts (13) and remove the air compressor from front housing (6).

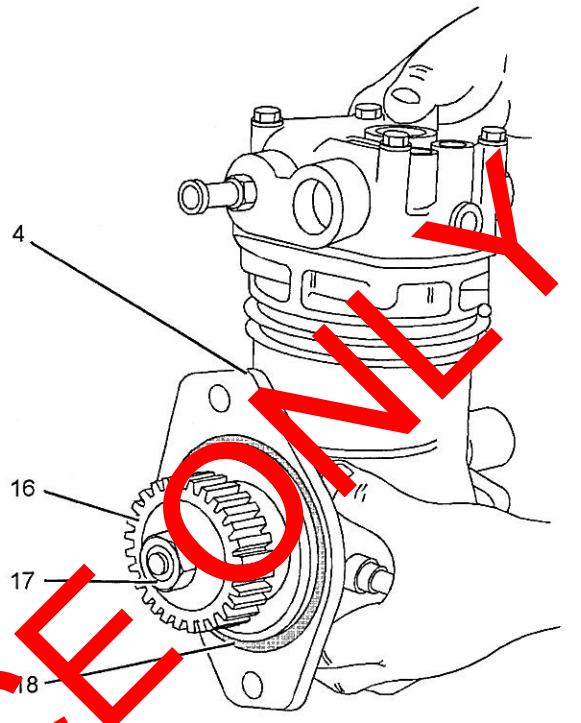



Illustration 373 g01250889
Typical example

**12.** Remove O-ring seal (18) from air compressor (4).

**13.** If necessary, remove bolts (15) and remove plate (14). Remove O-ring seal (11) from plate (14). Refer to Illustration 372.

**14.** If necessary, remove nut (17) and remove the spring washer. Use Tooling (C) in order to remove gear (16) from the crankshaft of the air compressor.

## Installation Procedure

Table 95

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| B | 27610211 | Crankshaft Timing Pin | 1 |
| D | 21826051 | POWERPART High Strength Retainer | - |
| E | 21820221 | POWERPART Rubber Grease | - |

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

REFERENCE ONLY

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

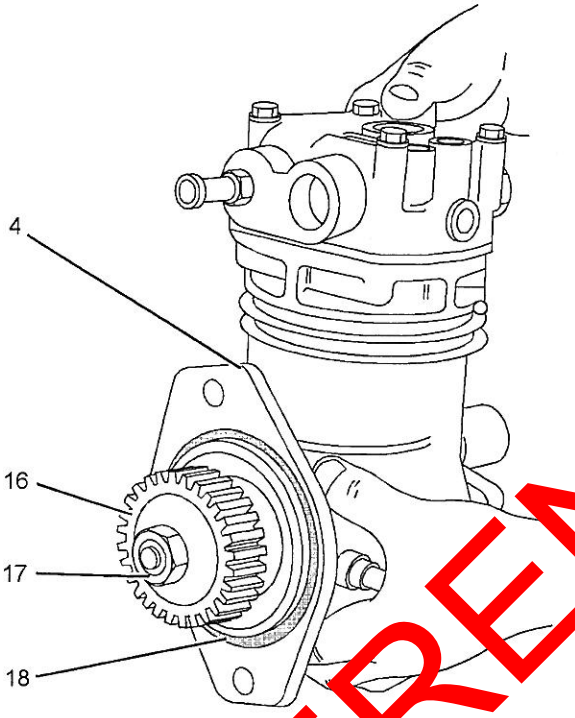



Illustration 374 g01250889
Typical example

1. If necessary, follow Step 1.a through Step 1.b in order to install the gear to the air compressor.
   a. Ensure that the shaft of air compressor (4) is clean and dry. Ensure that gear (16) is clean and free from damage.
   b. Install gear (16) and a new spring washer to the shaft of the air compressor.
   c. Apply Tooling (D) to the threads of the shaft. Install nut (17) to the shaft of air compressor (4). Tighten the nut to a torque of 120 N·m (89 lb ft).
2. Install the O-ring seal to air compressor (4). Use Tooling (E) in order to lubricate the O-ring seal.
3. Ensure that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

**Note:** The air compressor must be timed with the engine in order to minimize engine vibration.

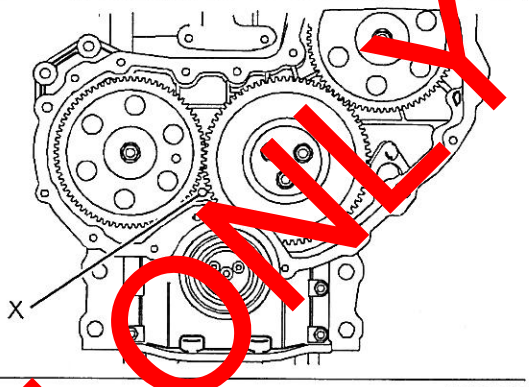



Illustration 375 g01272266
Typical example

4. Ensure that Tooling (B) is installed in Hole (X) in the front housing. Use Tooling (B) in order to lock the crankshaft in the correct position.

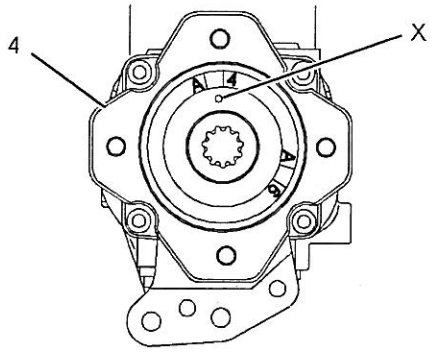



Illustration 376 g01250968
Typical air compressor with a SAE drive

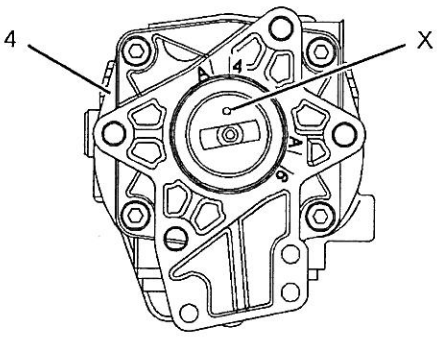



Illustration 377 g01251223
Typical air compressor with a DIN drive

REFERENCE ONLY

5. Rotate the crankshaft of the air compressor until timing Mark (X) is aligned with timing mark A4 on the rear face of air compressor (4). Refer to Illustration 376 for air compressors with a SAE drive. Refer to Illustration 377 for air compressors with a DIN drive.

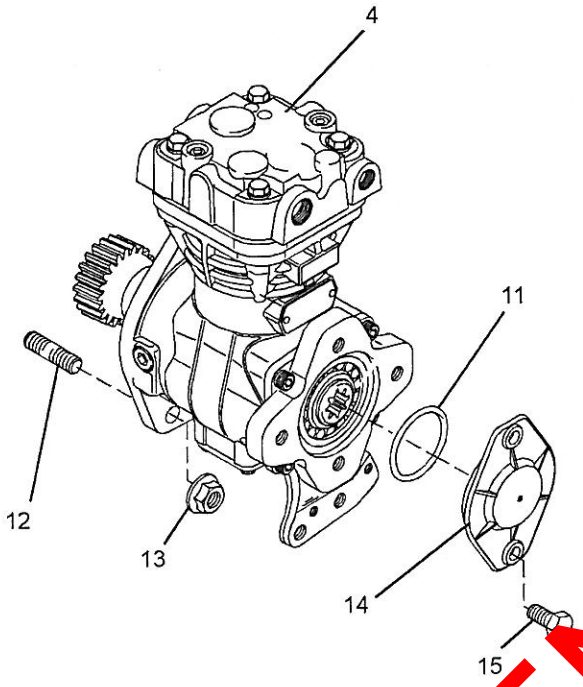



Illustration 378 g0[illegible]50816
Typical example

6. Align air compressor (4) with studs (12). Install the air compressor to the front housing. If necessary, rotate the crankshaft of the air compressor in a clockwise direction in order to align the gears.

**Note:** Ensure that timing Mark (X) is aligned with timing mark A4. Refer to Illustration 376 for air compressors with a SAE drive. Refer to Illustration 377 for air compressors with a DIN drive.

7. Install nuts (13). Tighten the nuts to a torque of [illegible] N·m (5[illegible] lb ft).

8. If necessary, follow Step 8.a through Step 8.c in order to install cover (14).

   a. Install a new O-ring seal (11) to cover (14). Use Tooling (E) in order to lubricate the O-ring seal.

   b. Install cover (14) to air compressor (4).

   c. Install bolts (15). Tighten the bolts to a torque of 13 N·m (9.5 lb ft).

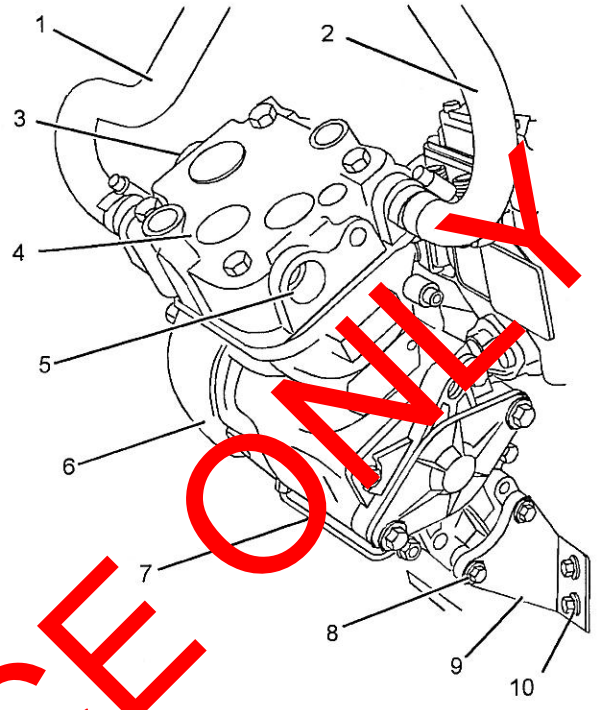



Illustration 379 g01250794
Typical example

9. Position support bracket (9) onto air compressor (4). Install bolts (8) finger tight.

10. Install bolts (10) finger tight.

11. Tighten bolts (8) to a torque of 22 N·m (16 lb ft). Tighten bolts (10) to a torque 22 N·m (16 lb ft).

**Note:** Ensure that the air compressor is not stressed as the bolts are tightened.

12. Install tube assembly (7) to air compressor (4) and to the cylinder block. Tighten the nuts to a torque of 9 N·m (80 lb in).

13. Remove Tooling (B) from Hole (X) in the front housing.

14. Install the front cover. Refer to Disassembly and Assembly, “Front Cover - Remove and Install”.

15. If the engine is equipped with a hydraulic pump on the rear of the air compressor, install the hydraulic pump.

16. Connect the air lines to ports (3) and (5) in the air compressor.

17. Connect coolant hoses (1) and (2) to air compressor (4).

REFERENCE ONLY

18. Fill the cooling system with coolant to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

i02933676

# Vacuum Pump - Remove and Install

## Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Put identification marks on all hoses, on all hose assemblies and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. This helps to prevent fluid loss and this helps to keep contaminants from entering the system.

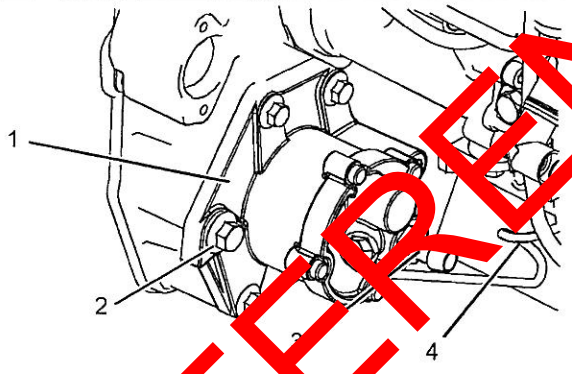



Illustration 380 g01254510
Typical example

1. Remove tube assembly (4) from vacuum pump (1) and from the cylinder block.
2. Disconnect the vacuum line from connector (3) on the vacuum pump.
3. Remove bolts (2). Remove vacuum pump (1) from the front housing.
4. Remove the gasket.

## Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

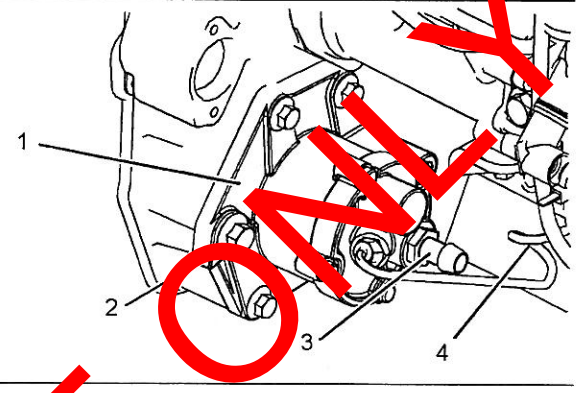



Illustration 381 g01254510
Typical example

1. Ensure that the vacuum pump is clean and free from damage. If necessary, replace the vacuum pump.
2. Clean the surfaces on the front housing.
3. Install a new gasket to vacuum pump (1).
4. Install vacuum pump (1) to the front housing. If necessary, rotate the shaft of the vacuum pump in order to align the gears.
5. Install bolts (2).

   Tighten M8 bolts to a torque of 22 N·m (16 lb ft).

   Tighten M10 bolts to a torque of 44 N·m (32 lb ft).
6. Connect the vacuum line to connector (3).
7. Install tube assembly (4) to vacuum pump (1) and to the cylinder block. Tighten the nuts on the tube assembly to a torque of 9 N·m (80 lb in).

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January 2009

# Troubleshooting

## 1104D and 1106D Industrial Engines

NH (Engine)
NJ (Engine)
PJ (Engine)

REFERENCE ONLY

# Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

**Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.**

**Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.**

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by "NOTICE" labels on the product and in this publication.

**Perkins cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Perkins is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.**

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Perkins dealers or Perkins distributors have the most current information available.

**⚠ WARNING**

**When replacement parts are required for this product Perkins recommends using Perkins replacement parts.**

**Failure to heed this warning can lead to premature failures, product damage, personal injury or death.**

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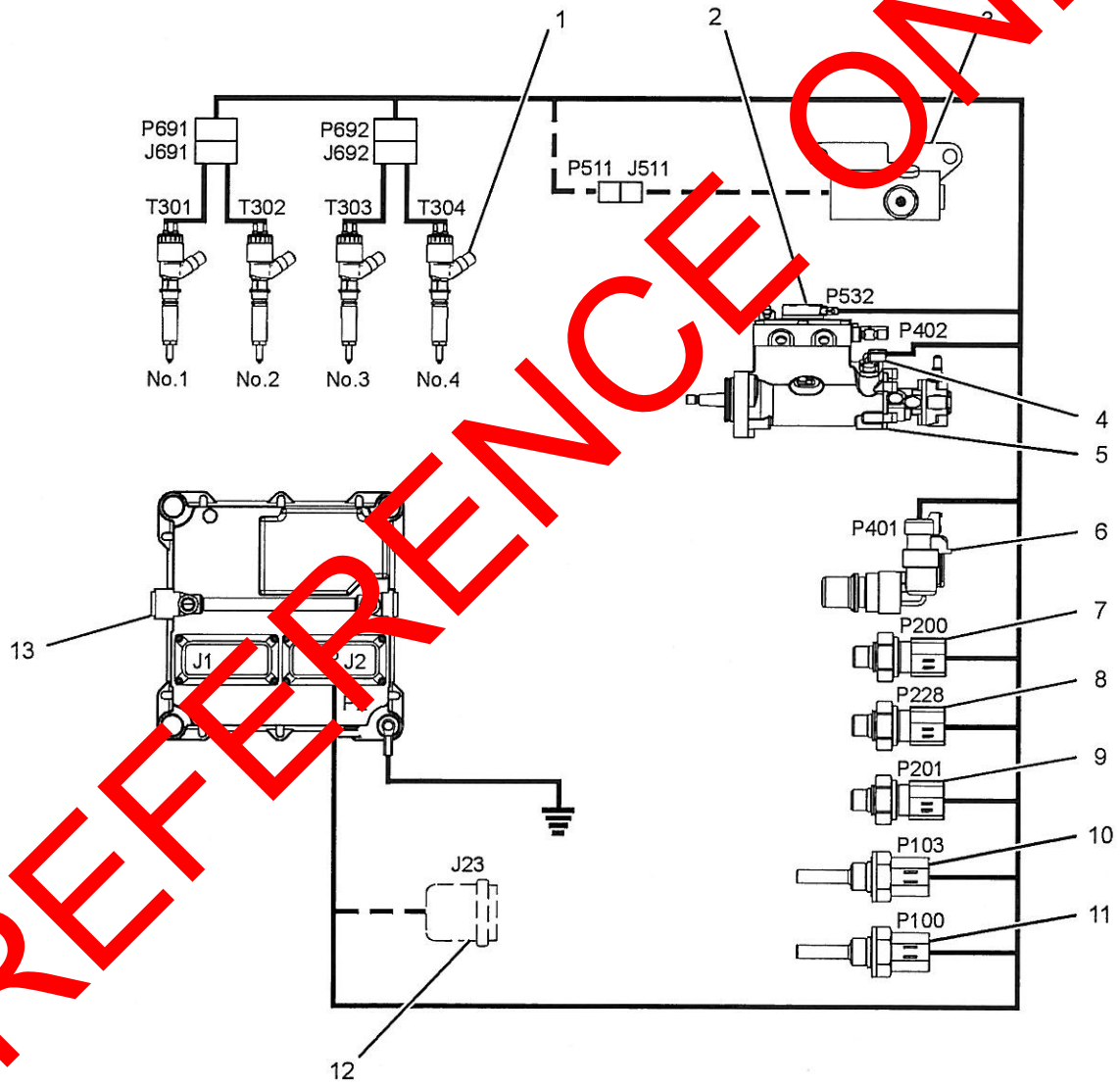
# Troubleshooting Section

# Electronic Troubleshooting

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## System Overview

### System Operation

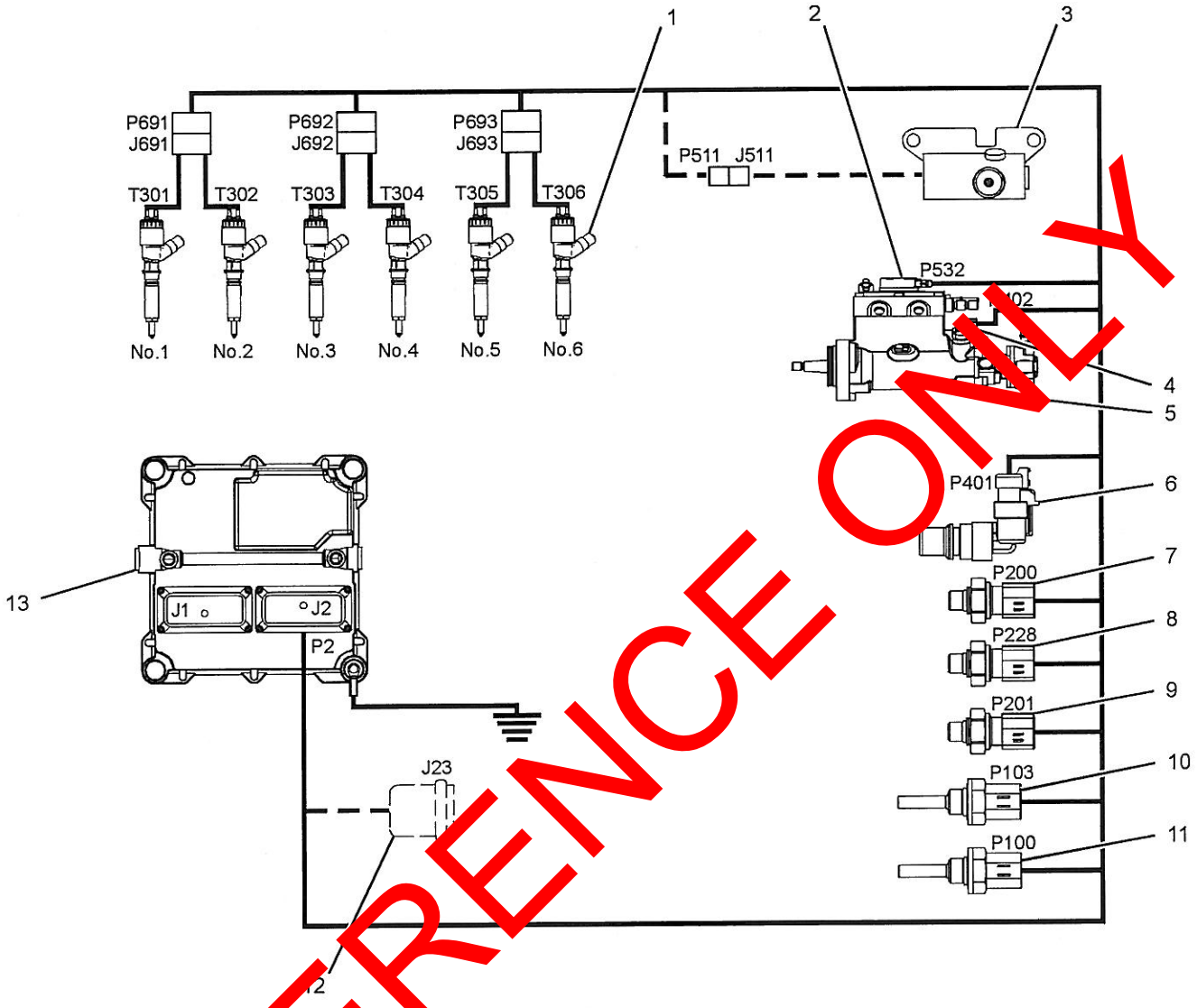



REFERENCE ONLY

Illustration 1 g01777753

1104D engine

(1) Electronic Unit Injector
(2) Solenoid for the Fuel Rail Pump
(3) Wastegate Regulator (if equipped)
(4) Secondary Speed/Timing Sensor
(5) Fuel Rail Pump
(6) Primary Speed/Timing Sensor
(7) Intake Manifold Pressure Sensor
(8) Fuel Rail Pressure Sensor
(9) Engine Oil Pressure Sensor
(10) Intake Manifold Air Temperature Sensor
(11) Coolant Temperature Sensor
(12) Diagnostic Connector (if equipped)
(13) Electronic Control Module (ECM)




g01777773

Illustration 2

1106D engine

(1) Electronic Unit Injecto
(2) Solenoid for the Fuel Ra Pump
(3) Wastegate Regulat (if eq ped)
(4) Secondary Spee Timing Sensor
(5) Fuel Rail Pu
(6) Primary Speed/Timing Sensor
(7) Intake Manifold Pressure Sensor
(8) Fuel Rail Pressure Sensor
(9) Engine Oil Pressure Sensor
(10) Intake Manifold Air Temperature Sensor
(11) Coolant Temperature Sensor
(12) Diagnostic Connector (if equipped)
(13) Electronic Control Module (ECM)

REFERENCE ONLY

The engine is designed for electronic control. The engine has an Electronic Control Module (ECM), a fuel rail pump and electronic unit injectors. All of these items are electronically controlled. There are also a number of engine sensors. Turbocharged engines can be equipped with an electronically controlled wastegate for the turbocharger. The ECM controls the engine operating parameters through the software within the ECM and the inputs from the various sensors. The software contains parameters that control the engine operation. The parameters include all of the operating maps and customer selected parameters.

The electronic system consists of the ECM, the engine sensors and inputs from the parent machine. The ECM is the computer. The flash file is the software for the computer. The flash file defines the following characteristics of the engine:

- Engine power
- Torque curves
- Engine speed (rpm)
- Engine Noise

- Smoke and Emissions

The ECM determines the injection timing, the amount of fuel that is delivered to the cylinders and the intake manifold pressure if an electronically controlled wastegate is installed on the turbocharger. These decisions are based on the actual conditions and the desired conditions at any given time.

### Engine Speed Governor

The governor has software that compares the desired engine speed to the actual engine speed. The actual engine speed is determined through the primary speed/timing sensor and the secondary speed/timing sensor. If the desired engine speed is greater than the actual engine speed, the governor injects more fuel in order to increase engine speed. If the actual engine speed is greater than the desired engine speed, the governor limits the amount of fuel that is supplied to the electronic unit injectors in order to reduce engine speed.

### Timing Considerations

Fuel injection timing is determined by the ECM after considering input from the following components:

- Engine coolant temperature sensor
- The sensor for the intake manifold air temperature
- The sensor for the intake manifold pressure
- Speed/timing sensors
- Throttle position sensor

At engine start-up, the ECM determines the top center position of the number 1 cylinder from the speed/timing sensors. The ECM determines when fuel injection should occur relative to the top center position. The ECM optimizes engine performance by control of each of the electronic unit injectors so that the required amount of fuel is injected at the precise point of the engine's cycle. The electronic unit injectors are supplied with high pressure fuel from the fuel rail. The ECM also provides the signal to the solenoid in the fuel rail pump. The solenoid in the fuel rail pump controls a valve in the fuel rail pump. This valve controls the pressure in the fuel rail. Fuel that is not required for the engine is diverted away from the fuel rail pump back to the fuel tank.

The ECM adjusts injection timing and fuel pressure for the best engine performance, the best fuel economy and the best control of exhaust emissions.

### Fuel Injection

The flash file inside the ECM sets certain limits on the amount of fuel that can be injected.

The Fuel Ratio Control Limit is a limit that is based on intake manifold pressure and engine rpm. The FRC Limit is used to control the air/fuel ratio in order to control the engine's exhaust emissions. When the ECM senses a higher intake manifold pressure, the ECM increases the FRC Limit. A higher intake manifold pressure indicates that there is more air in the cylinder. When the ECM increases the FRC Limit, the ECM allows more fuel into the cylinder.

The Rated Fuel Limit is a limit that is based on the power rating of the engine and on the engine rpm. The Rated Fuel Limit enables the engine power and torque outputs to conform to the power and torque curves of a specific engine model.

These limits are in the flash file and these limits cannot be changed by the operator.

## Diagnostic Codes

When the ECM detects an electronic system fault, the ECM generates a diagnostic code. Also, the ECM logs the diagnostic code in order to indicate the time of the occurrence of the fault. The ECM also logs the number of occurrences of the fault. Diagnostic codes are provided in order to indicate that the ECM has detected an electrical fault or an electronic fault with the engine control system. In some cases, the engine performance can be affected when the condition that is causing the code exists.

If the operator indicates that a performance problem occurs, the diagnostic code may indicate the cause of the fault. Use the electronic service tool to access the diagnostic codes. The fault should then be corrected.

### Event Codes

Event Codes are used to indicate that the ECM has detected an abnormal engine operating condition. The ECM will log the occurrence of the event code. This does not indicate an electrical malfunction or an electronic malfunction. For example, if the temperature of the coolant in the engine is higher than the permitted limit, then the ECM will detect the condition. The ECM will then log an event code for the condition.

## Programmable Parameters

Certain parameters that affect the engine operation may be changed with electronic service tools. The parameters are stored in the ECM and some of the parameters are protected from unauthorized changes by passwords. These parameters are System Configuration Parameters.

REFERENCE ONLY

System Configuration Parameters are set at the factory. System Configuration Parameters affect the emissions or the power ratings within the engine. Factory passwords must be obtained and used in order to changesome of the System Configuration Parameters. Examples of these parameters are FLS and FTS.

## Passwords

System Configuration Parameters are protected by factory passwords. Factory passwords are calculated on a computer system that is available only to Perkins distributors. Since factory passwords contain alphabetic characters, only an electronic service tool may change System Configuration Parameters. System Configuration Parameters affect the power rating or the emissions.

Refer to Troubleshooting, "Programming Parameters" and Troubleshooting, "Factory Passwords".

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# Glossary

**Active Diagnostic Code** – An active diagnostic code alerts the operator or the service technician that an electronic system malfunction is currently present. Refer to the term "Diagnostic Code" in this glossary.

**Adaptive Trim** – This is a software process that is performed in the Electronic Control Module (ECM) that optimizes engine performance.

**Alternating Current (AC)** – Alternating current is an electric current that reverses direction at a regular interval that is reoccurring.

**Before Top Center (BTC)** – BTC is the 180 degrees of crankshaft rotation before the piston reaches the top dead center position in the normal direction of rotation.

**Breakout Harness** – A breakout harness is a test harness that is designed to connect into the engine harness. This connection allows a normal circuit operation and the connection simultaneously provides a Breakout T in order to measure the signals.

**Bypass Circuit** – A bypass circuit is a circuit that is used as a substitute circuit for an existing circuit. A bypass circuit is typically used as a test circuit.

**CAN Data Link (see also J1939 CAN Data Link)** – The CAN Data Link is a serial communications port that is used for communication with other microprocessor based devices.

**Code** – Refer to "Diagnostic Code" or "Event Code".

**Communication Adapter Tool** – The communication adapter provides a communication link between the ECM and the electronic service tool.

**Component Identifier (CID)** – The CID is a number that identifies the specific component of the electronic control system that has experienced a diagnostic code.

**Coolant Temperature Sensor** – The coolant temperature sensor detects the engine coolant temperature for all normal operating conditions and for engine monitoring.

**Data Link** – The Data Link is a serial communication port that is used for communication with other devices such as the electronic service tool.

**Derate** – Certain engine conditions will generate event codes. Also, engine derates may be applied. The manner for the engine derate is programmed into the ECM software. The derate can be one or more of 3 types: reduction of rated power, reduction of rated engine speed, and reduction of rated machine speed for OEM products.

**Desired Engine Speed** – The desired engine speed input to the electronic governor within the ECM. The electronic governor uses the signal from the throttle position sensor, the engine speed/timing sensor, and other sensors in order to determine the desired engine speed.

**Diagnostic Code** – A diagnostic code is sometimes referred to as a fault code. These codes indicate an electronic system malfunction.

**Diagnostic Lamp** – A diagnostic lamp is sometimes called the check engine light. The diagnostic lamp is used to warn the operator of the presence of an active diagnostic code. The lamp may not be included in all applications.

**Digital Sensor Return** – The common line (ground) from the ECM is used as ground for the digital sensors.

**Digital Sensors** – Digital sensors produce a pulse width modulated signal. Digital sensors are supplied with power from the ECM.

**Digital Sensor Supply** – The power supply for the digital sensors is provided by the ECM.

**Direct Current (DC)** – Direct current is the type of current that flows consistently in only one direction.

**DT, DT Connector, or Deutsch DT** – This is a type of connector that is used on Perkins engines. The connectors are manufactured by Deutsch.

REFERENCE ONLY

**Duty Cycle** – Refer to "Pulse Width Modulation".

**Electronic Engine Control** – The electronic engine control is a complete electronic system. The electronic engine control monitors the engine operation under all conditions. The electronic engine control also controls the engine operation under all conditions.

**Electronic Control Module (ECM)** – The ECM is the control computer of the engine. The ECM provides power to the electronics. The ECM monitors data that is input from the sensors of the engine. The ECM acts as a governor in order to control the speed and the power of the engine.

**Electronic Service Tool** – The electronic service tool allows a computer (PC) to communicate with the ECM.

**Engine Monitoring** – Engine Monitoring is the part of the electronic engine control that monitors the sensors. This also warns the operator of detected problems.

**Engine Oil Pressure Sensor** – The engine oil pressure sensor measures engine oil pressure. The sensor sends a signal to the ECM that is dependent on the engine oil pressure.

**Engine Speed/Timing Sensor** – An engine speed/timing sensor is a hall effect switch that provides a digital signal to the ECM. The ECM interprets this signal as the crankshaft position and the engine speed. Two sensors are used to provide the speed and timing signals to the ECM. The primary sensor is associated with the crankshaft and the secondary sensor is associated with the camshaft.

**Event Code** – An event code may be activated in order to indicate an abnormal engine operating condition. These codes usually indicate a mechanical problem instead of an electrical system problem.

**Failure Mode Identifier (FMI)** – This identifier indicates the type of failure that is associated with the component. The FMI has been adopted from the SAE practice J1587 diagnostics. The FMI follows the parameter identifier (PID) in the descriptions of the fault code. The descriptions of the FMIs are in the following list.

**0** – The data is valid but the data is above the normal operational range.

**1** – The data is valid but the data is below the normal operational range.

**2** – The data is erratic, intermittent, or incorrect.

**3** – The voltage is above normal or the voltage is shorted high.

**4** – The voltage is below normal or the voltage is shorted low.

**5** – The current is below normal or the circuit is open.

**6** – The current is above normal or the circuit is grounded.

**7** – The mechanical system is not responding properly.

**8** – There is an abnormal frequency, an abnormal pulse width, or an abnormal time period.

**9** – There has been an abnormal update.

**10** – There is an abnormal rate of change.

**11** – The failure mode is not identifiable.

**12** – The device or the component is damaged.

**Flash File** – This file is software that is inside the ECM. The file contains all the instructions (software) for the ECM and the file contains the performance maps for a specific engine. The file may be reprogrammed through flash programming.

**Flash Programming** – Flash programming is the method of programming or updating an ECM with an electronic service tool over the data link instead of replacing components.

**Fuel Injector E-Trim** – Fuel injector E-trim is a software process that allows precise control of fuel injectors by parameters that are programmed into the ECM for each fuel injector. With the use of the electronic service tool, the service technician can read status information for the E-Trim. Data for E-Trim can also be programmed.

**FRC** – See "Fuel Ratio Control".

**Fuel Pump** – See "Fuel Rail Pump".

**Fuel Rail** – This item is sometimes referred to as the High Pressure Fuel Rail. The fuel rail supplies fuel to the electronic unit injectors. The fuel rail pump and the fuel rail pressure sensor work with the ECM in order to maintain the desired fuel pressure in the fuel rail. This pressure is determined by calibration of the engine in order to enable the engine to meet emissions and performance requirements.

**Fuel Rail Pressure Sensor** – The fuel rail pressure sensor sends an electronic signal to the ECM that is dependent on the pressure of the fuel in the fuel rail.

**Fuel Rail Pump** – This item is sometimes referred to as the High Pressure Fuel Rail Pump. This is a device that supplies fuel under pressure to the fuel rail (high pressure fuel rail).

REFERENCE ONLY

**Fuel Rail Pump Solenoid Valve** – This is sometimes referred to as the High Pressure Fuel Rail Pump Solenoid Valve. This is a control device in the high pressure fuel rail pump. The ECM controls the pressure in the fuel rail by using this valve to divert excess fuel from the pump to the fuel tank.

**Fuel Ratio Control (FRC)** – The FRC is a limit that is based on the control of the ratio of the fuel to air. The FRC is used for purposes of emission control. When the ECM senses a higher intake manifold air pressure (more air into the cylinder), the FRC increases the FRC Limit (more fuel into the cylinder).

**Full Load Setting (FLS)** – The FLS is the parameter that represents the fuel system adjustment. This adjustment is made at the factory in order to fine tune the fuel system. The correct value for this parameter is stamped on the engine information ratings plate. This parameter must be programmed.

**Full Torque Setting (FTS)** – The FTS is the parameter that represents the adjustment for the engine torque. This adjustment is made at the factory in order to fine tune the fuel system. This adjustment is made in conjunction with the FLS. This parameter must be programmed.

**Glow Plug** – The glow plug is an optional starting aid for cold conditions. One glow plug is installed in each combustion chamber in order to improve the abili of the engine to start. The ECM uses information fro the engine sensors such as the engine tem erature to determine when the glow plug relay m t pro de power to each glow plug. Each of the glow lugs then provides a very hot surface in t combu tion chamber in order to vaporize the ixture of air a d fuel. This improves ignition during he com ession stroke of the cylinder.

**Glow Plug Relay** – The g ow ug relay is controlled by the ECM in order to pro e high current to the glow plugs that are used in the t ting aid system.

**Harness** – T e harn s is the bundle of wiring (loom) that onne s all components of the electronic system.

**Her z (Hz)** – He is the measure of electrical fre uen cycles per second.

**High P ssure Fuel Rail Pump** – See “Fuel Rail Pump”.

**High Pressure Fuel Rail Pump Solenoid Valve** – See “Fuel Rail Pump Solenoid Valve”.

**High Pressure Fuel Rail** – See “Fuel Rail”.

**Injector Codes** – The injector codes or trim codes are numeric codes or alphanumeric codes that are etched or stamped on individual electronic unit injectors. These codes are used to fine tune the fuel delivery.

**Injector Trim Files** – Injector trim files are downloaded from a disk to the ECM. The injector trim files compensate for variances in manuf cturing of the electronic unit injector and for the life of the electronic unit injector. The serial num for he electronic unit injector must be obtained in ord to retrieve the correct injector trim file.

**Intake Manifold Air Temperat re S nsor** – The intake manifold air temperature s nsor tects the air temperature in the int e m ifold. The ECM monitors the air temperatu and other data in the intake manifold in order t adj t injection timing and other performan e functio s.

**Intake Manifold P ssur Sensor** – The Intake Manifold Pressure Sensor measures the pressure in the intake manifold. The pressure in the intake mani ld ay be different to the pressure outside th eng e (atm spheric pressure). The difference in pressu ay be caused by an increase in air pressu by a turbocharger (if equipped).

**I tegrated Electronic Controls** – The engine is designed with the electronic controls as a necessary part of the system. The engine will not operate without the electronic controls.

**J1939 CAN Data Link** – This data link is a SAE standard diagnostic communications data link that is used to communicate between the ECM and the electronic devices.

**Logged Diagnostic Codes** – Logged diagnostic codes are codes which are stored in the memory. These codes are meant to be an indicator of possible causes for intermittent problems. Refer to the term “Diagnostic Code” in this glossary for more information.

**OEM** – OEM is an abbreviation for the Original Equipment Manufacturer. This is the manufacturer of the machine or the vehicle that uses the engine.

**Open Circuit** – An open circuit is a condition that is caused by an open switch, or by an electrical wire or a connection that is broken. When this condition exists, the signal or the supply voltage can no longer reach the intended destination.

**Parameter** – A parameter is a value or a limit that is programmable. This helps determine specific characteristics or behaviors of the engine.

REFERENCE ONLY

**Password** – A password is a group of numeric characters or a group of alphanumeric characters that is designed to restrict access to parameters. The electronic system requires correct passwords in order to change some parameters (Factory Passwords). Refer to Troubleshooting, "Factory Passwords" for more information.

**Personality Module** – See "Flash File".

**Power Cycling** – . Power cycling refers to the action of cycling the keyswitch from any position to the OFF position, and to the START/RUN position.

**Primary Speed/Timing Sensor** – This sensor determines the position of the crankshaft during engine operation. If the primary speed/timing sensor fails during engine operation, the secondary speed/timing sensor is used to provide the signal.

**Pulse Width Modulation (PWM)** – A PWM signal consists of pulses that are of variable width. These pulses occur at fixed intervals. The ratio of "TIME ON" versus total "TIME OFF" can be varied. This ratio is also referred to as a duty cycle.

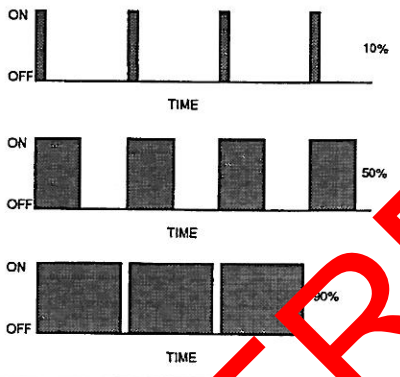



Illustration 3 g00284479

**Rated Fuel Limit** – This is a limit that is based on the power rating of the engine and on the engine rpm. The Rated Fuel Limit enables the engine power and torque outputs to conform to the power and torque curves of a specific engine model. These limits are in the flash file and these limits cannot be changed.

**Reference Voltage** – Reference voltage is a regulated voltage and a steady voltage that is supplied by the ECM to a sensor. The reference voltage is used by the sensor to generate a signal voltage.

**Relay** – A relay is an electromechanical switch. A flow of electricity in one circuit is used to control the flow of electricity in another circuit. A small current or voltage is applied to a relay in order to switch a much larger current or voltage.

**Secondary Speed/Timing Sensor** – This sensor determines the position of the camshaft during engine operation. If the primary speed/timing sensor fails during engine operation, the secondary speed/timing sensor is used to provide the signal.

**Sensor** – A sensor is a device that is used to detect the current value of pressure or temperature, or mechanical movement. The information that is detected is converted into an electrical signal.

**Short Circuit** – A short circuit is a condition that has an electrical circuit that is inadvertently connected to an undesirable point. An example of a short circuit is a wire which rubs against a vehicle frame and this rubbing eventually wears off the wire insulation. Electrical contact with the frame is made and a short circuit results.

**Signal** – The signal is a voltage or a waveform that is used in order to transmit information typically from a sensor to the ECM.

**Supply Voltage** – The supply voltage is a continuous voltage that is supplied to a component in order to provide the electrical power that is required for the component to operate. The power may be generated by the ECM or the power may be battery voltage that is supplied by the engine wiring.

**System Configuration Parameters** – System configuration parameters are parameters that affect emissions and/or operating characteristics of the engine.

**Tattletale** – Certain parameters that affect the operation of the engine are stored in the ECM. These parameters can be changed by use of the electronic service tool. The tattletale logs the number of changes that have been made to the parameter. The tattletale is stored in the ECM.

**Throttle Position** – The throttle position is the interpretation by the ECM of the signal from the throttle position sensor or the throttle switch.

**Throttle Position Sensor** – The throttle position sensor is a sensor that is usually connected to an accelerator pedal or a hand lever. This sensor sends a signal to the ECM that is used to calculate desired engine speed.

**Throttle Switch** – The throttle switch sends a signal to the ECM that is used to calculate desired engine speed.

**Timing Calibration** – The timing calibration is the adjustment of an electrical signal. This adjustment is made in order to correct the timing error between the camshaft and the engine speed/timing sensors or between the crankshaft and the engine speed/timing sensors.

REFERENCE ONLY

**Top Center Position** – The top center position refers to the crankshaft position when the No.1 piston position is at the highest point of travel. The engine must be turned in the normal direction of rotation in order to reach this point.

**Total Tattletale** – The total tattletale is the total number of changes to all the parameters that are stored in the ECM.

**Wait To Start Lamp** – This is a lamp that is included in the cold starting aid circuit in order to indicate when the wait to start period has expired. The glow plugs have not deactivated at this point in time.

**Wastegate** – This is a device in a turbocharged engine that controls the maximum boost pressure that is provided to the inlet manifold.

**Wastegate Regulator (if equipped)** – The wastegate regulator controls the pressure in the intake manifold to a value that is determined by the ECM. The wastegate regulator provides the interface between the ECM and the mechanical system that regulates intake manifold pressure to the desired value that is determined by the software.

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# Electronic Service Tools

Perkins electronic service tools are designed to help the service technician:

- Retrieve diagnostic codes.
- Diagnose electrical problems.
- Read parameters.
- Program parameters.
- Install trim files.

## Required Service Tools

Table 1

| Required Service Tools | |
|---|---|
| **Part Number** | **Description** |
| CH11155 | Crimp Tool (12-AWG TO 18-AWG) |
| 2900A019 | Wire Removal Tool |
| 27610285 | Removal Tool |
| - | Suitable Digital Multimeter |

Two short jumper wires are needed to check the continuity of some wiring harness circuits by shorting two adjacent terminals together in a connector. A long extension wire may also be needed to check the continuity of some wiring harness circuits.

## Optional Service Tools

Table 2 lists the optional service tools that can be used when the engine is serviced.

Table 2

| Part Number | Description |
|---|---|
| U5MK1092 | Spoon Probe Kit (MULTIMETER) |
| -<br>or<br>- | Suitable Digital Pressure Indicator<br>or<br>Engine Pressure Group |
| - | Suitable Battery Load Tester |
| - | Suitable Temperature Adapter (MULTIMETER) |
| 27610107 | Bypass Harness As |
| 2900A038 | Harness As |

## Perkins Electronic Service Tool

The Perkins Electronic Service Tool can display the following information:

- Status of all pressure sensors and temperature sensors
- Programmable parameter settings
- Active diagnostic codes and logged diagnostic codes
- Logged events
- Histograms

The Electronic Service Tool can also be used to perform the following functions:

- Diagnostic tests
- Sensor calibrations
- Programming of flash files
- Parameter programming
- Copy configuration function for ECM replacement
- Data logging
- Graphs (real time)

Table 3 lists the service tools that are required in order to use the Electronic Service Tool.

REFERENCE ONLY

Table 3

| Service Tools for the Use of the Electronic Service Tool | |
|---|---|
| **Part Number** | **Description** |
| -(1) | Single Use Program License |
| -(1) | Data Subscription for All Engines |
| 27610251 | Communication Adapter (Electronic Service Tool to ECM interface) |
| 27610164 | Adapter Cable As |

(1) Refer to Perkins Engine Company Limited.

**Note:** For more information regarding the use of the Electronic Service Tool and the PC requirements for the Electronic Service Tool, refer to the documentation that accompanies your Perkins Electronic Service Tool software.

### Connecting the Electronic Service Tool and the Communication Adapter II

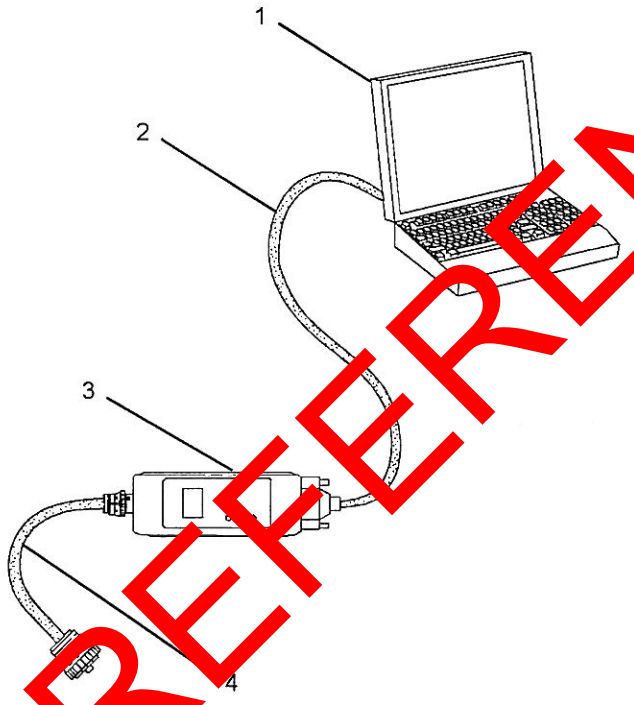



Illustration 1 g01121866

(1) Personal Computer (PC)
(2) Adapter Cable (Computer Serial Port)
(3) Communication Adapter II
(4) Adapter Cable Assembly

**Note:** Items (2), (3) and (4) are part of the Communication Adapter II kit.

Use the following procedure in order to connect the Electronic Service Tool and the Communication Adapter II.

1. Turn the keyswitch to the OFF position.
2. Connect cable (2) between the "COMPUTER" end of communication adapter (3) and the RS232 serial port of PC (1).

**Note:** The Adapter Cable Assembly (4) is required to connect to the USB port on computers that are not equipped with a RS232 serial port.

3. Connect cable (4) between the "DATA LINK" end of communication adapter (3) and the service tool connector.
4. Place the keyswitch in the ON position. If the Electronic Service Tool and the communication adapter do not communicate with the Electronic Control Module (ECM), refer to the diagnostic procedure Troubleshooting "Electronic Service Tool Will Not Communicate With ECM".

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# Indicator Lamps

## Indicator Lamps

The functions of the indicator lamps are designed to display the maximum amount of information on the minimum number of lamps.

Five lamps are available as options. The "Shutdown" lamp and the "Warning" lamp will normally be installed in the application. Dedicated optional lamps for other items may also be installed. The remaining optional lamps are "Wait to start", "Low oil pressure" and "PTO mode on".

The "Shutdown" lamp and the "Warning" lamp can also be used to indicate a diagnostic code by use of the "Flash Code" feature. The "Flash Code" feature can be used to indicate all active diagnostic codes and logged diagnostic codes.

## Functions of the Lamps

### Shutdown Lamp

**Lamp check** – When the keyswitch is turned to ON, the lamp will illuminate for 2 seconds. The lamp will then be extinguished unless there is an active warning.

**Flashing** – The lamp will be flashing when a derate is active or when a derate is present because of an active diagnostic code or an active event code. An example of an active diagnostic code is "System Voltage High". An example of an active event code is "Low Engine Oil Pressure".

REFERENCE ONLY

**On** – The lamp will illuminate when the shutdown level in the engine protection strategy has been reached. The "Warning" lamp will also be illuminated.

### Warning Lamp

**Lamp check** – When the keyswitch is turned to ON, the lamp will illuminate for 2 seconds. The lamp will then be extinguished unless there is an active warning.

**Flashing** – The lamp will be flashing when a "warning" or a "warning and derate" is active. This includes low oil pressure.

**On** – The lamp will illuminate when the shutdown level has been reached. The "Shutdown" lamp will also be illuminated.

### Wait to Start Lamp

**Lamp check** – When the keyswitch is turned to ON, the lamp will illuminate for 2 seconds. The lamp will then be extinguished unless "Wait to Start" is active.

**On** – The lamp illuminates during a "Wait to Start" period.

### Low Oil Pressure

**Lamp check** – When the keyswitch is turned to ON, the lamp will illuminate for 2 seconds. The lamp will then be extinguished unless there is an active warning.

**On** – The lamp will illuminate when a low oil pressure event is detected. The "Warning" lamp and the "Shutdown" lamp may also illuminate.

### PTO Lamp

**Lamp check** – When the keyswitch is turned to ON, the lamp will illuminate for 2 seconds. The lamp will then be extinguished unless the PTO mode is active.

**Flashing** – The lamp will be flashing when the PTO mode is turned on but when the PTO is not engaged.

**On** – The lamp will illuminate when PTO mode is engaged.

## Color of Lamps

Typically, the "Shutdown" lamp is colored red and the "Warning" lamp is colored amber. The other lamps are optional.

REFERENCE ONLY

## Operation of the Indicator Lamps

Table 4

| Warning Lamp (Alert Lamp) | Shutdown Lamp (Action Lamp) | Lamp State | Description of the Indication | Engine State |
|---|---|---|---|---|
| On | On | Lamp Check | When the keyswitch is switched on, the lamps illuminate for a period of 2 seconds and the lamps will then be extinguished. | The keyswitch is on but the engine has not yet been cranked. |
| Off | Off | No Faults | With the engine in operation, there are no active warnings, diagnostic codes or event codes. | The engine is operating with no detected faults. |
| On | Off | Active Diagnostic | If the warning lamp illuminates during engine operation, this indicates that an active diagnostic code (an electrical fault) is present. | The engine is operating normally but there is one or more faults with the electronic system for the engine. |
| On | Flashing | Derate (A derate is caused by certain active codes.) | If the warning lamp illuminates and the shutdown lamp flashes during engine operation, this indicates that an active diagnostic code (an electrical fault) is present. The diagnostic is sufficiently serious in order to cause an engine derate. | The engine is operating but there is one or more active diagnostic codes that have initiated an engine derate. |
| Flashing | Off | Warning (Warning only) | When the warning lamp flashes during operation of the engine, the lamp indicates that one or more of the warning values for the engine protection strategy has been exceeded. However, the value has not been exceeded to a level that will cause a derate or a shutdown. | The engine is operating normally. However, there is one or more of the monitored engine parameters that are outside of the range that is acceptable. |
| Flashing | Flashing | Derate (Warning and Derate) | If both the warning lamp and shutdown lamp flash during operation of the engine, the lamps indicate that one or more of the values for the engine protection strategy have been exceeded beyond the level that will cause an engine derate. | The engine is operating. However, one or more of the monitored engine parameters is outside of the acceptable range. The acceptable range has been exceeded to a level which requires a warning and an engine derate. |
| On | On | Engine Shutdown | If both the warning lamp and the shutdown lamp illuminate during engine operation, this indicates one of the following conditions.<br><br>1. One or more of the shutdown values for the engine protection strategy has been exceeded.<br><br>2. A serious active diagnostic code has been detected.<br><br>After a short period of time, the engine will shut down. | The engine is either shutdown or an engine shutdown is imminent. One or more monitored engine parameters have exceeded the limit for an engine shutdown. This pattern of lamps can be caused by the detection of a serious active diagnostic code. |

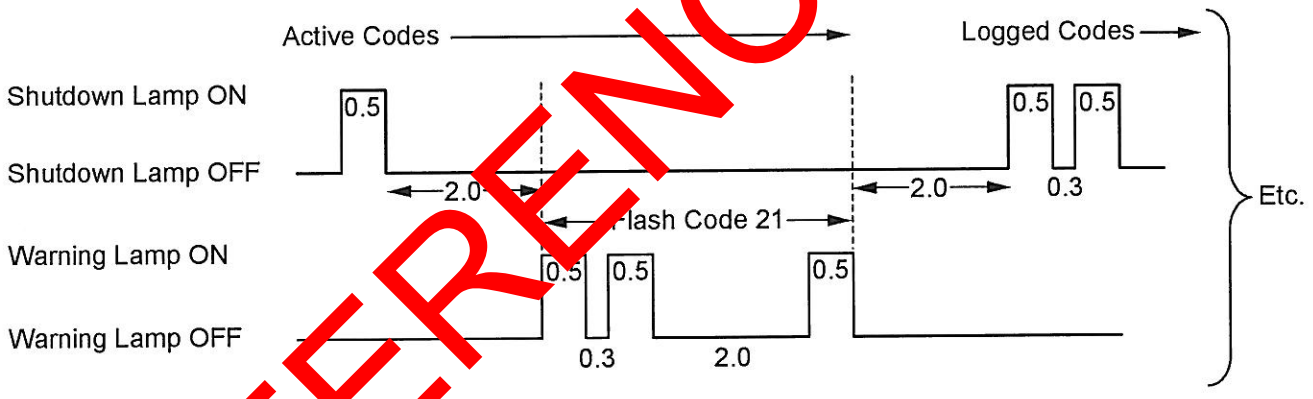
REFERENCE ONLY

## Flash Codes

The “Flash Code” feature is used to flash the code of all active diagnostic codes and logged diagnostic codes.

The sequence for the flash code is started by moving the keyswitch to "Off" and then moving the keyswitch to "On" twice within a period of three seconds. After a delay of 2 seconds, the "Shutdown" lamp will flash once for a period of half a second. This sequence indicates the start of the active fault codes. After a further delay of 2 seconds, the "Warning" lamp will flash repeatedly in order to indicate the active diagnostic codes. Each flash will be on for half a second and off for 300 milliseconds. The "Warning" lamp will remain off for 2 seconds between each digit of a code. If there is more than one active diagnostic code, the "Shutdown" lamp will go off for 2 seconds. The lamp will then illuminate for a period of half a second. The "Warning" lamp will be extinguished for a period of 2 seconds before starting the next code. If there are no active diagnostic codes, the "Warning" lamp will flash the code "551". Refer to Troubleshooting Guide, "No Diagnostic Code Detected".

As an example, an active diagnostic code of "21" is indicated by the "Warning" lamp coming on for 500 ms, then off for 300 ms, then on for 500 ms, then off for 2000 ms, then on for 500 ms and then off.




Note: All times shown in seconds

Illustration 5 g01779334

After all of the active diagnostic codes have been displayed, the "Shutdown" lamp will be extinguished for 2 seconds. The "Shutdown" lamp will flash twice in order to indicate the start of the sequence that will display the logged diagnostic codes. The process for flashing logged diagnostic codes is identical to the process for flashing active diagnostic codes.

**Note:** If there are no logged codes then the "551" code will be flashed again.

After all of the codes have been displayed, the "Shutdown" lamp will flash 3 times in order to indicate that there are no further codes. Cycling the keyswitch twice within a period of 3 seconds will start the process again. All codes will be displayed in ascending numerical order.

Refer to the Troubleshooting Guide, "Diagnostic Code Cross Reference" for the flash code that is related to the diagnostic code.

REFERENCE ONLY

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# Replacing the ECM

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.

The engine is equipped with an Electronic Control Module (ECM). The ECM contains no moving parts. Follow the troubleshooting procedures in this manual in order to be sure that replacing the ECM will correct the fault. Verify that the suspect ECM is the cause of the fault.

**Note:** Ensure that the ECM is receiving power and that the ECM is properly grounded before replacement of the ECM is attempted. Refer to the Schematic Diagram.

A test ECM can be used in order to determine if the ECM on the engine is faulty. Install a test ECM in place of the suspect ECM. Install the flash file into the test ECM. Program the parameters for the test ECM. The parameters must match the parameters in the suspect ECM. Refer to the following test steps for details. If the test ECM resolves the fault, reconnect the suspect ECM. Verify that the fault returns. If the fault returns, replace the ECM.

Use the Electronic Service Tool to read the parameters in the suspect ECM. Record the parameters in the suspect ECM. Install the flash file into the test ECM. After the ECM is installed on the engine, the parameters must be programmed into the test ECM.

**Note:** When a test ECM is not available, you may need to remove an ECM from an engine that is not in service. The ECM must have the same serial number suffix. Ensure that the replacement ECM and the flash file match the suspect ECM. Be sure to record the parameters from the replacement ECM. Use the "Copy Configuration ECM Replacement" function in the Electronic Service Tool.

NOTICE
If the flash file and engine application are not matched, engine damage may result.

Perform the following procedure in order to replace the ECM.

1. Connect the Electronic Service Tool to the diagnostic connector.
2. Use the "Copy Configuration ECM Replacement" function from the Electronic Service Tool. If the "Copy Configuration" is successful, proceed to Step 4. If the "Copy Configuration" failed, proceed to Step 3.

**Note:** Record any Logged Faults and Events for your records.

3. Record the following parameters:
   - Record all of the parameters on the "Configuration" screen.
   - Record all of the parameters on the "Throttle Configuration" screen.
   - Record all of the parameters on the "Mode Configuration" screen.
   - Record the serial numbers of the electronic unit injectors. The injector serial numbers are shown on the "Injector Trim Calibration" screen.

**Note:** If the parameters cannot be read, the parameters must be obtained elsewhere. Some parameters are stamped on the engine information plate, but most parameters must be obtained from the PTMI data on the Perkins Secured Internet.

4. Remove power from the ECM.
5. Remove the ECM. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".
6. Install the replacement ECM. Refer to Disassembly and Assembly, "Electronic Control Module - Remove and Install".
7. Download the flash file.
   a. Connect the Electronic Service Tool to the diagnostic connector.
   b. Select "WinFlash" from the "Utilities" menu of the electronic service tool.
   c. Select the downloaded flash file.

REFERENCE ONLY

8. If necessary, use the electronic service tool to clear the rating interlock. To clear the rating interlock, enter the factory password when the electronic service tool is first connected. Activating the "Test ECM" mode will also clear the rating interlock.

9. Use the electronic service tool to program the parameters. Perform the following procedure.

   a. If the "Copy Configuration" procedure was successful, use the "Copy Configuration, ECM Replacement" function to load the configuration file into the ECM.

**Note:** During the following procedure, Factory Passwords may be required.

   b. If the "Copy Configuration" procedure failed, configure the parameters individually. The parameters should match the parameters from step 3.

      Perform the "Fuel System Verification Test".

10. Check for logged diagnostic codes. Factory passwords are required to clear Logged Events.

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## Self-Diagnostics

The Electronic Control Module (ECM) has the ability to detect faults in the electronic system and with engine operation. When a fault is detected, a code is generated. An alarm may also be generated. There are two types of codes:

- Diagnostic
- Event

**Diagnostic Code** – When a fault in the electronic system is detected, the ECM generates a diagnostic code. This indicates the specific fault in the circuitry.

Diagnostic codes can have two different states:

- Active
- Logged

**Active Code** – An active diagnostic code indicates that an active fault has been detected by the control system. Active codes require immediate attention. Always service active codes prior to servicing logged codes.

**Logged Code** – Every generated code is stored in the permanent memory of the ECM. The codes are logged for 100 operating hours unless a code is cleared by use of the electronic service tool.

**Event Code** – An event code is generated by the detection of an abnormal engine operating condition. For example, an event code will be generated if the oil pressure is too low. In this case, the event code indicates the symptom of a fault.

Logged codes may not indicate that a repair is needed. The fault may have been temporary. The fault may have been resolved since the logging of the code. If the system is powered, it is possible to generate an active diagnostic code whenever a component is disconnected. When the component is reconnected, the code is no longer active. Logged codes may be useful to help troubleshoot intermittent faults. Logged codes can also be used to review the performance of the engine and the electronic system.

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## Sensors and Electrical Connectors

The Electronic Control Module (ECM) and the sensors are located on the left side of the engine. Refer to Figure 6 or 8.

REFERENCE ONLY

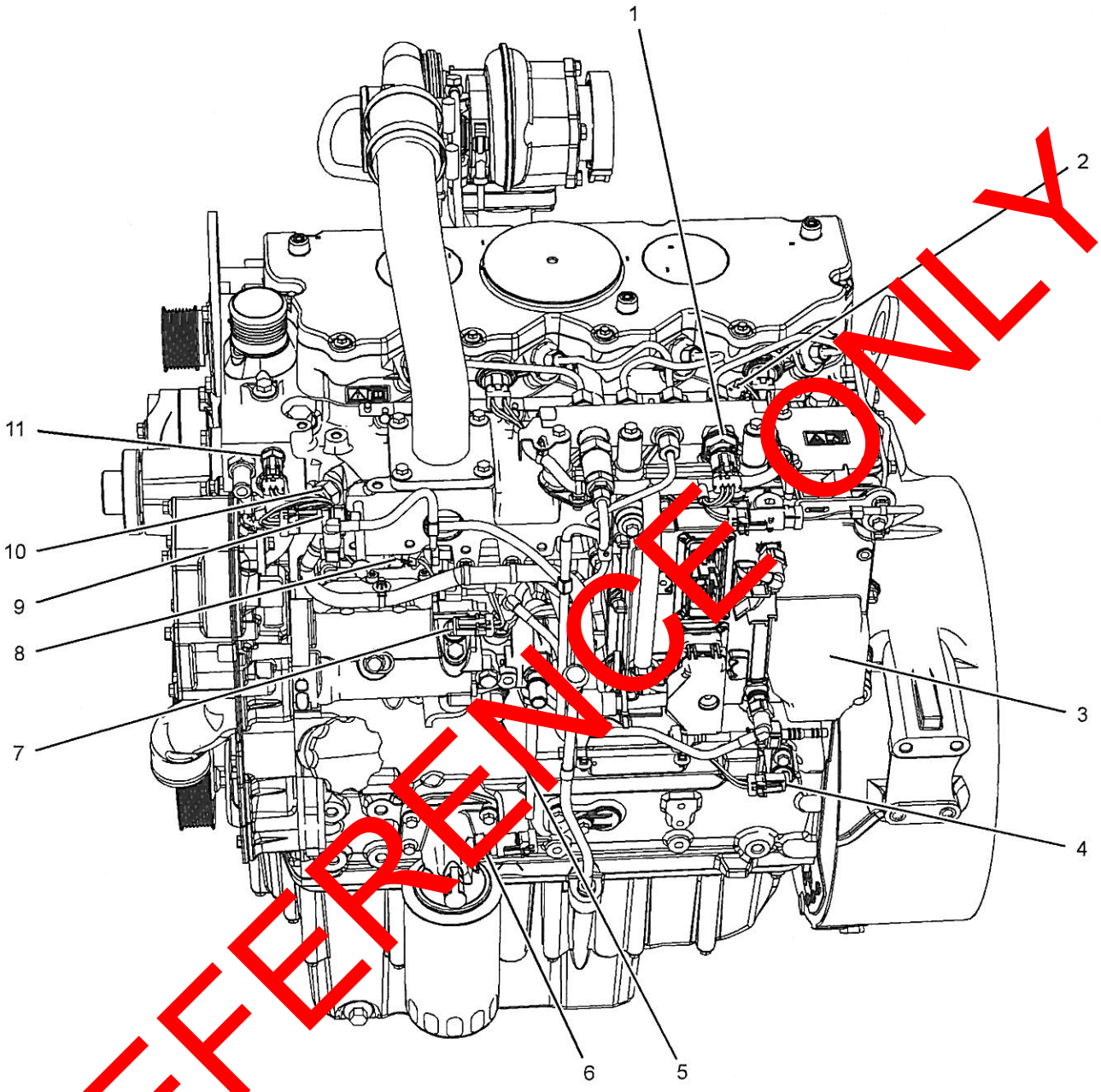


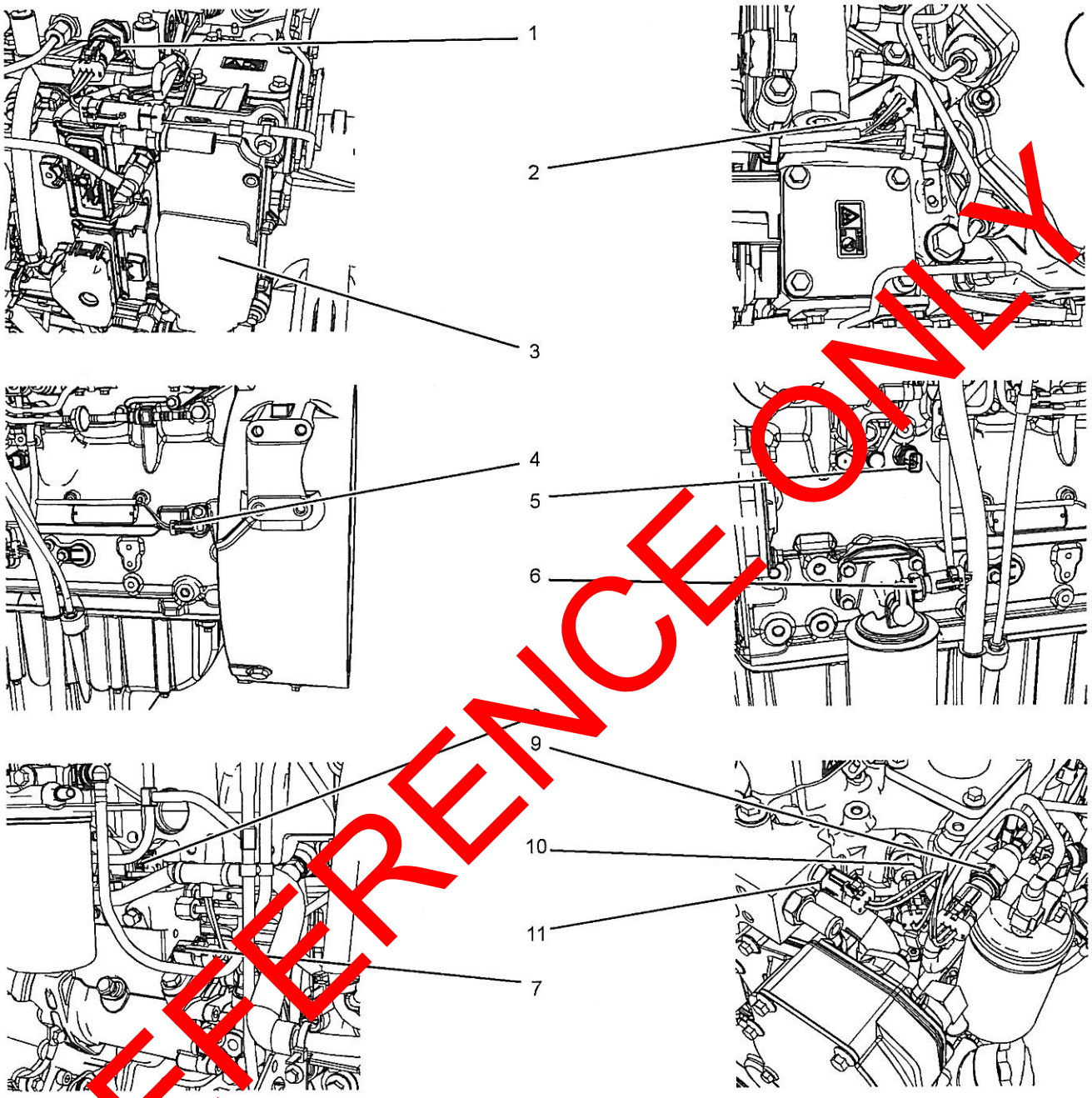

Illustration 1 g01779721

Sensor locations on the 1104D engine

(1) Fuel Rail Pressure Sensor
(2) Intake Manifold Air Temperature Sensor
(3) Electronic Control Module (ECM)
(4) Primary Speed/Timing Sensor
(5) Oil Pressure Sensor
(6) Oil Pressure Sensor (alternative location)
(7) Secondary Speed/Timing Sensor
(8) Solenoid for the Fuel Rail Pump
(9) Intake Manifold Pressure Sensor
(10) Intake Manifold Pressure Sensor (alternative location)
(11) Coolant Temperature Sensor

**Note:** If equipped, the wastegate regulator is installed on the right side of the engine.

REFERENCE ONLY




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Illustration 7
Detailed view of the sensor locations on the 1104D engine

REFERENCE ONLY

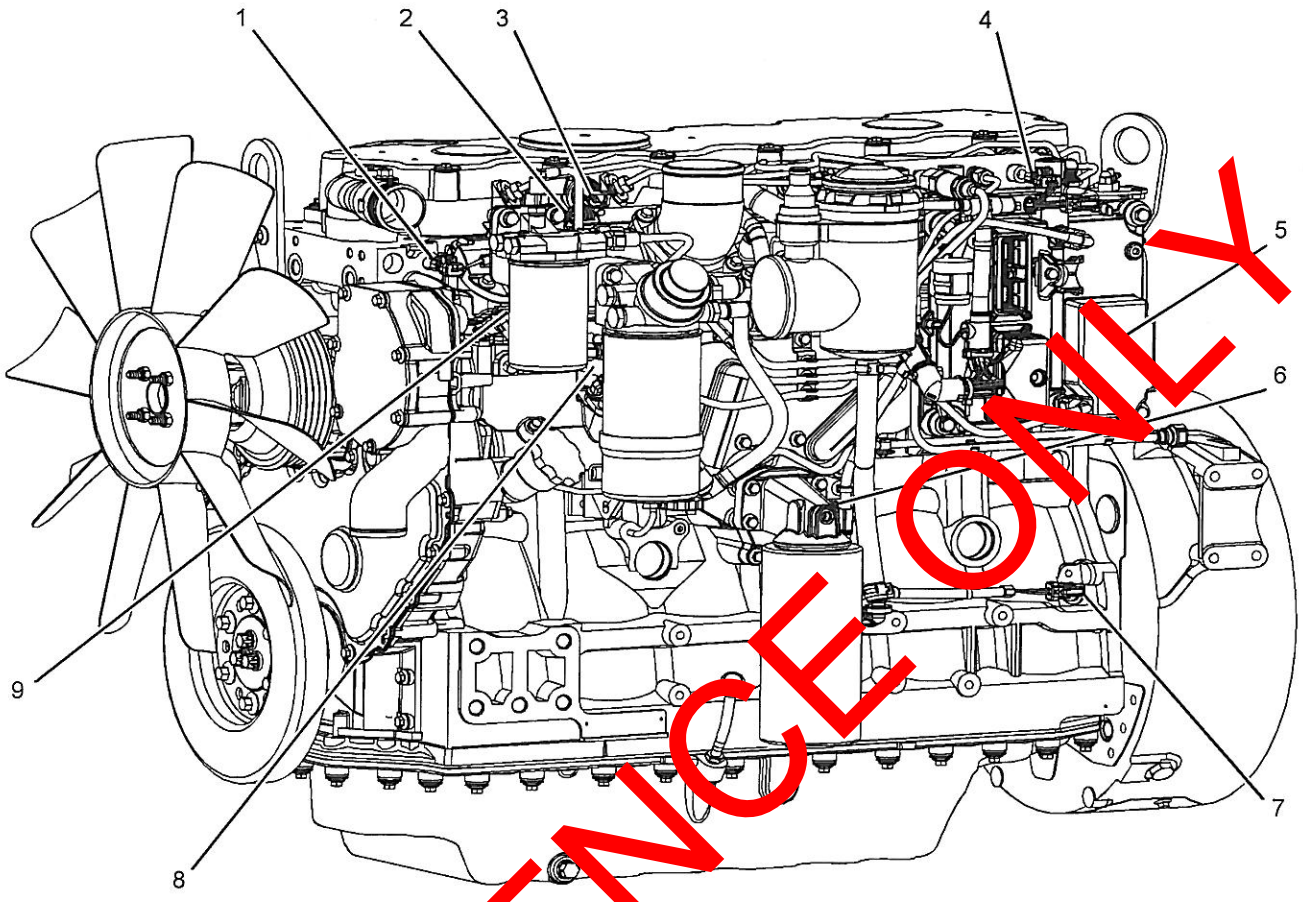


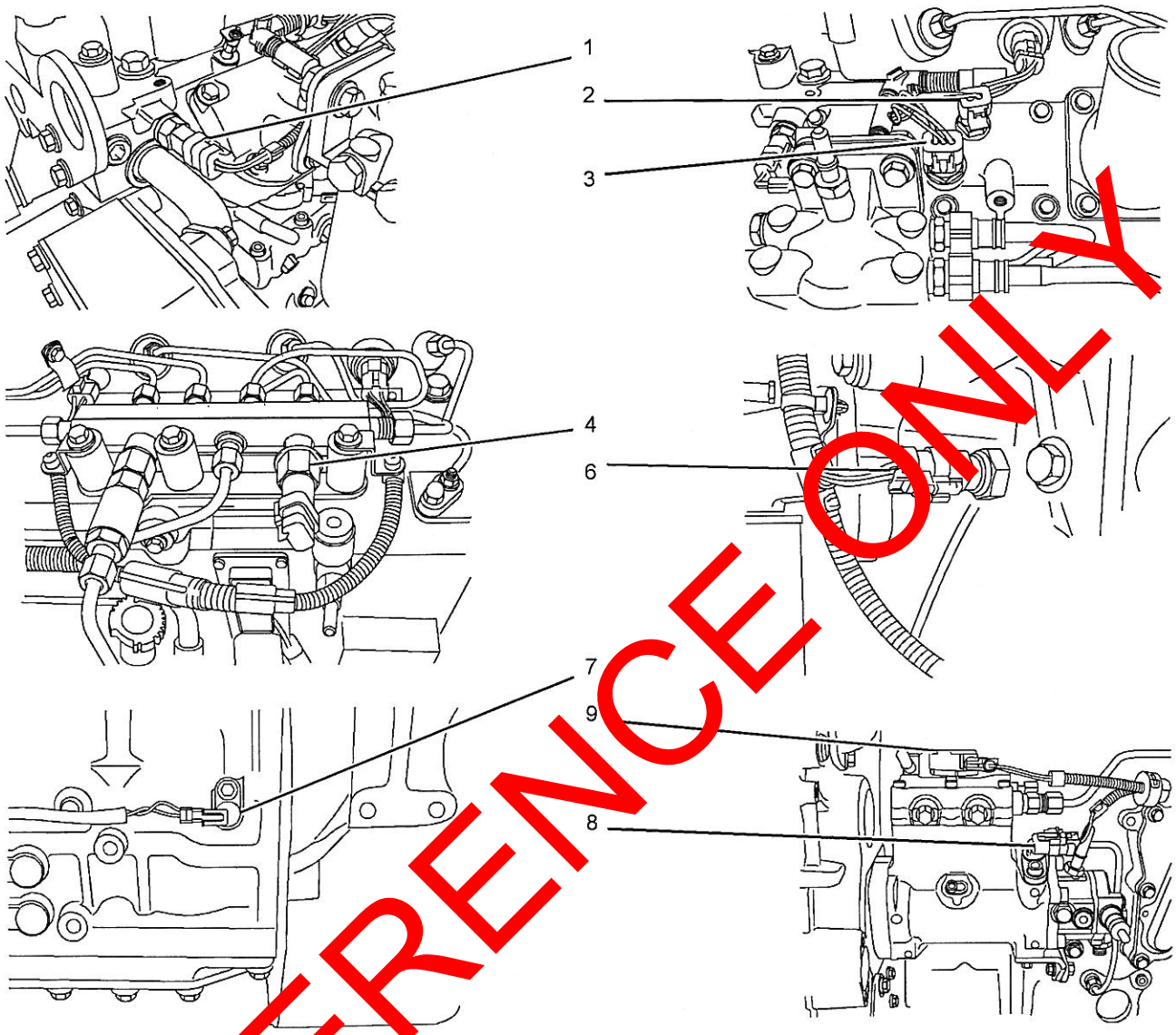

Illustration 8 g01780873

Sensor locations on the 1106D engine

(1) Coolant Temperature Sensor
(2) Intake Manifold Air Temperature Sensor
(3) Intake Manifold Pressure Sensor
(4) Fuel Rail Pressure Sensor
(5) Electronic Control Module (ECM)
(6) Oil Pressure Sensor
(7) Primary Speed/Timing Sensor
(8) Secondary Speed/Timing Sensor
(9) Solenoid for the Fuel Rail Pump

**Note:** If equipped, the wastegate regulator is installed on the right side of the engine.

REFERENCE ONLY




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Illustration 9

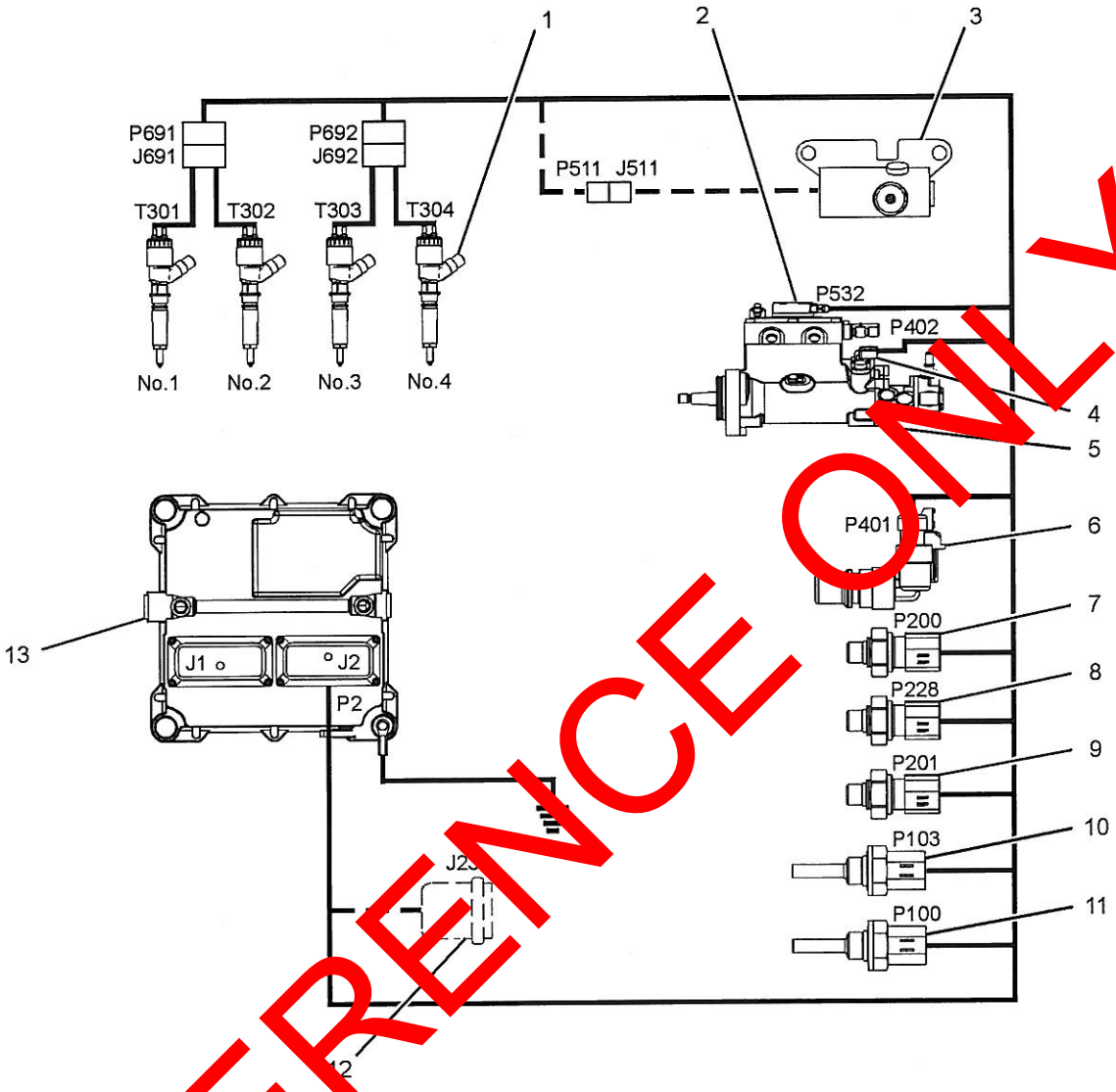
Detailed views of the sensor locations of the 1106D engine

REFERENCE ONLY

Table 5

| Connector | Function |
|---|---|
| P1 | Machine Harness to ECM Connector (64 Pin Connector) |
| P2 | Engine Harness to ECM Connector (64 Pin Connector) |
| P532 | Fuel Rail Pump Solenoid Connector (2 Pin Connector) |
| P402 | Secondary Speed/Timing Sensor (2 Pin Connector) |
| P401 | Primary Speed/Timing Sensor (2 Pin Connector) |
| P201 | Engine Oil Pressure Sensor (3 Pin Connector) |
| P228 | Fuel Rail Pressure Sensor (3 Pin Connector) |
| P200 | Intake Manifold Pressure Sensor (3 Pin Connector) |
| P103 | Intake Manifold Air Temperature Sensor (2 Pin Connector) |
| P100 | Coolant Temperature Sensor (2 Pin Connector) |
| J23 | Diagnostic Connector (if equipped) |
| P691/J691 | Electronic Unit Injectors for No. 1 and No. 2 Cylinders (4 Pin Connector) |
| P692/J692 | Electronic Unit Injectors for No. 3 and No. 4 Cylinders (4 Pin Connector) |
| P693/J693 (1106D engine only) | Electronic Unit Injectors for No. 5 and No. 6 Cylinders (4 Pin Connector) |
| P511 | Wastegate Regulator (if equipped) (2 Pin Connector) |

REFERENCE ONLY




REFERENCE ONLY

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Illustration 10

Schematic diagram for the 1106D engine

(1) Electronic Unit Injector
(2) Solenoid for the Fuel Rail Pump
(3) Wastegate Regulator (if equipped)
(4) Secondary Speed/Timing Sensor
(5) Fuel Rail Pump
(6) Primary Speed/Timing Sensor
(7) Intake Manifold Pressure Sensor
(8) Fuel Rail Pressure Sensor
(9) Engine Oil Pressure Sensor
(10) Intake Manifold Air Temperature Sensor
(11) Coolant Temperature Sensor
(12) Diagnostic Connector (if equipped)
(13) Electronic Control Module (ECM)

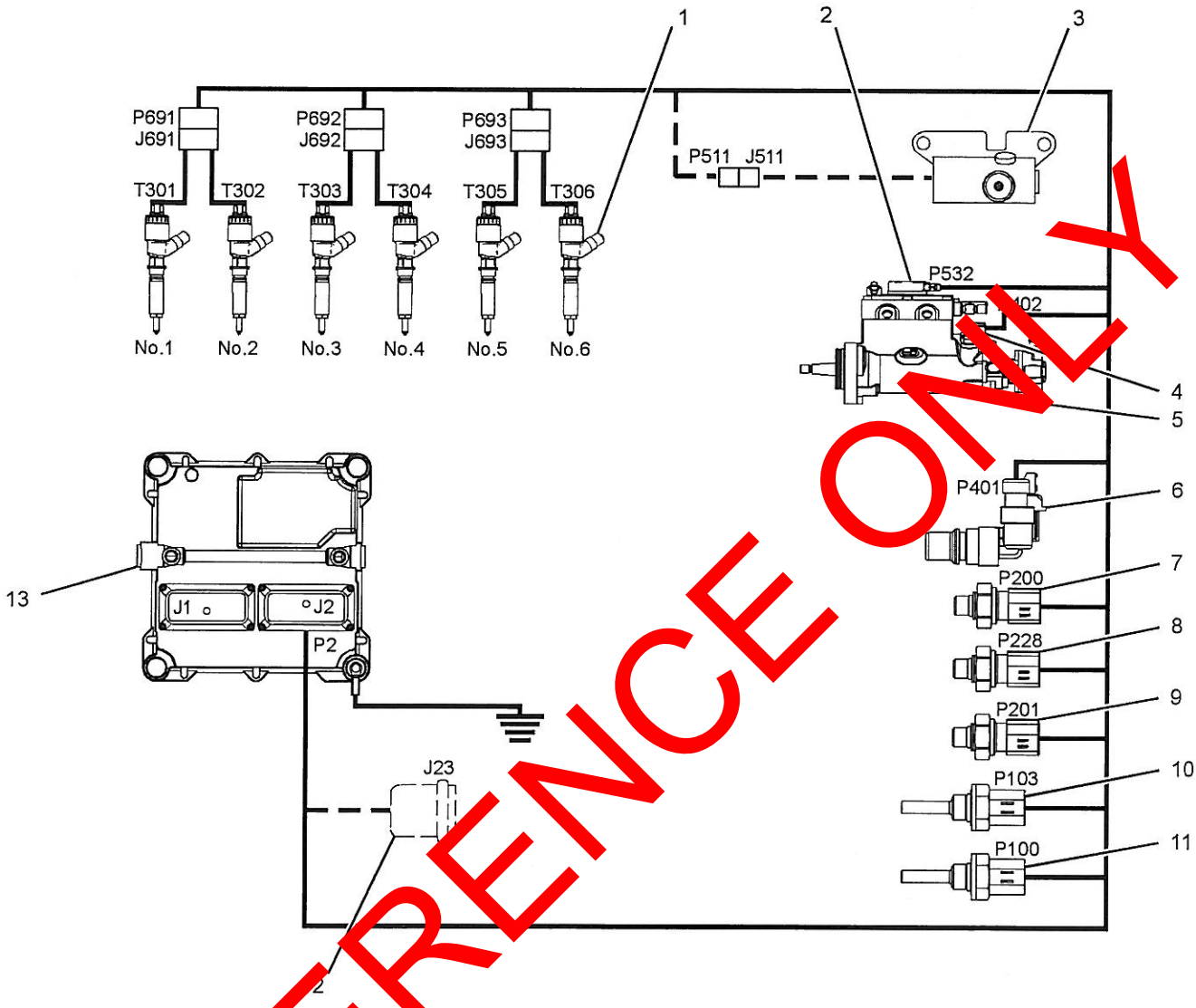



Illustration 11 g01777773

Schematic diagram for the 1106D engine

(1) Electronic Unit Injector
(2) Solenoid for the Fuel Rail Pump
(3) Wastegate Regulator (if equipped)
(4) Secondary Speed/Timing Sensor
(5) Fuel Rail Pump
(6) Primary Speed/Timing Sensor
(7) Intake Manifold Pressure Sensor
(8) Fuel Rail Pressure Sensor
(9) Engine Oil Pressure Sensor
(10) Intake Manifold Air Temperature Sensor
(11) Coolant Temperature Sensor
(12) Diagnostic Connector (if equipped)
(13) Electronic Control Module (ECM)

REFERENCE ONLY

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# Engine Wiring Information

## Harness Wire Identification

Perkins identifies all wires with eleven solid colors. The circuit number is stamped on the wire at a 25 mm (1 inch) spacing. Table 6 lists the wire colors and the color codes.

Table 6

| Color Codes for the Harness Wire | | | |
|---|---|---|---|
| **Color Code** | **Color** | **Color Code** | **Color** |
| BK | Black | BU | Blue |
| BR | Brown | PU | Purple |
| RD | Red | GY | Gray |
| OR | Orange | WH | White |
| YL | Yellow | PK | Pink |
| GN | Green | | |

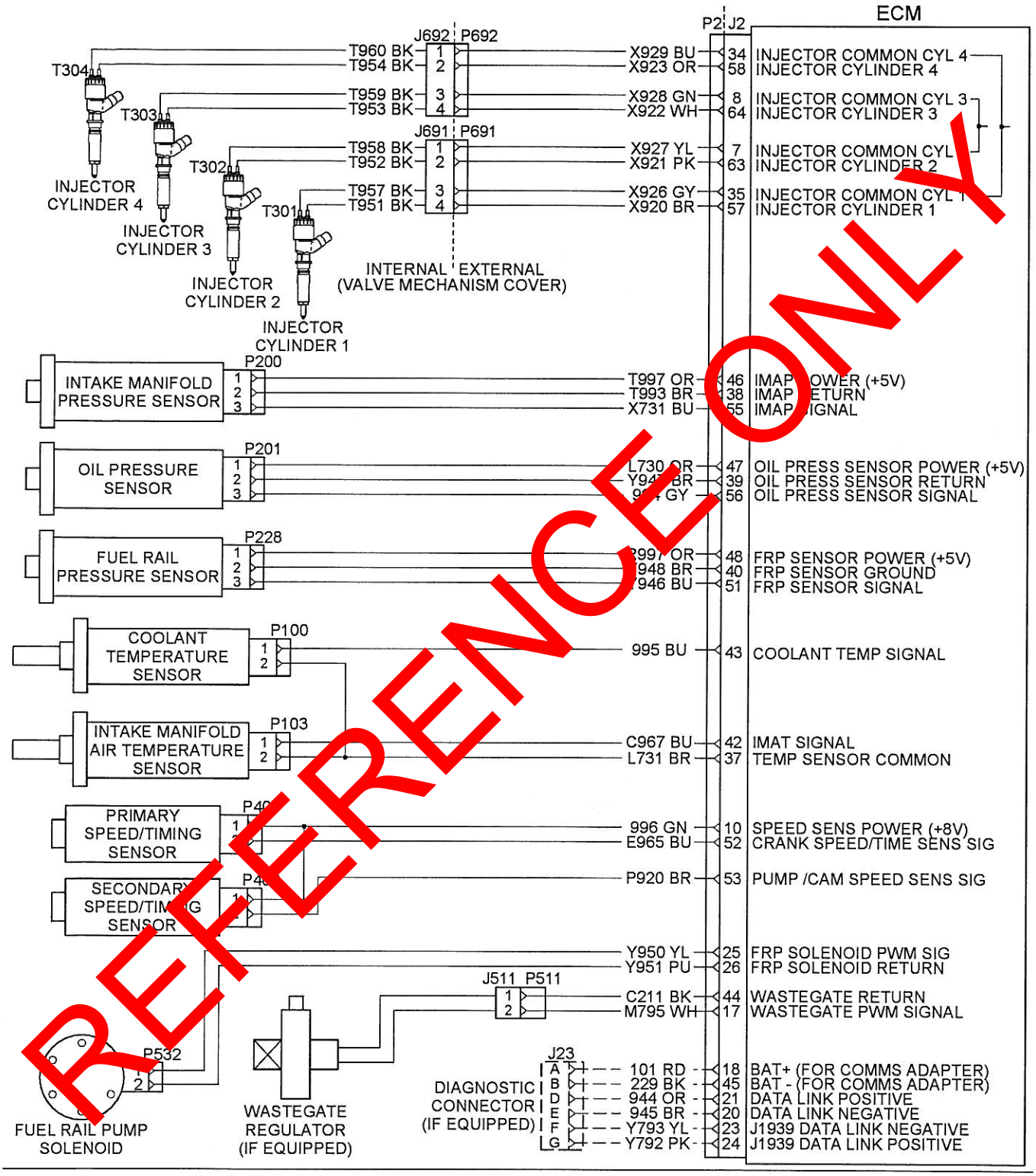
For example, a wire identification of F730-OR on the schematic would signify an orange wire with the circuit number F730. F730-OR identifies the power supply for the oil pressure sensor.

**Note:** Always replace a harness wire with the same gauge of wire and with the same color code.

**Note:** In the following diagrams, "Pxxx" signifies a plug and "Jxxx" signifies a jack.

REFERENCE ONLY

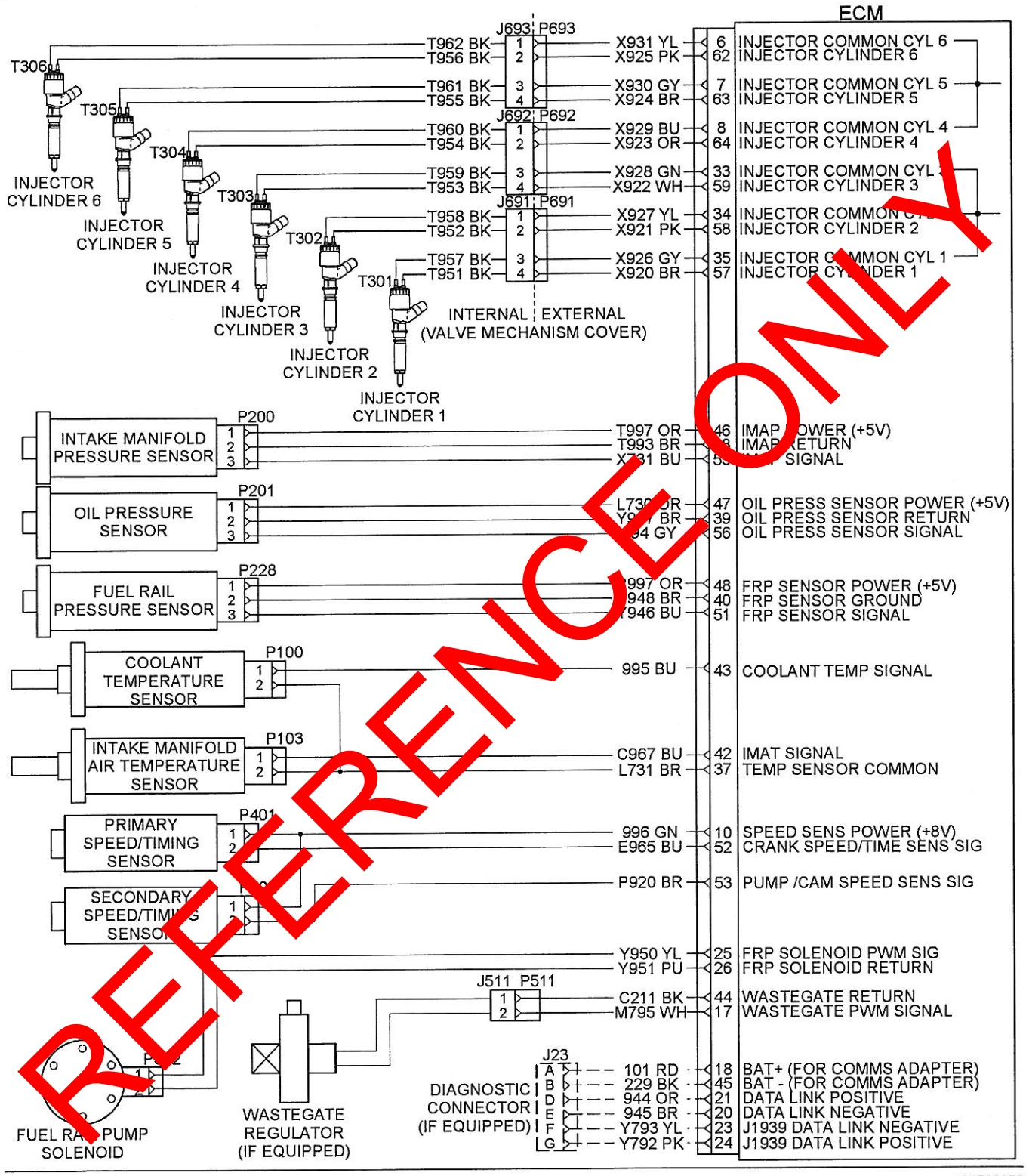
## Schematic Diagrams




REFERENCE ONLY

Illustration 12 g01780895

Schematic Diagram for the 1104D Engine Harness




REFERENCE ONLY

g01782875

Illustration 13

Schematic Diagram for the 1106D Engine Harness

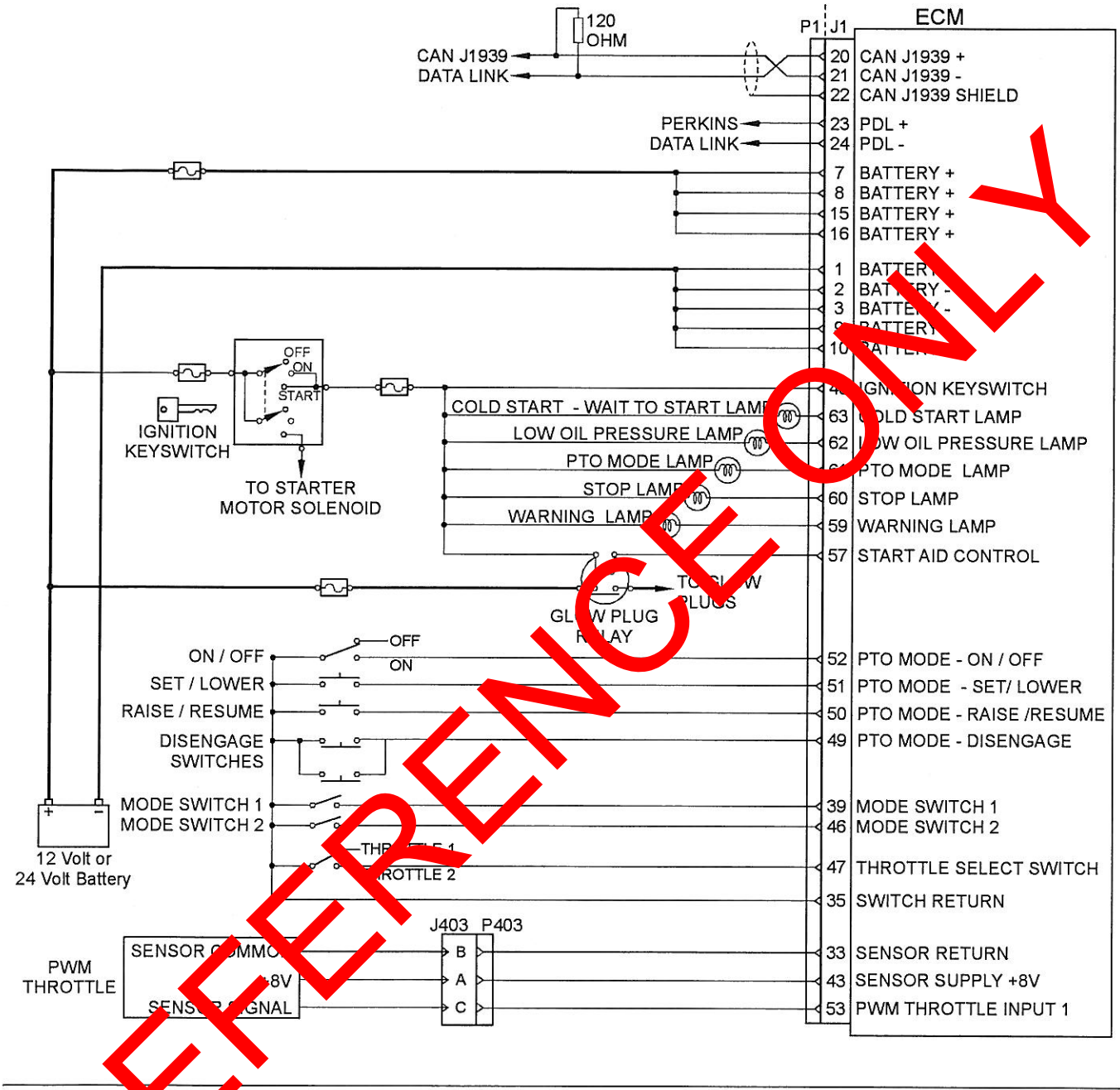



Illustration 1 g01783140

Schematic Diagram for a Typical Application

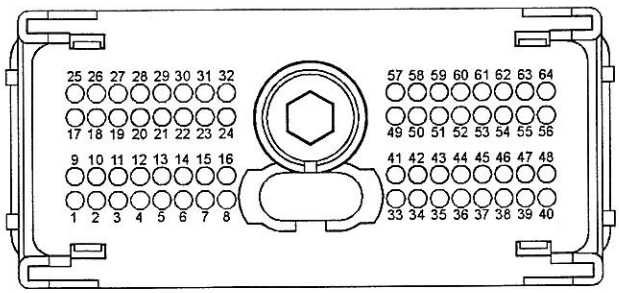
**Note:** The functionality of most of the connections to the J1 connector depend on the engine application.

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## ECM Harness Connector Terminals

The Electronic Control Module (ECM) uses connectors that have 64 terminals to interface to the wiring harness.

REFERENCE ONLY




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Illustration 15

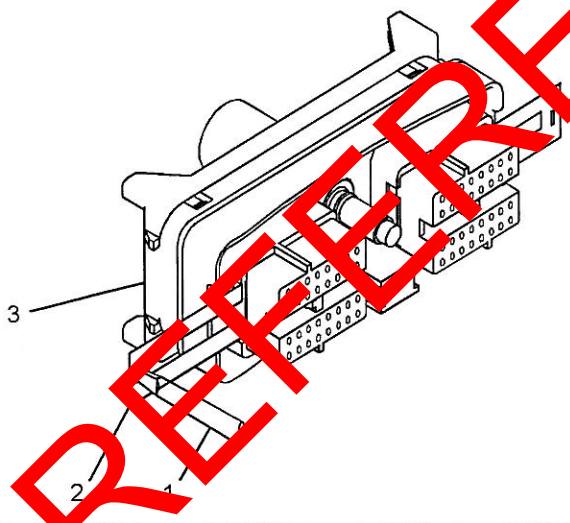
Layout of the Connector Pins (view from the rear)

## Removal and Installation of the Harness Connector Terminals

### Terminal Removal

Table 7

| Required Tools | | |
|---|---|---|
| **Part Number** | **Part Description** | **Qty** |
| 27610285 | Removal Tool | 1 |




g01784793

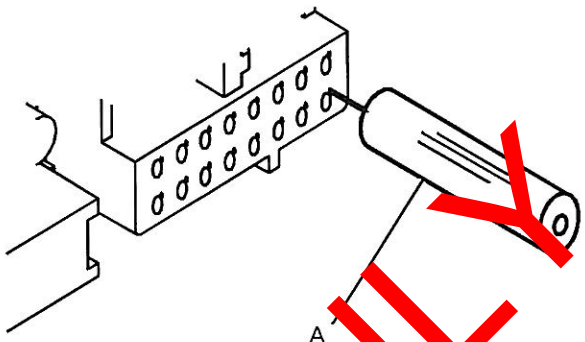
Illustration 16

Removal of Terminal Position Assurance Components

1. Remove the connector from the ECM. Refer to Disassembly and Assembly, “Electronic Control Module - Remove and Install”.

2. Use a screwdriver that has a flat blade (1) to remove the two terminal position assurance components (2) from the connector (3).

**Note:** Do not use the removal tool to remove the terminal position assurance components.




g01784822

Illustration 17

Removal Tool

3. Insert the removal tool into the hole that is adjacent to the terminal in order to release the locking device.

**Note:** Make sure that the tool stays perpendicular to the face of the connector.

4. Hold the tool in position and gently pull the wire in order to remove the terminal from the rear of the connector (3).

5. Remove the removal tool from the face of the connector (3).

**Note:** If a terminal must be replaced, part number 28170085 must be used.

### Terminal Insertion

1. Push the terminal into the rear of the connector (3) until the terminal engages with the locking device.

2. Gently pull on the wire in order to make sure that the terminal is retained by the locking device.

3. Install the two terminal position assurance components (2) into the sides of the connector (3).

4. Connect the connector to the ECM. Refer to Disassembly and Assembly, “Electronic Control Module - Remove and Install”.

REFERENCE ONLY

# Programming Parameters

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## Programming Parameters

The electronic service tool can be used to view certain parameters that can affect the operation of the engine. The electronic service tool can also be used to change certain parameters. The parameters are stored in the Electronic Control Module (ECM). Some of the parameters are protected from unauthorized changes by passwords. Parameters that can be changed have a tattletale number. The tattletale number shows if a parameter has been changed.

i03434204

## Test ECM Mode

"Test ECM Mode" is a feature in the software that can be used to help troubleshoot an engine that may have a fault in the Electronic Control Module (ECM). This feature allows a standard ECM to be used as a test ECM. This feature eliminates the need to stock a test ECM.

1. Search for the latest flash file for the engine.

**Note:** If a newer software version is available for the engine, install the newest software on the suspect ECM. If the new software does not rectify the fault, continue with this procedure.

2. Use the "Copy Configuration" feature on the electronic service tool to copy the parameters from the suspect ECM.

**Note:** If the "ECM Replacement" feature cannot be used, record the programmed values into the "Customer Specified Parameters Worksheet". Also record the system configuration parameters.

3. Disconnect the suspect ECM. Temporarily connect the test ECM to the engine. Do not mount the test ECM on the engine.

4. Flash program the test ECM with the newest software that is available.

5. Start the "Test ECM Mode" on the electronic service tool. Access the feature through the "Service" menu. The electronic service tool will display the status of the test ECM and the hours that are remaining for the "Test ECM Mode".

**Note:** "Test ECM Mode" can only be activated if the engine serial number has not already been programmed during normal operation of the ECM. If the engine serial number is programmed and the ECM is not in "Test ECM Mode", the ECM can never be used as a test ECM.

6. Use the "Copy Configuration" feature on the electronic service tool to program the test ECM.

**Note:** If the "ECM Replacement" feature cannot be used, program the test ECM with the values from the "Customer Specified Parameters Worksheet" and the values from the System Configuration Parameters.

7. Program the engine serial number into the test ECM.

**Note:** The "Test ECM Mode" must be activated before the engine serial number is programmed into the ECM.

8. Verify that the test ECM rectifies the fault.

When the "Test ECM Mode" is activated, an internal timer sets a 24 hour clock. This clock will count down only while the ECM is powered and the keyswitch is in the ON position. After the ECM has counted down the 24 hour period, the ECM will exit the "Test ECM Mode". The parameters and the engine serial number will be set.

If the test ECM rectifies the fault, the engine can be released while the "Test ECM Mode" is still active.

Once an ECM has been activated in the "Test ECM Mode", the ECM will stay in the "Test ECM Mode" until the timer times out. If the ECM is used as a test ECM for more than one engine, the "Test ECM Mode" must be reactivated. Anytime prior to the "Test ECM Mode" timing out, the ECM can be reset to 24 hours.

i03434261

## Factory Passwords

NOTICE
Operating the engine with a flash file not designed for that engine will damage the engine. Be sure the flash file is correct for your engine.

**Note:** Factory passwords are provided only to Perkins dealers.

Factory passwords are required to perform each of the following functions:

REFERENCE ONLY

- Program a new Electronic Control Module (ECM).

  When an ECM is replaced, the system configuration parameters must be programmed into the new ECM. A new ECM will allow these parameters to be programmed once without factory passwords. After the initial programming, some parameters are protected by factory passwords.

- Rerate the engine.

  This may require changing the interlock code, which is protected by factory passwords.

- Clear engine events and certain diagnostic codes.

  Most engine events require factory passwords in order to clear the code from ECM memory. Clear these codes only when you are certain that a fault has been rectified. For example, the E362-1 Engine Overspeed requires the use of factory passwords in order to clear the code from ECM memory.

Since factory passwords contain alphabetic characters, the electronic service tool must be used to perform these functions. In order to obtain factory passwords, proceed as if you already have the password. If factory passwords are needed, the electronic service tool will request the factory passwords and the electronic service tool will display the information that is required to obtain the passwords.

i04115238

## Flash Programming

**Flash Programming** – A method of loading a flash file into the Electronic Control Module (ECM)

The electronic service tool can be utilized to flash program a flash file into the ECM. The flash programming transfers the flash file from the PC to the ECM.

### Flash Programming a Flash File

1. Obtain the part number for the new flash file.

**Note:** If you do not have the part number for the flash file, use "PTMI" on the Perkins Internet.

**Note:** You must have the engine serial number in order to search for the flash file's part number.

2. Connect the electronic service tool to the service tool connector.

3. Turn the keyswitch to the ON position. Do not start the engine.

4. Select "WinFlash" from the "Utilities" menu on the electronic service tool.

**Note:** If "WinFlash" will not communicate with the ECM, refer to Troubleshooting, "Electronic Service Tool Will Not Communicate with ECM".

5. Flash program the flash file into the ECM.

   a. Select the engine ECM under the "Detected ECMs".

   b. Press the "Browse" button in order to select the part number of the flash file that will be programmed into the ECM.

   c. When the correct flash file is selected, press the "Open" button.

   d. Verify that the "File Values" match the application. If the "File Values" do not match the application, search for the correct flash file.

   e. When the correct flash file is selected, press the "Begin Flash" button.

   f. The electronic service tool will indicate when flash programming has been successfully completed.

6. Start the engine and check for proper operation.

7. Access the "Configuration" screen under the "Service" menu in order to determine the parameters that require programming. Look under the "Tattletale" column. All of the parameters should have a tattletale of 1 or more. If a parameter has a tattletale of 0, program that parameter.

### "WinFlash" Error Messages

If you receive any error messages during flash programming, click on the "Cancel" button in order to stop the process. Access the information about the "ECM Summary" under the "Information" menu. Ensure that you are programming the correct flash file for your engine.

i03434501

## Injector Trim File

The electronic service tool is used to load the injector trim files into the Electronic Control Module (ECM).

The injector trim files must be loaded into the ECM if any of the following conditions occur:

- An electronic unit injector is replaced.

REFERENCE ONLY

- The ECM is replaced.
- Diagnostic code 0268-02 is active.
- Electronic unit injectors are exchanged between cylinders.

**Exchanging Electronic Unit Injectors**

Exchanging electronic unit injectors can help determine if a fault is in the electronic unit injector or in the cylinder. If two electronic unit injectors that are currently installed in the engine are exchanged between cylinders, the injector trim files can also be exchanged. Press the "Exchange" button at the bottom of the "Injector Trim Calibration" screen on the electronic service tool. Select the two electronic unit injectors that will be exchanged and press the "OK" button. The tattletale for the electronic unit injectors that were exchanged will increase by one.

**Note:** The serial number for the electronic unit injector and the confirmation code number for the electronic unit injector are located on the electronic unit injector.

1. Record the serial number and the confirmation code number for each electronic unit injector.
2. Obtain the injector trim file by one of the following methods:
   - Select "Service Software Files" on the Perkins Internet.
   - Use the compact disc that is included with a replacement electronic unit injector.
3. Enter the serial number for the electronic unit injector in the search field.
4. Download the injector trim file to the PC. Repeat this procedure for each electronic unit injector, as required.
5. Connect the electronic service tool to the diagnostic connector. Refer to Troubleshooting, "Electronic Service Tools".
6. Turn the keyswitch to the ON position.
7. Select the following menu options on the electronic service tool:
   - Service
   - Calibrations
   - Injector Trim Calibration
8. Select the appropriate cylinder.
9. Click on the "Change" button.
10. Select the appropriate injector trim file from the PC.
11. Click on the "Open" button.
12. If you are prompted by the electronic service tool, enter the confirmation code number for the electronic unit injector into the field.
13. Click on the "OK" button.

    The injector trim file is loaded into the ECM.
14. Repeat the procedure for each cylinder, as required.

i02680013

# Mode Switch Setup

The Mode Switches can be used to change the performance characteristics of the engine. The electronic service tool is used to program the characteristics. Select the "Service" drop-down menu and then select "Engine Operating Mode Configuration". A maximum of two switches can be used. "Switch 1" is connected to J1:39 Mode Switch 1. "Switch 2" is connected to J1:46 Mode Switch 2. The other contact on both switches is connected to J1:35 Switch Return.

## Number of Switch Inputs

This is the total number of switches that will be used. The switches can be individual switches or a multiple rotary switch.

Table 8

| Range | Default |
|---|---|
| 0 to 2 | 0 |

## Mode Selection Number

This parameter is a non-programmable parameter that represents the number of possible combinations of switch positions. This parameter is based on the value that is programmed into the "Number of Switch Inputs" parameter.

## Mode Selection Switch Input 2 and Mode Selection Switch Input 1

The number of these non-programmable parameters that are visible depends on the value that is programmed into the "Number of Switch Inputs" parameter. "Open" signifies that the switch is in the OFF position. "Ground" signifies that the switch is in the ON position.

REFERENCE ONLY

## Enabled

If "Yes" is selected on the drop-down menu, the ECM is programmed to use the values that are programmed into "Rating Number", "Throttle 1 Droop Percentage", "Throttle 2 Droop Percentage" and "TSC1 Droop Percentage" for the given combination of switch positions.

Table 9

| Values | Default | Factory Password |
|---|---|---|
| Yes<br>No | No | Yes |

## Rating Number

This parameter is the engine rating that is used by the Electronic Control Module (ECM) for a given combination of switch positions. There is a maximum of four ratings in a flash file.

Table 10

| Range | Default | Factory Password |
|---|---|---|
| 1 to the maximum number of ratings in the currently installed Flash File | 1 | No |

## Rated Speed (RPM)

This parameter represents the engine speed that is selected when the mode switch or the mode switches are in a particular position.

Table 11

| Range | Default | Factory Password |
|---|---|---|
| "Programmed Low Idle" to "Programmed High Idle" | 5.0% | No |

## Throttle 1 Droop Percentage

This parameter represents the amount of droop that is applied to the "Throttle 1" input.

Table 12

| Range | Default | Factory Password |
|---|---|---|
| 0 to 10 percent | 5.0% | No |

## Throttle 2 Droop Percentage

This parameter represents the amount of droop that is applied to the "Throttle 2" input.

Table 13

| Range | Default | Factory Password |
|---|---|---|
| 0 to 10 percent | 5.0% | No |

## TSC1 Droop Percentage

This parameter represents the amount of droop that is applied to the "Torque Speed Control 1(TSC1)" input.

Table 14

| Range | Default | Factory Password |
|---|---|---|
| 0 to 10 percent | 5.0% | No |

i03434552

# Throttle Setup

The engine can have a digital throttle that uses a Pulse Width Modulated (PWM) signal, an analog throttle or a multi-position switched throttle. The Electronic Control Module (ECM) must be programmed for the type of throttle input that is being used.

Table 15

| Throttle 1 | Throttle 2 |
|---|---|
| PWM (Digital Throttle) | Analog Throttle |
| PWM (Digital Throttle) | None |
| PWM (Digital Throttle) | Multi-position Throttle Switch |
| Analog Throttle | Analog Throttle |
| Analog Throttle | None |
| Analog Throttle | Multi-position Throttle Switch |
| None | Analog Throttle |
| None | None |
| None | Multi-position Throttle Switch |
| Multi-position Throttle Switch | Analog Throttle |
| Multi-position Throttle Switch | None |

The throttle is set up using the electronic service tool. From the menu, select "Services". On the "Services" screen, select "Throttle Configuration". Select the type of throttle from the following list:

- No throttle
- Analog throttle

REFERENCE ONLY

- PWM throttle
- Multi-position switch

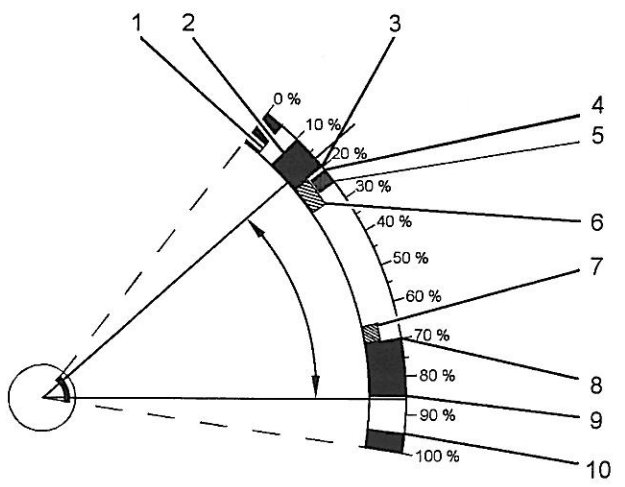



Illustration 18 g01785156

Typical Range of Throttle

(1) Lower Diagnostic Limit (Default=5)
(2) Lower Position Limit (Default=10)
(3) Initial Lower Position (Default=20)
(4) Idle Validation Minimum Off Threshold (Default=21)
(5) Idle Validation Maximum On Threshold (Default=25)
(6) Lower Dead Zone % (Default=5)
(7) Upper Dead Zone % (Default=5)
(8) Initial Upper Position (Default=70)
(9) Upper Position Limit (Default=85)
(10) Upper Diagnostic Limit (Default=90)

PWM throttles require additional programming. If a multi-position switch is selected, additional parameters must be programmed. Refer to Troubleshooting, "Multiposition Switch Setup". If an analog throttle is selected, the following parameters must be programmed into the ECM.

## Idle Validation

All analog throttles on mobile applications require an idle validation switch. If this parameter is programmed to "Yes", the ECM will look for this switch input on pin J1:5 for Idle Validation Switch 1 (IVS1) and J1:44 for Idle Validation Switch 2 (IVS2).

Table 16

| Values | Default |
|---|---|
| No<br>Yes | Yes |

## Idle Validation Minimum Off (Open) Threshold

This is the minimum throttle percentage that will be detected by the ECM when the IVS is ON (Closed).

If the ECM detects a throttle percentage below this value with the idle validation switch OFF (Open), a fault code will be generated and the engine will remain at idle.

Refer to Table 17 and Table 18.

REFERENCE ONLY

Table 17

| Throttle Position Sensor (TPS) | Idle Validation Switch (IVS) | Throttle Demand Output | Fault Status | Comment |
|---|---|---|---|---|
| TPS< IVS Min OFF | OFF | Minimum Position | Raise missing idle | Force throttle demand to minimum |
| TPS< IVS Min OFF | ON | Throttle Position | Clear missing idle | Normal operation |

Table 18

| Range | Default |
|---|---|
| 0 to 100% | 21% |

## Idle Validation Maximum On (Closed) Threshold

This is the maximum throttle percentage that will be detected by the ECM when the idle validation switch (IVS) is OFF (Open) . When the idle validation switch is OFF (Open) and the ECM detects a signal that is higher than the programmed value for IVS Max ON, the ECM will generate a fault code and the engine will remain at idle.

Refer to Table 19 and Table 20.

Table 19

| Throttle Position Sensor (TPS) | Idle Validation Switch (IVS) | Throttle Demand Output | Fault Status | Comment |
|---|---|---|---|---|
| TPS> IVS Max ON | OFF | Throttle Position | Clear unexpected idle | Normal operation |
| TPS< IVS Min Off | ON | Minimum Position | Raise unexpected idle. | Force throttle demand to minimum |

Table 20

| Range | Default |
|---|---|
| 0 to 100% | 25% |

## Lower Diagnostic Limit

This is the minimum throttle percentage that should be detected by the ECM in normal operation when the pedal is in the "off" position. A value below this limit will generate a short circuit diagnostic code. The range of this diagnostic detection area is from 0 percent to the programmed value for the lower position limit.

Table 21

| Range | Default |
|---|---|
| 0 to 100% | 5% |

## Upper Diagnostic Limit

This is the minimum throttle percentage that is detected by the ECM in normal operation when the pedal is in the maximum position. A value above this limit will generate an open circuit diagnostic code. The range of this diagnostic detection area is from the programmed value of the upper position limit to 100 percent.

Table 22

| Range | Default |
|---|---|
| 0 to 100% | 95% |

## Lower Position Limit

This is the minimum throttle percentage that will be interpreted by the ECM as zero throttle. This parameter is used with the value of initial lower position limit to make an allowance for manufacturing tolerances between different pedals.

REFERENCE ONLY

Table 23

| Range | Default |
|---|---|
| 0 to 100% | 10% |

## Upper Position Limit

This is the maximum throttle percentage that will be interpreted by the ECM as full throttle. This parameter is used with the value of the initial upper position limit to make an allowance for manufacturing tolerances between different pedals.

Table 24

| Range | Default |
|---|---|
| 0 to 100% | 85% |

## Initial Lower Position Limit

This is the maximum throttle percentage that will be interpreted by the ECM as zero throttle. This parameter is used with the value of the lower position limit to make an allowance for manufacturing tolerances between different pedals.

Table 25

| Range | Default |
|---|---|
| 0 to 100% | 20% |

## Initial Upper Position Limit

This is the minimum throttle percentage that will be interpreted by the ECM as full throttle. This parameter is used with the value of the upper position limit to make an allowance for manufacturing tolerances between different pedals.

Table 26

| Range | Default |
|---|---|
| 0 to 100% | 70% |

## Lower Dead Zone

This is a throttle range above the initial lower position limit before the engine will increase in rpm.

Table 27

| Range | Default |
|---|---|
| 0 to 100% | 8% |

## Upper Dead Zone

This is a throttle range that is below the initial upper position limit that does not allow the engine speed to increase.

Table 28

| Range | Default |
|---|---|
| 0 to 100% | 5% |

i02415246

# Multiposition Switch Setup

The multi-position throttle switch is an optional throttle input. A maximum of four switches can be used. Four switches will allow a maximum of 16 speeds to be selected.

When the multi-position switch is selected as the "Throttle Type" on the "Throttle Configuration Screen" of the electronic service tool, additional information is required.

## Number of Switch Inputs

This parameter is the total number of switches that will be used. The switches may be individual switches or a ganged rotary switch.

Table 29

| Range | Default |
|---|---|
| 1 to 4 | 1 |

## Physical Position

This parameter is non-programmable. The parameter is used to signify the position of the rotary switch.

## Input 4, Input 3, Input 2, Input 1

The number of these non-programmable parameters that are visible depends on the value that is programmed into the "Number of Switch Inputs" parameter. "Open" signifies that the switch is in the OFF position. "Ground" signifies that the switch is in the ON position.

## Physical Position Enabled

If "Yes" is selected from the drop-down menu, the Electronic Control Module (ECM) sets the engine rpm to the value that is programmed into the "Engine Speed" for the configuration of the switches that is defined for that Physical Position.

REFERENCE ONLY

Table 30

| Value | Default |
|---|---|
| No<br>Yes | No |

## Logical Position

The Logical Position is the order that is required by the user for a unique Physical Position.

Table 31

| Range | Default |
|---|---|
| 1 to 16 | 1 |

## Engine Speed (in RPM)

The "Engine Speed" is the programmed engine rpm for a particular position of the multi-position throttle switch.

If the ECM detects a switch combination that has been configured as "No", a fault code will be generated. In this situation, the ECM will ignore the multi-position switch until the keyswitch is cycled through OFF and ON.

Table 32

| Range | Default |
|---|---|
| Programmed Low Idle to Programmed High Idle | 0 |

REFERENCE ONLY

# Customer Specified Parameters

i02517248

## Customer Specified Parameters

Customer specified parameters allow the engine to be configured to the exact needs of the application.

Customer parameters may be changed repeatedly as a customer's operation changes.

The following information is a brief description of the customer specified parameters. The following parameter values are included with the descriptions:

- Minimum
- Maximum
- Default

## Engine Rating Parameter

### Rating Number

The rating number is the selected rating within a power rating family. The flash file defines the power rating family. The flash file can contain one to four ratings. The rating number defines the power rating that is used within the power rating family.

Table 33

| Minimum | Maximum | Default |
|---|---|---|
| 1 | 4 | 1 |

## Low/High Idle Parameters

### Low Idle Speed

The "Low Idle Speed" is the minimum engine rpm.

Table 34

| Minimum | Maximum | Default |
|---|---|---|
| 700 rpm | 1200 rpm | 750 rpm |

### High Idle Speed

The "High Idle Speed" is the maximum engine rpm.

Table 35

| Minimum | Maximum | Default |
|---|---|---|
| 1900 rpm | 2900 rpm | 2650 rpm |

## ECM Identification Parameter

### Equipment ID

"Equipment ID" is the identification of the equipment that is assigned by the customer. The "Equipment ID" is only for reference only by the customer. The "Equipment ID" is not required by the Electronic Control Module (ECM).

Table 36

| Value | Default |
|---|---|
| 17 digit<br>The available characters are dependent on the service tool that is being used. | Not programmed |

## PTO and Throttle Lock Parameters

### Throttle Lock Feature Installation Status

The "Throttle Lock Feature Installation Status" is used to turn on the throttle lock features. When this parameter is changed to "Installed", the "PTO engine Speed Setting", the "Throttle Lock Increment Speed Ramp Rate" and the "Throttle Lock Engine Set Speed Increment" parameters are active and the parameters can be programmed.

Table 37

| Value | Default |
|---|---|
| Not Installed<br>Installed | Not Installed |

### PTO Engine Speed Setting

The "PTO Engine Speed Setting" is the engine speed that is attained when the PTO switch is moved to the ON position. If the "PTO Engine Speed Setting" parameter is programmed, the feature is turned off. If the "PTO Engine Speed Setting" parameter is set to a value that is between "1" and the low idle speed, the parameter is set to the low idle speed value. If the "PTO Engine Speed Setting" parameter is set to a value that is higher than the high idle speed, the parameter is set to the high idle speed value.

Table 38

| Minimum | Maximum | Default |
|---|---|---|
| 0 rpm | 3000 rpm | 0 rpm |

REFERENCE ONLY

### Throttle Lock Increment Speed Ramp Rate

The "Throttle Lock Increment Speed Ramp Rate" is the rate of engine acceleration when the PTO switch is held in the ACCELERATE position. If this parameter is set to "0", the feature is turned off.

Table 39

| Minimum | Maximum | Default |
|---|---|---|
| 0 rpm/sec | 600 rpm/sec | 400 rpm/sec |

### Throttle Lock Engine Set Speed Increment

The "Throttle Lock Engine Set Speed Increment" controls the increase in engine speed when the PTO switch is briefly operated to ACCELERATE or DECELERATE. If this parameter is set to "0", the feature is turned off.

Table 40

| Minimum | Maximum | Default |
|---|---|---|
| 0 rpm | 200 rpm | 10 rpm |

## Miscellaneous

### Monitoring Mode Shutdowns

"Monitoring Mode Shutdowns" controls the shutdown feature that is associated with the engine monitoring feature. When this feature is enabled and an event code with a "-3" suffix is detected, the engine will be shut down.

Table 41

| Value | Default |
|---|---|
| Disabled<br>Enabled | Disabled |

### Monitoring Mode Derates

"Monitoring Mode Derates" controls the derate that is associated with the engine monitoring feature. When this feature is enabled and an event code with a "-2" is detected, the engine will be derated.

Table 42

| Value | Default |
|---|---|
| Disabled<br>Enabled | Enabled |

### Limp Home Desired Engine Speed

The "Limp Home Desired Engine Speed" is the maximum speed of the engine when the engine has been derated.

Table 43

| Minimum | Maximum | Default |
|---|---|---|
| 700 rpm | 1800 rpm | 1200 rpm |

## J1939 Continuous Fault Handling

### Remote Torque Speed Control Enable Status

The "Remote Torque Speed Control Enable Status" parameter determines the way that faults will be handled by the ECM when the "J1939 Torque Speed Control (TSC1)" message is used as a speed request input to the ECM. Programming the "Remote Torque Speed Control Enable Status" to "Enabled" will cause the ECM to display a fault code if a valid TSC1 message is not received by the engine ECM within 5 seconds of the engine starting. If the" Remote Torque Speed Control Enable Status" is programmed to "Disabled", the engine will display a 247-12 Data Link malfunction immediately after a loss of a TSC1 message. Program "Remote Torque Speed Control Enable Status" to "Enabled" if the ECM will always be receiving a TSC1 message.

Table 44

| Value | Default |
|---|---|
| Disabled<br>Enabled | Disabled |

## Configurable Inputs

### Coolant Level Sensor

A coolant level sensor is an optional switch input. Programming the "Coolant Level Sensor" parameter to "Enabled" notifies the ECM that a coolant level sensor input is present on pin J1:38. If this parameter is programmed to "Enabled" and the coolant level falls below the measured level, a "E2143-3" event code will be displayed.

Table 45

| Value | Default |
|---|---|
| Installed<br>Not Installed | Not Installed |

REFERENCE ONLY

## Air Filter Restriction Switch Installation Status

An "Air Filter Restriction Switch" is an optional switch input. Programming the "Air Filter Restriction Switch Installation Status" parameter to "Enabled" notifies the ECM that an input from the air filter restriction switch is present on pin J1:47. When this parameter is programmed to "Enabled" and the air filter restriction switch closes, an E172-1 or J107-15 event code will be displayed.

Table 46

| Value | Default |
|---|---|
| Installed<br>Not Installed | Not Installed |

## Fuel/Water Separator Switch Installation Status

A fuel/water separator switch is an optional switch input. Programming the "Fuel/Water Separator Switch Installation Status" parameter to "Enabled" notifies the ECM that a fuel/water separator switch input is present on pin J1:44. When this parameter is programmed to "Enabled" and the fuel/water separator switch closes, an E232-1 or J97-15 event code will be displayed.

Table 47

| Value | Default |
|---|---|
| Installed<br>Not Installed | Not Installed |

## User Defined Switch Installation Status

A user defined shutdown switch is an optional switch input. Programming the "User Defined Switch Installation Status" parameter to "Enabled" notifies the ECM that a user defined switch input is present on pin J1:48. If this parameter is programmed to "Enabled" and the user defined shutdown switch closes, the engine will shut down.

Table 48

| Value | Default |
|---|---|
| Installed<br>Not Installed | Not Installed |

REFERENCE ONLY

i02527577

# Customer Specified Parameters Table

Table 49

| Customer Specified Parameters | | |
|---|---|---|
| **ECM Parameter** | **Possible Values** | **Default Val** |
| **Engine Rating Parameter** | | |
| "Rating Number" | 1 to 4 | |
| **Low/High Idle Parameters** | | |
| "Low Idle Speed" | 700 to 1200 rpm | |
| "High Idle Speed" | 1900 to 2900 rpm | 2650 rpm |
| **ECM Identification Parameter** | | |
| "Equipment ID" | 17 Digits<br>Available characters are dependent on the service tool that is us | ot Programmed |
| **PTO and Throttle Lock Parameters** | | |
| "Throttle Lock Feature Installation Status" | Installed<br>Not Installed | Not Installed |
| "PTO Engine Speed Setting" | 0 to 300 rpm | 0 rpm |
| "Throttle Lock Increment Speed Ramp Rate" | 0 to 600 rpm/s | 400 rpm/sec |
| "Throttle Lock Engine Set Speed Increment" | 0 to 200 rpm | 10 rpm |
| **Miscellaneous** | | |
| "Monitoring Mode Shutdowns" | Disabled<br>Enabled | Disabled |
| "Monitoring Mode Derates" | Disabled<br>Enabled | Enabled |
| "Limp Home Desired Engine Speed" | 700 to 1800 rpm | 1200 rpm |
| **J1939 Continuous ault Handl** | | |
| "Remote Torque Speed Control Enable Status" | Disabled<br>Enabled | Disabled |
| **Configura e Inputs** | | |
| "Coolant Level Sens | Not Installed<br>Installed | Not Installed |
| "Air Filter Restriction Switch Installation Status | Not Installed<br>Installed | Not Installed |
| "Fuel/Water Separator Switch Installation Status" | Not Installed<br>Installed | Not Installed |
| "User Defined Switch Installation Status" | Not Installed<br>Installed | Not Installed |

REFERENCE ONLY

i02415254

# Customer Specified Parameters Worksheet

Table 50

| Customer Specified Parameters Worksheet | |
|---|---|
| **Engine Rating Parameter** | |
| "Rating Numbers" | |
| **Low/High Idle Parameters** | |
| "Low Idle Speed" | |
| "High Idle Speed" | |
| **ECM Identifications Parameters** | |
| "Equipment ID" | |
| **PTO and Throttle Lock Parameters** | |
| "Throttle Lock Feature Installation Status" | |
| "PTO Engine Speed Setting" | |
| "Throttle Lock Increment Speed Ramp Rate" | |
| "Throttle Lock Engine Set Speed Increment" | |
| **Miscellaneous** | |
| "Monitoring Mode Shutdowns" | |
| "Monitoring Mode Derates" | |
| "Limp Home Desired Engine Speed" | |
| **J1939 Continuous Fault Handling** | |
| "Remote Torque Speed Control Enable Status" | |
| **Configurable Inputs** | |
| "Coolant Level Sensor" | |
| "Air Filter Restriction Switch Installation Status" | |
| "Fuel/Water Separator Switch Installation Status" | |
| "User Defined Switch Installation Status" | |

REFERENCE ONLY

# System Configuration Parameters

i03436280

## System Configuration Parameters

System configuration parameters affect the emissions of the engine or the power of the engine. System configuration parameters are programmed at the factory. Normally, system configuration parameters would never need to be changed through the life of the engine. System configuration parameters must be reprogrammed if an Electronic Control Module (ECM) is replaced. System configuration parameters do not need to be reprogrammed if the ECM software is changed. Factory passwords are required to change these parameters. The following information is a description of the system configuration parameters.

### Full Load Setting

The full load setting is a number that represents the adjustment to the fuel system that was made at the factory in order to fine tune the fuel system. If the ECM is replaced, the full load setting must be reprogrammed in order to prevent a 0268-02 diagnostic code from becoming active.

### Full Torque Setting

Full torque setting is similar to full load setting. If the ECM is replaced, the full torque setting must be reprogrammed in order to prevent a 0268-02 diagnostic code from becoming active.

### Rating Interlock

The rating interlock is a code that prevents the use of an incorrect power rating and/or emission rating for a specific engine. Each horsepower rating and each emission certification has a different code to all other horsepower ratings and emission certifications.

When an ECM is replaced, this rating interlock code must match the code that is stored in the ECM. If the rating interlock code does not match the code that is stored in the ECM, both of the following situations will exist:

- The engine will not run.
- Diagnostic code 0253-02 (Personality Module erratic, intermittent or incorrect) will be active.

**Note:** The flash programming of a new rating interlock replaces the old rating interlock.

This code does not need to be programmed when the replacement ECM is for the same engine rating.

If the ECM is for a different engine rating, then the following components may need to be changed: pistons, fuel injectors, and other components. The engine information ratings plate must also be changed in order to reflect the new rating.

Some systems such as the cooling system or the transmission may also require changes when the engine is rerated. Contact the application OEM for further information.

### Engine Serial Number

When a new ECM is delivered, the engine serial number in the ECM is not programmed. The engine serial number should be programmed to match the engine serial number that is stamped on the engine information plate.

### ECM Software Release Date

This parameter is defined by the rating interlock and this parameter is not programmable. The ECM software release date is used to provide the version of the software. The Customer parameters and the software change levels can be monitored by this date. The date is provided in the month and the year (DEC08). DEC is the month (December). 08 is the year (2008).

REFERENCE ONLY

# Troubleshooting without a Diagnostic Code

i03436321

## Alternator Noise

**Note:** This is not an electronic system fault.

Refer to Systems Operation, Testing and Adjusting for information on possible electrical causes of this condition.

### Probable Causes

- Alternator drive belt
- Alternator mounting bracket
- Automatic tensioner
- Alternator drive pulley
- Alternator bearings

### Recommended Actions

#### Alternator Drive Belt

Inspect the condition of the alternator drive belt. If the alternator drive belt is worn or damaged, check that the drive belt and the pulley are correctly aligned. If the alignment is incorrect, investigate the cause of the misalignment. If the alignment is correct, replace the drive belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

#### Alternator Mounting Bracket

Inspect the alternator mounting bracket for cracks and wear. Repair the mounting bracket or replace the mounting bracket in order to ensure that the alternator drive belt and the alternator drive pulley are in alignment.

#### Automatic Tensioner

Check the tension on the alternator drive belts. If necessary, replace the automatic tensioner. Refer to Disassembly and Assembly, "Alternator - Remove" and Disassembly and Assembly, "Alternator - Install".

#### Alternator Drive Pulley

Remove the nut for the alternator drive pulley and then inspect the nut and the drive shaft. If no damage is found, install the nut and tighten the nut to the correct torque. Refer to Specifications, "Alternator and Regulator" for the correct torque.

#### Alternator Bearings

Check for excessive play of the shaft in the alternator. Check for wear in the alternator bearings. The alternator is a nonserviceable item. The alternator must be replaced if the bearings are worn. Refer to Disassembly and Assembly, "Alternator - Remove" and Disassembly and Assembly, "Alternator - Install".

i03436581

## Alternator Will Not Charge

**Note:** This is not an electronic system fault.

### Probable Causes

- Alternator drive belt
- Automatic tensioner
- Charging circuit
- Alternator

### Recommended Actions

#### Alternator Drive Belt

Inspect the condition of the alternator drive belt. If the alternator drive belt is worn or damaged, check that the drive belt for the alternator and the pulley are correctly aligned. If the alignment is incorrect, investigate the cause of the misalignment. If the alignment is correct, replace the drive belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".

#### Automatic Tensioner

Check the tension on the alternator drive belt. If necessary, replace the automatic tensioner. Refer to Disassembly and Assembly, "Alternator - Remove" and Disassembly and Assembly, "Alternator - Install".

#### Charging Circuit

Inspect the battery cables, wiring, and connections in the charging circuit. Clean all connections and tighten all connections. Replace any faulty parts.

REFERENCE ONLY

### Alternator

Verify that the alternator is operating correctly. Refer to Systems Operation, Testing and Adjusting, "Alternator - Test". The alternator is not a serviceable item. If the alternator is not operating correctly, the alternator must be replaced. Refer to Disassembly and Assembly, "Alternator - Remove" and Disassembly and Assembly , "Alternator - Install".

i02344743

# Battery

**Note:** This is not an electronic system problem.

## Probable Causes

- Charging circuit
- Battery
- Auxiliary device

## Recommended Actions

### Charging Circuit

If a fault in the battery charging circuit is suspected, refer to Troubleshooting, "Alternator Will Not Charge".

### Faulty Battery

1. Check that the battery is able to maintain a charge. Refer to Testing and Adjusting, "Battery - Test".
2. If the battery does not maintain a charge, replace the battery. Refer to the Operation and Maintenance Manual, "Battery - Replace".

### Auxiliary Device

1. Check that an auxiliary device has drained the battery by leaving it in the ON position.
2. Charge the battery.
3. Verify that the battery is able to maintain a charge when all auxiliary devices are switched off.

i03436601

# Can Not Reach Top Engine RPM

**Note:** If this fault occurs only under load, refer to Troubleshooting, "Low Power/Poor or No Response to Throttle".

## Probable Causes

- Diagnostic codes
- ECM parameters
- Throttle signal from the throttle position sensor
- Air intake and exhaust system
- Fuel supply
- Individual malfunctioning cylinders
- Electronic unit injectors

## Recommended Actions

### Diagnostic Codes

Check for active diagnostic codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

### ECM Parameters

1. Ensure that the fault is not being caused by an incorrect programmed parameter.
2. Use the electronic service tool in order to ensure that the correct mode is selected.
3. Use the electronic service tool to verify the correct engine rating for the engine.
4. Use the electronic service tool to verify the maximum engine speed limit.
5. Use the electronic service tool to verify the following parameters at maximum speed: the boost pressure, the smoke limit, the torque limit, and the amount of fuel that is delivered.
6. Use the electronic service tool to reset the parameters to the OEM specifications.
7. Check that the repairs have eliminated the fault.
8. If the repairs have not eliminated the fault proceed to "Throttle Signal for the Throttle Position Sensor".

REFERENCE ONLY

### Throttle Signal for the Throttle Position Sensor

1. Use the electronic service tool and observe the signal for the throttle position sensor. Make sure that the throttle reaches the 100% raw position and the calibrated position.
2. If the signal is erratic, refer to Troubleshooting, "Analog Throttle Position Sensor Circuit - Test" or refer to Troubleshooting, "Digital Throttle Position Sensor Circuit - Test".
3. If the engine has a throttle switch refer to Troubleshooting, "Throttle Switch Circuit - Test".
4. If the fault has not been eliminated, proceed to "Air Intake and Exhaust System".

### Air Intake and Exhaust System

1. Check the air filter restriction indicator, if equipped.
2. Ensure that the air filter is clean and serviceable.
3. Check the air intake and the exhaust system for the following defects:
   - Blockages
   - Restrictions
   - Damage to the air intake and exhaust lines and hoses
4. Make all necessary repairs to the engine.
5. Ensure that the repairs have eliminated the fault.
6. If the fault has not been eliminated, proceed to "Fuel Supply".

### Fuel Supply

1. Visually check the fuel tank for fuel. The fuel gauge may be faulty.
2. Ensure that the fuel supply valve is in the full OPEN position.
3. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).
4. Visually inspect the fuel supply lines for restrictions.
5. Check that the low pressure fuel lines are tight and secured properly.
6. Remove the fuel filters. Inspect the fuel filters for contamination. Install new fuel filters. Refer to the Operation and Maintenance Manual, "Fuel System Filter- Replace and Fuel System Primary Filter (Water Separator) Element - Replace". Determine the cause of the contamination.
7. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".
8. Check for air in the low pressure fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".
9. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System Prime".
10. Check the fuel pressure. Refer to Systems Operation, Testing and Adjusting, "Fuel System Pressure - Test".

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

NOTICE
Contact with high pressure fuel may cause personal injury or death. Wait 60 seconds after the engine has stopped to allow fuel pressure to purge before any service or repair is performed on the engine fuel lines.

11. If the high pressure fuel lines have a leak, the high pressure fuel lines must be replaced. Refer to Disassembly and Assembly, "Fuel injection lines - Remove and Fuel injection lines - Install".
12. If the repairs do not eliminate the fault, proceed to "Individual Malfunctioning Cylinders".

### Individual Malfunctioning Cylinders

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated cylinder is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the cylinder is operating below normal performance. Investigate the cause of the fault on any cylinder that is not operating. Investigate the cause of the fault on any cylinder that is operating below normal performance.

REFERENCE ONLY

2. If all cylinders have been checked and no faults were detected proceed to “Electronic Unit Injectors”.

### Electronic Unit Injectors

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.

2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, “Electronic Unit Injector - Remove”.

3. Install a new electronic unit injector. Refer to Disassembly and Assembly, “Electronic Unit Injector - Install”.

4. Repeat the test in 1. If the fault is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, “Electronic Unit Injector - Remove” and Disassembly and Assembly, “Electronic Unit Injector - Install”.

5. If the fault is still apparent, carefully repeat the diagnostic process from the beginning.

i03[illegible]7380

## Coolant in Engine Oil

**Note:** This is not an electronic system problem.

## Probable Causes

- Engine oil cooler
- Cylinder head gasket
- Cylinder head
- Cylinder block

## Recommended Actions

### Engine Oil Cooler

1. Drain the engine lubricating oil from the engine.

2. Check for leaks in the oil cooler assembly. Refer to Systems Operation, Testing and Adjusting, “Cooling System” for the correct procedure. If a leak is found, install a new oil cooler. Refer to Disassembly and Assembly, “Engine Oil Cooler - Remove” and Disassembly and Assembly, “Engine Oil Cooler - Install” for the correct procedure.

### Cylinder Head Gasket

1. Remove the cylinder head. Refer to Disassembly and Assembly, “Cylinder Head - Remove” for the correct procedure.

2. Inspect the cylinder head gasket for faults and any signs of leakage.

3. To fit a new cylinder head gasket, refer to Disassembly and Assembly, “Cylinder Head - Install” for the correct procedure.

4. If there was no obvious signs of a faulty head gasket proceed to “Cylinder Head”.

### Cylinder Head

1. Check the cylinder head for flatness. Refer to Systems Operation, Testing and Adjusting, “Cylinder Head - Inspect” for the correct procedure.

2. Check the mating face of the cylinder head for faults and signs of leakage. If a fault is found, replace the cylinder head. If signs of leakage are found, determine the cause of the leakage. Refer to Systems Operation, Testing and Adjusting, “Cylinder Head - Inspect” for the correct procedure.

3. Check the internal core plugs in the cylinder head for signs of leakage.

4. If the cylinder head is flat and if the cylinder head does not have any faults, refer to “Cylinder Block”.

### Cylinder Block

Inspect the top face of the cylinder block for faults and signs of leakage. If a fault is found, replace the cylinder block. If signs of leakage are found, determine the cause of the leakage. Refer to Systems Operation, Testing and Adjusting, “Cylinder Block - Inspect” for the correct procedure.

### Assembly after Repair

1. Install the cylinder head. Refer to Disassembly and Assembly, “Cylinder Head - Install”.

REFERENCE ONLY

2. Remove the oil filter element. Install a new engine oil filter element. Fill the engine with clean engine oil to the correct level. Refer to the Operation and Maintenance Manual, "Engine Oil and Filter - Change" for more information.

i03438642

# Coolant Temperature Is Too High

**Note:** This is not an electronic system fault.

## Probable Causes

- Radiator fins
- Coolant level
- Radiator cap and/or pressure relief valve
- Coolant temperature gauge
- Restriction in the coolant system
- Water temperature regulator
- Engine cooling fan
- Coolant pump
- Cylinder head gasket

## Recommended Actions

### Radiator Fins

Check the radiator fins for dirt, debris, and/or damage. Remove any dirt and/or debris. Do not straighten any bent fins.

### Coolant Level

1. Inspect the coolant level. If necessary, add coolant.
2. Check the cooling system for leaks. Repair any leaks immediately.

### Radiator Cap and/or Pressure Relief Valve

1. Pressure test the cooling system. Refer to Systems Operation, Testing and Adjusting, "Cooling System" for the correct procedure.
2. Check that the seating surfaces of the pressure relief valve and the radiator cap are clean and undamaged.
3. Check operation of the pressure relief valve and/or the radiator cap. If necessary, clean the components and/or replace the components.

### Coolant Temperature Gauge

Compare the reading for the coolant temperature from the electronic service tool to the reading for the coolant temperature from a calibrated test gauge.

### Restriction in the Coolant System

1. Visually inspect the cooling system for collapsed hoses and/or other restrictions.
2. Clean the radiator and flush the radiator. Refer to Systems Operation, Testing and Adjusting, "Cooling System".

### Water Temperature Regulator

Check the water temperature regulator for correct operation. Refer to Systems Operation, Testing and Adjusting, "Cooling System" for the proper procedure. If necessary, replace the water temperature regulator. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install" for more information.

### Engine Cooling Fan

1. Make sure that the engine cooling fan is correctly installed.
2. Make sure that the engine cooling fan is being driven correctly by the drive belt. If necessary, tighten the drive belt or replace the drive belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install".
3. Check the engine cooling fan for damage. If necessary, replace the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

### Coolant Pump

1. Inspect the impeller of the coolant pump for damage and/or erosion.
2. Make sure that the drive gear is not loose on the drive shaft of the coolant pump.
3. If necessary, replace the coolant pump. Refer to Disassembly and Assembly, "Water Pump - Remove" and Disassembly and Assembly, "Water Pump - Install".

REFERENCE ONLY

### Cylinder Head Gasket

Switch off the engine and allow the engine to cool to below normal working temperature. Remove the pressure cap for the coolant system. Start the engine and inspect the coolant for the presence of bubbles. If bubbles are present in the coolant, combustion gases may be entering the cooling system. Check the cylinder head gasket. Refer to the recommended action for the cylinder head gasket within Troubleshooting, "Coolant in Engine Oil". Check the cylinder head for flatness. Refer to the recommended action for checking flatness of the cylinder head within Systems Operation, Testing and Adjusting, "Cylinder Head - Inspect". Fit the pressure cap if there are no bubbles in the coolant.

i02413819

## ECM Will Not Accept Factory Passwords

### Probable Causes

One of the following items may not be recorded correctly on the electronic service tool:

- Passwords
- Serial numbers
- Total tattletale
- Reason code

### Recommended Actions

1. Verify that the correct passwords were entered. Check every character in each password. Remove the electrical power from the engine for 30 seconds and then retry.
2. Verify that the electronic service tool is on the "Factory Password" screen.
3. Use the electronic service tool to verify that the following information has been entered correctly:
   - Engine serial number
   - Serial number for the electronic control module
   - Serial number for the electronic service tool
   - Total tattletale
   - Reason code

i03438660

## ECM Will Not Communicate with Other Systems or Display Modules

### Probable Causes

- Electrical connectors
- Electronic Control Module (ECM)

### Recommended Actions

1. Connect the electronic service tool to the diagnostic connector. If the ECM does not communicate with the electronic service tool, refer to Troubleshooting, "Electronic Service Tool Will Not Communicate with ECM".
2. Ensure that the following items are correctly installed and undamaged. Refer to Troubleshooting, "Electrical Connectors - Inspect".
   - P1/J1 and P2/J2 connectors on the ECM
   - Wiring to display modules
   - Wiring to other control modules
3. Troubleshoot the Perkins Data Link for possible faults. Refer to Troubleshooting, "Data Link Circuit - Test".

i03438721

## Electronic Service Tool Will Not Communicate with ECM

### Probable Causes

- Configuration for the communications adapter
- Electrical connectors
- Communication adapter and/or cables
- Electrical power supply to the diagnostic connector
- Electronic service tool and related hardware
- Electrical power supply to the Electronic Control Module (ECM)
- Perkins Data Link

REFERENCE ONLY

## Recommended Actions

Start the engine. If the engine starts, but the ECM will not communicate with the electronic service tool, continue with this procedure. If the engine will not start, refer to Troubleshooting, "Engine Cranks but Will Not Start". If the engine will not crank, refer to Troubleshooting, "Engine Will Not Crank".

### Configuration for the Communications Adapter

1. Access "Preferences" under the "Utilities" menu on the electronic service tool.
2. Verify that the correct "Communications Interface Device" is selected.
3. Verify that the correct port is selected for use by the communication adapter.

**Note:** The most commonly used port is "COM 1".

4. Check for any hardware that is utilizing the same port as the communications adapter. If any devices are configured to use the same port, exit or close the software programs for that device.

### Electrical Connectors

Check for correct installation of the P1/J1 and P2/J2 ECM connectors and of the diagnostic connector. Refer to Troubleshooting, "Electrical Connectors - Inspect".

### Communication Adapter and/or Cable

1. Make sure that the firmware and driver files are the most current files that are available for the type of communication adapter that is being used. If the firmware and driver files do not match, the communication adapter will not communicate with the electronic service tool.
2. Disconnect the communication adapter and the cables from the diagnostic connector. Reconnect the communication adapter to the diagnostic connector.
3. Verify that the correct cable is being used between the communication adapter and the diagnostic connector. Refer to Troubleshooting, "Electronic Service Tools".
4. If the laptop computer is using a Windows operating system, restart the laptop computer in order to eliminate the possibility of a conflict in the software.

### Electrical Power Supply to the Diagnostic Connector

Verify that battery voltage is present between terminals A and B of the diagnostic connector. If the communication adapter is not receiving power, the LED display on the communication adapter will not be illuminated.

### Electronic Service Tool and Related Hardware

In order to eliminate the electronic service tool and the related hardware as the cause of the fault, connect the electronic service tool to a different engine. If the same fault occurs on a different engine, check the electronic service tool and the related hardware in order to determine the cause of the fault.

### Electrical Power Supply to the Electronic Control Module (ECM)

Check power to the ECM. Refer to Systems Operation, Testing and Adjusting, "Charging System Test".

**Note:** If the ECM is not receiving battery voltage, the ECM will not communicate.

### Perkins Data Link

Troubleshoot the Perkins Data Link for possible faults. Refer to Troubleshooting, "Data Link Circuit - Test".

i03438749

# Engine Cranks but Will Not Start

## Probable Causes

- Diagnostic codes
- Visible faults
- Air intake and exhaust system
- Primary speed/timing sensor
- Low pressure fuel system
- Secondary speed/timing sensor
- High pressure fuel system
- Glow plugs

REFERENCE ONLY

- Valve lash
- Low compression (cylinder pressure)

## Recommended Actions

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.

### Diagnostic Codes

Use one of the following methods to check for active diagnostic codes:

- The display on the control panel
- The electronic service tool

#### Display on the Control Panel

**Note:** The following procedure is only applicable if the application is equipped with a display on the control panel.

1. Check the display on the control panel for active diagnostic codes.
2. Troubleshoot any active codes before continuing with this procedure. Refer to Troubleshooting, "Troubleshooting with a Diagnostic Code".
3. Attempt to start the engine. If the engine will not start, proceed to "Visible Faults".

#### Electronic Service Tool

1. Connect the electronic service tool to the diagnostic connector.
2. Check for active diagnostic codes on the electronic service tool.
3. Troubleshoot any active codes before continuing with this procedure. Refer to Troubleshooting, "Troubleshooting with a Diagnostic Code".
4. Attempt to start the engine. If the engine will not start, proceed to "Visible Faults".

### Visible Faults

1. Visually inspect the engine for the following faults:
   - Missing components
   - Damaged components
   - Damaged electrical cables or loose electrical cables
   - Oil leaks
   - Fuel leaks
2. Check the following items:
   - Check for smoke from the exhaust when the engine is cranking. If smoke is seen during cranking, there may be a mechanical fault in the engine. Refer to "Low Compression (Cylinder Pressure)".
   - Check for the proper level of fuel, oil and coolant.
   - Ensure that the fuel supply valve (if equipped) is in the full OPEN position.
   - If the ambient temperature is below 0 °C (32 °F), make sure that the correct specification of engine oil and oil for the machine is used.
   - Check that the battery voltage is correct.
   - Use the electronic service tool to check the average cranking speed of the engine. If the cranking speed is less than 150 rpm, investigate the cause of the low cranking speed.
   - Make sure that all fuel filters are correctly installed.
   - Drain any water from the primary fuel filter/water separator.
3. Rectify any faults that are found during the visual checks.
4. Attempt to start the engine. If the engine will not start, proceed to "Air Intake and Exhaust System".

### Air Intake and Exhaust System

1. Check the air filter restriction indicator, if equipped.
2. Ensure that the air filter is clean and serviceable.
3. Check the air intake and exhaust systems for the following defects:
   - Blockages
   - Restrictions
   - Damage to lines or hoses
4. Repair any defects before attempting to restart the engine.
5. Attempt to start the engine. If the engine will not start, proceed to "Primary Speed/timing Sensor".

REFERENCE ONLY

## Primary Speed/timing Sensor

1. Disconnect connector P401 from the primary speed/timing sensor.
2. Attempt to start the engine.
3. If the engine starts, check for a fault in the circuit for the primary speed/timing sensor. Refer to Troubleshooting, "Engine Speed/Timing Sensor Circuit - Test".
4. If the engine does not start, inspect the timing ring on the crankshaft for misalignment.
5. If necessary, repair the timing ring. Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install".
6. Attempt to start the engine. If the engine will not start, proceed to "Low Pressure Fuel System".

## Low Pressure Fuel System

1. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).
2. Check for fuel supply lines that are restricted.
3. Check that the low pressure fuel lines are correctly installed.
4. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".
5. Check for air in the fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".
6. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".
7. Attempt to start the engine. If the engine will not start, continue with this procedure.
8. Replace the primary fuel filter and the secondary fuel filter. Refer to the Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace".
9. Attempt to start the engine. If the engine will not start, continue with this procedure.
10. Check the flow of fuel through the transfer pump. If the flow of fuel through the transfer pump is less than 250 mL per minute at 150 rpm, replace the transfer pump. Refer to Disassembly and Assembly, "Fuel Transfer Pump - Remove" and Disassembly and Assembly, "Fuel Transfer Pump - Install".
11. Attempt to start the engine. If the engine will not start, proceed to "Secondary Speed/timing Sensor".

## Secondary Speed/timing Sensor

1. Connect the electronic service tool to the diagnostic connector.
2. Check that the desired fuel rail pressure is at least 25 MPa (3625 psi) when the engine is cranking.
3. If the desired fuel rail pressure is less than 25 MPa (3625 psi), perform the following procedure:
   a. Use the electronic service tool to check the signal from the secondary speed/timing sensor while the engine is cranking.
   b. If the signal from the secondary speed/timing sensor is 0 rpm, investigate the secondary speed/timing sensor circuit. Refer to Troubleshooting, "Engine Speed/Timing Sensor Circuit - Test".
   c. If a fault is identified in the circuit for the secondary speed/timing sensor, repair the fault and then attempt to start the engine. If the engine will not start, proceed to "High Pressure Fuel System".
   d. If the signal from the secondary speed/timing sensor is greater than 0 rpm and the engine will not start, proceed to "High Pressure Fuel System".

## High Pressure Fuel System

1. Use the electronic service tool to check the absolute fuel rail pressure while the engine is cranking at a minimum speed of 150 rpm.
2. If the absolute fuel rail pressure is less than 25 MPa (3625 psi), perform the following procedure:
   a. Check that the inlet pressure at the fuel rail pump is greater than 50 kPa (7.25 psi). If the inlet pressure is less than 50 kPa (7.25 psi), repeat the diagnostic process from "Low Pressure Fuel System".
   b. Check for fuel leaks in the high pressure fuel system. Rectify any fuel leaks and then recheck the pressure in the fuel rail. If the fuel rail pressure is greater than 25 MPa (3625 psi), proceed to test step 3.
   c. Use the electronic service tool to perform a solenoid test on the fuel rail pump. Refer to Troubleshooting, "Fuel Rail Pump Solenoid - Test".

REFERENCE ONLY

**d.** If any service has been performed as a result of Step 2.c, attempt to start the engine. If the engine will not start, repeat the diagnostic process from "Diagnostic Codes".

**e.** Check the pressure relief valve in the fuel rail for leakage. If the pressure relief valve is leaking, replace the valve and recheck the pressure in the fuel rail.

**f.** If the pressure relief valve in the fuel rail is not leaking, check for fuel in the engine oil system. If fuel is suspected in the oil system, take an engine oil sample for analysis, refer to the Operation and Maintenance Manual, "Engine Oil Sample - Obtain". If the analysis confirms that there is fuel in the engine oil system, investigate the cause.

**g.** If fuel is not found in the oil system, check the electronic unit injectors for excessive fuel leak off. Refer to Systems Operation, Testing and Adjusting, "Injector Leakoff - Test".

**h.** If the leak off is greater than 38 mL (1.3 oz) in 30 seconds for a 6 cylinder engine or the leak off is greater than 25 mL (0.85 oz) in 30 seconds for a 4 cylinder engine, replace the electronic unit injectors.

**Note:** The fault is not in the fuel rail pump. Do not replace the pump.

**i.** If the leak off is less than 38 mL (1.3 oz) in 30 seconds for a 6 cylinder engine or the leak off is less than 25 mL (0.85 oz) in 30 seconds for a 4 cylinder engine, proceed to Test Step 3.

3. If the absolute fuel rail pressure is greater than 25 MPa (3625 psi), perform the following procedure:

**a.** Use the electronic service tool to make sure that the status of the electronic unit injectors is not "Disabled". If the injectors are disabled but the injectors were not intentionally disabled with the electronic service tool, proceed to test step 3.d.

**b.** If the electronic unit injectors are not disabled, use the electronic service tool to perform an injector solenoid test. Refer to Troubleshooting, "Injector Solenoid Circuit - Test".

**c.** If any service has been performed as a result of Step 3.b, attempt to start the engine. If the engine will not start, proceed to "Glow Plugs".

**d.** Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

**e.** Consult a Perkins dealer.

**Note:** This consultation can greatly reduce the repair time.

**f.** If the Perkins dealer recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

**g.** Attempt to start the engine. If the engine will not start, install the original ECM and then proceed to Test Step 3.l.

**h.** If the engine starts normally, stop the engine and then attempt to start the engine again. If the engine will not start at the second attempt, proceed to Test Step 3.k.

**i.** If the engine starts normally, disconnect the suspect ECM and then verify that the fault returns when the suspect ECM is installed.

**j.** If the engine will not start with the suspect ECM, replace the ECM. Check that the engine starts normally. If the engine starts normally, no further testing is required.

**k.** Replace the ECM again and then replace the fuel rail pump. Verify that the fault has been eliminated. If the engine will not start, proceed to "Glow Plugs".

**l.** Check the timing of the fuel rail pump. Refer to Systems Operation, Testing and Adjusting, "Fuel Injection Timing - Check".

**m.** If the timing of the fuel rail pump required adjustment and the engine will not start, proceed to "Glow Plugs".

**n.** If the timing of the fuel rail pump was correct, replace the fuel rail pump. If the engine will not start, proceed to "Glow Plugs".

## Glow Plugs

**Note:** Faulty glow plugs will only affect engine starting when the ambient temperature is below 10 °C (50 °F).

1. Check the operation of the glow plugs. Refer to Systems Operation, Testing and Adjusting, "Glow Plugs - Test".

2. If necessary, replace faulty glow plugs. Refer to Disassembly and Assembly, "Glow Plug - Remove and Install".

3. Attempt to start the engine. If the engine will not start, proceed to "Valve Lash".

REFERENCE ONLY

### Valve Lash

1. Check the valve lash. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

2. Attempt to start the engine. If the engine will not start, proceed to "Low Compression (Cylinder Pressure)".

### Low Compression (Cylinder Pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".

2. If low compression is noted on any cylinders, investigate the cause and rectify the cause.

   Possible causes of low compression are shown in the following list:

   - Loose glow plugs
   - Faulty piston
   - Faulty piston rings
   - Worn cylinder bores
   - Worn valves
   - Faulty cylinder head gasket
   - Damaged cylinder head

3. Perform all necessary repairs.

4. Ensure that the repairs have eliminated the fault.

i03438961

## Engine Has Early Wear

**Note:** This is not an electronic system fault.

### Probable Causes

- Multiple starts or cold operation
- Incorrect maintenance intervals
- Dirt in engine oil
- Incorrect oil
- Contaminated oil
- Leaks in air intake system
- Dirt in fuel
- Low oil pressure

## Recommended Actions

### Multiple Starts or Cold Operation

Frequent starting and stopping of the engine can cause early wear. Also, operation of the engine for short periods of time in cold conditions can cause early wear.

### Incorrect Maintenance Intervals

If the engine is not correctly maintained, early wear will occur.

Make sure that the engine is maintained at the correct maintenance intervals. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule".

### Dirt in Engine Oil

1. Drain the oil from the crankcase and refill the crankcase with clean engine oil. Install new engine oil filters. Refer to the Operation and Maintenance Manual for more information.

### Incorrect Oil

1. Check that the engine is filled with oil of the correct specification. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations".

2. If necessary, drain the engine oil system and refill the engine oil system. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

### Contaminated Oil

Check an oil sample for contamination with fuel. If contamination is found, investigate the cause.

### Leaks in Air Intake System

A leak in the air intake system may allow unfiltered air into the engine. Inspect the air intake system for streaks which may indicate a leakage of unfiltered air. Inspect all of the gaskets and the connections. Repair any leaks. Refer to Systems Operation, Testing and Adjusting, "Air Intake System" for more information.

REFERENCE ONLY

### Dirt in Fuel

1. Remove the fuel filters. Inspect the fuel filters for contamination. Install new fuel filters. Refer to the Operation and Maintenance Manual, "Fuel System Filter- Replace" and Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace". Determine the cause of the contamination.

2. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".

### Low Oil Pressure

Refer to Troubleshooting, "Low Engine Oil Pressure" for the testing procedure. Repair any identified faults.

i03438984

# Engine Misfires, Runs Rough or Is Unstable

**Note:** If the fault is intermittent and the fault cannot be duplicated, refer to Troubleshooting, "Intermittent Low Power or Power Cutout".

**Note:** If the fault only occurs under certain conditions, test the engine under those conditions. Examples of certain conditions are high rpm, full load, and engine operating temperature. Troubleshooting the symptoms under other conditions can give misleading results.

The probable root causes are listed in order below:

## Probable Causes

- Diagnostic codes
- Throttle position sensor
- Air intake and exhaust system
- Fuel supply
- Fuel rail pump
- Low compression (cylinder pressure)
- Individual malfunctioning cylinder
- Electronic unit injectors

## Recommended Actions

### Diagnostic Codes

Check for active diagnostic codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

### Throttle Position Sensor

1. Use the electronic service tool and observe the signal for the throttle position sensor. Make sure that the throttle reaches the 100% raw position and the calibrated position.

2. If the signal is erratic, refer to Troubleshooting, "Analog Throttle Position Sensor Circuit - Test" or Troubleshooting, "Digital Throttle Position Sensor Circuit - Test".

3. If the engine has a 10 position throttle switch refer to Troubleshooting, "Throttle Switch Circuit - Test".

4. If the repairs do not eliminate the fault proceed to "Air Intake and Exhaust System".

### Air Intake and Exhaust System

1. Check the air filter restriction indicator, if equipped.

2. Ensure that the air filter is clean and serviceable.

3. Check the air intake and exhaust systems for the following defects:

   - Blockages
   - Restrictions
   - Damage to lines or hoses

4. If the repairs do not eliminate the fault proceed to "Fuel Supply".

### Fuel Supply

1. Visually check the fuel tank for fuel. The fuel gauge may be faulty.

2. Ensure that the fuel supply valve (if equipped) is in the full OPEN position.

3. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).

4. Check the primary filter/water separator for water in the fuel.

5. Check for fuel supply lines that are restricted.

6. Check that the low pressure fuel lines are tight and secured properly.

REFERENCE ONLY

7. Check the fuel filters.

8. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".

9. Check for air in the fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".

10. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".

11. Check the fuel pressure. Refer to Systems Operation, Testing and Adjusting, "Fuel System Pressure - Test".

12. If the repair does not eliminate the fault refer to "Fuel Rail Pump".

## Fuel Rail Pump

**Note:** The fuel rail pump that is installed by the factory is a nonserviceable item. If any mechanical fault or any electrical fault occurs within the fuel rail pump then the fuel rail pump must be replaced.

1. Use the electronic service tool to select the correct screen display. Refer to Troubleshooting, "Troubleshooting with a Diagnostic Code".

2. If the fault is not eliminated, refer to "Low Compression (Cylinder Pressure)".

## Low Compression (Cylinder Pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".

2. If low compression is noted on any cylinders, investigate the cause and rectify the cause.

   Possible causes of low compression are shown in the following list:

   - Loose glow plugs
   - Faulty piston
   - Faulty piston rings
   - Worn cylinder bores
   - Worn valves
   - Faulty cylinder head gasket
   - Damaged cylinder head

3. Perform all necessary repairs.

4. Ensure that the repairs have eliminated the faults.

5. If the repair does not eliminate the fault refer to "Individual Malfunctioning Cylinders".

## Individual Malfunctioning Cylinders

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated cylinder is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the cylinder is operating below normal performance. Investigate the cause of the fault on any cylinder that is not operating. Investigate the cause of the fault on any cylinder that is operating below normal performance.

2. Rectify any faults.

3. If all cylinders have been checked and no problems were detected proceed to "Electronic Unit Injectors".

## Electronic Unit Injectors

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.

2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

3. Install a new electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

4. Repeat the test in 1. If the fault is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

5. If the fault is not eliminated, check for active diagnostic fault codes.

REFERENCE ONLY

i03439006

# Engine Oil in Cooling System

**Note:** This is not an electronic system fault.

## Probable Causes

- Engine oil cooler
- Cylinder head gasket
- Cylinder head
- Cylinder block

## Recommended Actions

### Engine Oil Cooler

1. Drain the coolant from the engine and the radiator. Drain the lubricating oil from the engine oil cooler. Refer to the Operation and Maintenance Manual for more information.
2. Check for leaks in the oil cooler assembly. Refer to Systems Operation, Testing and Adjusting, "Cooling System" for the correct procedure. If a leak is found, install a new oil cooler. Refer to Disassembly and Assembly, "Engine Oil Cooler - Remove" and Disassembly and Assembly, "Engine Oil Cooler - Install" for the correct procedure.

### Cylinder Head Gasket

1. Remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove" for the correct procedure.
2. Inspect the cylinder head gasket for faults and any signs of leakage.
3. To fit a new cylinder head gasket, refer to Disassembly and Assembly, "Cylinder Head - Install" for the correct procedure.
4. If there was no obvious signs of a faulty head gasket proceed to "Cylinder Head".

### Cylinder Head

1. Check the cylinder head for flatness. Refer to Systems Operation, Testing and Adjusting, "Cylinder Head - Inspect" for the correct procedure.
2. Check the mating face of the cylinder head for faults and signs of leakage. If a fault is found, replace the cylinder head. If signs of leakage are found, determine the cause of the leakage. Refer to Systems Operation, Testing and Adjusting, "Cylinder Head - Inspect" for the correct procedure.
3. If the cylinder head is flat and if the cylinder head does not have any faults, refer to "Cylinder Block".

### Cylinder Block

Inspect the top face of the cylinder block for faults and signs of leakage. If a fault is found, replace the cylinder block. If signs of leakage are found, determine the cause of the leakage. Refer to Systems Operation, Testing and Adjusting, "Cylinder Block - Inspect" for the correct procedure.

### Assembly after Repair

1. Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".
2. Replenish the engine with clean engine oil to the correct level. Refer to the Operation and Maintenance Manual, "Engine Oil and Filter - Change" for more information.
3. Fill the cooling system. Refer to the Operation and Maintenance Manual, "Cooling System Coolant (ELC) - Change".

i02534845

# Engine Speed Does Not Change

**Note:** Use this procedure only if the engine speed does not change. This fault will not occur in a generator set application.

## Probable Causes

- Diagnostic codes
- Multi-position throttle switch
- Throttle position sensor

## Recommended Repairs

### Diagnostic Codes

Check for active diagnostic codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

REFERENCE ONLY

Use the electronic service tool to check the setup of the throttle.

### Multi-position Throttle Switch

**Note:** When the engine is operating and the fault occurs, the configuration of the throttle will not change. The configuration of the throttle only needs to be checked if the engine has never run.

If a fault with the multi-position throttle switch is suspected, refer to Troubleshooting, "Throttle Switch Circuit - Test".

### Throttle Position Sensor

Refer to Troubleshooting, "Analog Throttle Position Sensor Circuit - Test" or Troubleshooting, "Digital Throttle Position Sensor Circuit - Test" if any of the following diagnostic codes are active:

- 0041-03 8 Volt DC Supply voltage above normal
- 0041-04 8 Volt DC Supply voltage below normal
- 0091-08 Throttle Position Sensor abnormal frequency, pulse width or period
- 0774-08 Sec Throttle Position Sensor abnormal frequency, pulse width or period

i03439009

## Engine Stalls at Low RPM

## Probable Causes

- Diagnostic codes
- Accessory equipment
- Power mode control (if equipped)
- Fuel supply
- Electronic unit injectors

## Recommended Actions

### Diagnostic Codes

Check for active diagnostic codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

### Accessory Equipment

Check all accessory equipment for faults that may create excessive load on the engine. Repair any damaged components or replace any damaged components.

If there are no faults with the accessory equipment, refer to "Power Mode Control (If Equipped)".

### Power Mode Control (If Equipped)

1. Check the data link. Refer to Troubleshooting, "Data Link Circuit - Test".
2. Check the engine wiring harness for defects. Refer to Troubleshooting, "Electrical Connectors - Inspect".
3. If there are no apparent faults, refer to "Fuel Supply".

### Fuel Supply

1. Visually check the fuel tank for fuel. The fuel gauge may be faulty.
2. Ensure that the fuel supply valve (if equipped) is in the full OPEN position.
3. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).
4. Check the primary filter/water separator for water in the fuel.
5. Check for fuel supply lines that are restricted.
6. Check that the low pressure fuel lines are tight and correctly secured.
7. Check the fuel filters.
8. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".
9. Check for air in the fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".
10. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".
11. Check the fuel pressure. Refer to Systems Operation, Testing and Adjusting, "Fuel System Pressure - Test".
12. If necessary, repair any faults.

REFERENCE ONLY

13. If there are no apparent faults, refer to "Electronic Unit Injectors".

### Electronic Unit Injectors

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.

2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

3. Install a new electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

4. Repeat the test in 1. If the fault is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

5. If the fault is not eliminated, check for active diagnostic fault codes.

## Engine Vibration

**Note:** This is not an electronic system fault.

Refer to Systems Operation, Testing and Adjusting for information on determining the cause of this condition.

### Probable Causes

- Vibration damper
- Engine supports
- Low compression (cylinder pressure)
- Individual malfunctioning cylinder
- Electronic unit injectors

## Recommended Actions

### Vibration Damper

Check the vibration damper for damage. Install a new vibration damper, if necessary. Inspect the mounting bolts for damage and/or for wear. Replace any damaged bolts. Refer to Disassembly and Assembly, "Vibration Damper and Pulley - Remove" and Disassembly and Assembly, "Vibration Damper and Pulley - Install".

Ensure that the repairs have eliminated the fault. If the vibration is still present proceed to "Engine Supports".

### Engine Supports

1. Check for any of the following conditions:
   - Loose engine supports
   - Loose mounting brackets or broken mounting brackets
   - Loose bolts
   - Omitted bolts
2. Make all necessary repairs. Ensure that the repairs have eliminated the fault. If the vibration is still present proceed to "Low Compression (Cylinder Pressure)".

### Low Compression (Cylinder Pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".

2. If low compression is noted on any cylinders, investigate the cause and rectify the fault.

   Possible causes of low compression are shown in the following list:
   - Loose glow plugs
   - Faulty piston
   - Faulty piston rings
   - Worn cylinder bores
   - Worn valves
   - Faulty cylinder head gasket
   - Damaged cylinder head

3. Perform all necessary repairs.

REFERENCE ONLY

4. Ensure that the repairs have eliminated the fault.

5. If the repair does not eliminate the fault refer to "Malfunctioning Individual Cylinder".

### Malfunctioning Individual Cylinder

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated cylinder is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the cylinder is operating below normal performance. Investigate the cause of the fault on any cylinder that is not operating. Investigate the cause of the fault on any cylinder that is operating below normal performance.

2. If all cylinders have been checked and no faults were detected proceed to "Electronic Unit Injectors".

### Electronic Unit Injectors

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.

2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

3. Install a new electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

4. Repeat the test in 1. If the fault is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

i03443681

# Engine Will Not Crank

## Probable Causes

- Battery cables and/or batteries
- Starting motor solenoid or starting circuit
- Starting motor and/or flywheel ring gear
- Electrical power supply
- Internal engine fault

## Recommended Repairs

### Battery Cables and/or Batteries

1. Inspect the main power switch, battery posts, and battery cables for loose connections and corrosion. If the battery cables are corroded, remove the battery cables and clean the battery cables. Clean the battery posts. Replace the cables. Tighten any loose connections.

2. Inspect the batteries.

   a. Charge the batteries.

   b. Load test the batteries. Refer to Systems Operation, Testing and Adjusting, "Battery - Test".

### Starting Motor Solenoid or Starting Circuit

1. Test the operation of the starting motor solenoid. Refer to Systems Operation, Testing and Adjusting, "Electric Starting System - Test".

2. Check the wiring to the starting motor solenoid.

### Starting Motor and/or Flywheel Ring Gear

1. Test the operation of the starting motor. Check the wiring for the starting motor. Refer to Systems Operation, Testing and Adjusting, "Electric Starting System - Test".

2. Inspect the pinion on the starting motor and the flywheel ring gear for damage.

### Electrical Power Supply

Check the electrical power supply. Refer to Troubleshooting, "Electrical Power Supply Circuit - Test".

### Internal Engine Fault

1. Remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

REFERENCE ONLY

2. Attempt to rotate the crankshaft through 360 degrees in both directions. If the crankshaft rotates correctly but fluid is expelled from the hole for the glow plug, investigate the cause of the fluid in the cylinder.

3. If the crankshaft does not rotate through 360 degrees in both directions, perform the following procedure:

   a. Disassemble the engine. Refer to Disassembly and Assembly.

   b. Inspect the internal components for the following conditions:

      - Seizure
      - Broken components
      - Bent components

4. If the crankshaft rotates correctly and no fluid is expelled, install the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".

i03443742

# Excessive Black Smoke

## Probable Causes

- Diagnostic codes
- ECM software
- Air intake system or exhaust system
- Valve lash
- Turbocharger
- Low compression (cylinder pressure)
- Individual malfunctioning cylinder
- Electronic unit injectors

## Recommended Actions

### Diagnostic Codes

Check for active diagnostic codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

### ECM Software

1. Connect the electronic service tool to the diagnostic connector and check for the following conditions:

   - Check for the correct engine serial number
   - Check for the correct arrangement number
   - Check for the correct software

2. Use the electronic service tool to verify any active diagnostic codes.

3. If diagnostic codes are present, the Electronic Control Module (ECM) must be reprogrammed with the correct information.

4. If the repairs have not eliminated the fault proceed to "Air Intake System or Exhaust System".

### Air Intake System or Exhaust System

1. Check the air filter restriction indicator, if equipped.

2. Ensure that the air filter is clean and serviceable.

3. Check the air intake and the exhaust system for the following defects:

   - Blockages
   - Restrictions
   - Damage to the air intake and exhaust lines and hoses

4. Make all necessary repairs to the engine.

5. If the fault has not been eliminated, proceed to "Valve Lash".

### Valve Lash

Ensure that the valve lash is correct. Reset the valve lash if it is not correct. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

If the repair does not eliminate the fault proceed to "Turbocharger".

### Turbocharger

**Note:** The turbocharger that is installed on this engine is a nonserviceable item. If any mechanical fault exists, then the turbocharger must be replaced.

1. Ensure that the mounting bolts for the turbocharger are tight.

REFERENCE ONLY

2. Check that the oil drain for the turbocharger is not blocked or restricted.

3. Check that the compressor housing for the turbocharger is free of dirt, debris and damage.

4. Check that the turbine housing for the turbocharger is free of dirt, debris and damage.

5. Check that the turbine blades rotate freely in the turbocharger.

6. Ensure that the wastegate on the turbocharger is adjusted correctly. Refer to Systems Operation, Testing and Adjusting, "Wastegate - Inspect". If the wastegate actuator is faulty, replace the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" and Disassembly and Assembly, "Turbocharger - Install".

7. If necessary, replace the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" and Disassembly and Assembly, "Turbocharger - Install".

8. Check that the repairs have eliminated the faults.

9. If the repairs have not eliminated the fault proceed to "Low Compression (Cylinder Pressure)".

### Low Compression (Cylinder Pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".

2. If low compression is noted on any cylinders, investigate the cause and rectify the cause.

   Possible causes of low compression are shown in the following list:

   - Loose glow plugs
   - Faulty piston
   - Faulty piston rings
   - Worn cylinder bores
   - Worn valves
   - Faulty cylinder head gasket
   - Damaged cylinder head

3. Perform all necessary repairs.

4. Ensure that the repairs have eliminated the faults.

5. If the repair does not eliminate the fault refer to "Individual Malfunctioning Cylinder".

### Individual Malfunctioning Cylinder

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated cylinder is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the cylinder is operating below normal performance. Investigate the cause of the fault on any cylinder that is not operating. Investigate the cause of the fault on any cylinder that is operating below normal performance.

2. If all cylinders have been checked and no problems were detected, proceed to "Electronic Unit Injectors".

### Electronic Unit Injectors

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.

2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

3. Install a new electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

4. Repeat the test in 1. If the fault is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

5. If the fault is not eliminated, refer to the Troubleshooting Guide for the application.

i03443800

## Excessive Engine Oil Consumption

### Probable Causes

- Misreading oil level

REFERENCE ONLY

- Oil leaks
- Engine crankcase breather
- Oil level
- Air intake and exhaust system
- Turbocharger
- Low compression (cylinder pressure)

## Recommended Actions

### Misreading Oil Level

1. Accurately measure the consumption of oil and fuel over a period of 50 engine hours.
2. If the oil consumption is greater than 0.2% of the fuel consumption, use the following procedure in order to investigate the cause of the high oil consumption.

### Oil Leaks

1. Check for evidence of oil leaks on the engine.
2. Rectify any oil leaks from the engine.
3. Check for evidence of oil in the coolant. Refer to Troubleshooting, "Engine Oil in Cooling System".
4. If no oil leaks are identified, refer to "Engine Crankcase Breather".

### Engine Crankcase Breather

1. Check the engine crankcase breather for blockage or restrictions.
2. Check for excessive oil from the outlet of the breather.
3. Repair any defects. Verify that the repair has eliminated the fault.
4. If no faults are found, refer to "Oil Level".

### Oil Level

1. Check the oil level in the engine.
2. If the oil level is high, check for contamination of the oil with coolant. Refer to Troubleshooting, "Coolant in Engine Oil".
3. If no contamination is identified, remove any excess oil.
4. If the oil level is satisfactory, refer to "Air Intake and Exhaust System".

### Air Intake and Exhaust System

1. Check the air filter restriction indicator, if equipped.
2. Ensure that the air filter is clean and serviceable.
3. Check the air intake and the exhaust system for the following defects:
   - Blockages
   - Restrictions
   - Damage to the air intake and exhaust lines and hoses
4. Make all necessary repairs to the engine.
5. Ensure that the repairs have eliminated the diagnostic code.
6. If no faults are found, refer to "Turbocharger".

### Turbocharger

**Note:** The turbocharger that is installed on this engine is a nonserviceable item. If any mechanical fault exists, then the turbocharger must be replaced.

1. Check that the oil drain for the turbocharger is not blocked or restricted.
2. Check the turbocharger for evidence of internal oil leaks.
3. If necessary, replace the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" and Disassembly and Assembly, "Turbocharger - Install".
4. Check that the repairs have eliminated the faults.
5. If the repairs have not eliminated the fault proceed to "Low Compression (cylinder pressure)".

### Low Compression (cylinder pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".
2. If low compression is noted on any cylinders, investigate the cause and rectify the cause.

   Possible causes of low compression are shown in the following list:

   - Loose glow plugs

REFERENCE ONLY

- Faulty piston
- Worn piston rings
- Worn cylinder bores
- Worn valves
- Faulty cylinder head gasket
- Damaged cylinder head

3. Perform all necessary repairs.
4. Ensure that the repairs have eliminated the faults.
5. If the fault is not eliminated, refer to the Troubleshooting Guide for the application.

i03444021

# Excessive Fuel Consumption

## Probable Causes

- Diagnostic codes
- Misreading of fuel level
- Fuel quality
- Quality of oil
- Low engine temperature
- Prolonged operation at idle speed
- Engine operating speed
- Air intake and exhaust system
- Reduced pressure of intake air
- Excessive valve lash
- Failure of the primary speed/timing sensor

## Recommended Actions

### Diagnostic Codes

1. Use the electronic service tool to check for any diagnostic codes that may be related to high fuel consumption.

### Misreading of Fuel Level

1. Monitor the fuel consumption over a period of 50 engine hours. If the fuel consumption is excessive, perform the following procedure.

### Fuel Quality

1. The quality of the fuel that is used in the engine will affect the rate of fuel consumption. Refer to "General Fuel Information" in the Operation and Maintenance Manual, "Refill Capacities".
2. If the fuel is not of an acceptable quality, drain the fuel system and replace the fuel filters. Refill the fuel system with fuel of an acceptable quality. Refer to the applicable section in the Operation and Maintenance Manual.
3. If the fuel is of an acceptable quality, refer to "Quality of Oil".

### Quality of Oil

1. The nominal viscosity of the lubricating oil that is used in the engine will affect the rate of fuel consumption. The viscosity of lubricating oil is defined by the SAE grade of the lubricating oil. The grade of the lubricating oil must be correct for the ambient conditions. Lubricating oil that is intended for use in high ambient temperatures will have a negative effect upon the rate of fuel consumption in cold ambient temperatures. Refer to "Engine Oil" in the Operation and Maintenance Manual, "Refill Capacities".
2. The actual viscosity of the lubricating oil that is used in the engine will change throughout the service life of the oil. Lubricating oil that is heavily contaminated will have a negative effect upon the rate of fuel consumption.
3. If the oil is not of an acceptable quality or if the oil has exceeded the service life, drain the oil system and replace the oil filters. Refill the oil system with oil of an acceptable quality. Refer to the applicable sections in the Operation and Maintenance Manual.
4. If the oil is of an acceptable quality, refer to "Operation in Cold Conditions".

### Low Engine Temperature

1. The operating temperature of the engine will affect the rate of fuel consumption. Operation of the engine below the correct temperature will increase fuel consumption. Failure of the water temperature regulator can prevent the engine from operating at the correct temperature.

REFERENCE ONLY

2. If the engine operating temperature is low, check the operation of the water temperature regulator. If the water temperature regulator does not operate correctly, a new water temperature regulator must be installed. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

## Prolonged Operation at Idle Speed

Prolonged operation of the engine at idle speed increases fuel consumption.

When the engine is operated at idle speed, the fuel that is consumed provides no useful work. Prolonged operation at idle speed will cause a measurable deterioration in the overall fuel consumption of the engine.

Operation of the engine for long periods at idle speed will cause a deterioration of the internal components of the engine. A deterioration of the internal components of the engine will increase fuel consumption.

## Engine Operating Speed

The operating speed of the engine will affect the rate of fuel consumption.

High engine speed will increase fuel consumption. At high engine speeds, internal power losses in the engine increase and more power is required to drive the alternator and the fan. These power losses increase fuel consumption.

Lugging down the engine to a low engine speed will increase fuel consumption. At low engine speeds, the combustion efficiency of the engine is reduced. This will require more fuel to be used.

## Air Inlet and Exhaust System

Leakage of gas or an increased restriction in either the air intake or the exhaust system can reduce the flow of combustion gas through the engine. A change in the flow of combustion air into the engine adversely affects combustion efficiency and the rate of fuel consumption.

1. Check the air intake system for leakage or restrictions. Refer to Systems Operation, Testing and Adjusting, "Air Inlet and Exhaust System".

2. Check the exhaust system for leakage or restrictions. Refer to Systems Operation, Testing and Adjusting, "Air Inlet and Exhaust System".

3. Repair all defects. Verify that the repair has eliminated the fault.

## Reduced Pressure of Intake Air

1. If the pressure of the intake air at the intake manifold is lower than normal, either the speed of the engine will need to be higher or more fuel must be injected in order to produce the same power. Either of these conditions will increase the fuel consumption.

**Note:** If the engine is equipped with a wastegate regulator, low pressure in the intake manifold will create a 526-07 diagnostic code.

2. Check the pipe from the outlet of the turbocharger compressor to the intake manifold for leaks. If necessary, repair any leaks.

3. Check for the correct operation of the wastegate in the turbocharger. Refer to Systems Operation, Testing and Adjusting, "Turbocharger Wastegate - Test".

4. If the turbocharger or the wastegate is suspected as being faulty, replace the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" and Disassembly and Assembly, "Turbocharger - Install".

## Excessive Valve Lash

Excessive valve lash will cause a change in the timing of the opening and closing of the inlet and exhaust valves. Excessive valve lash can cause a reduction of the flow of combustion air into the engine. Reduced flow of combustion air will increase the fuel consumption rate.

Refer to the Troubleshooting Guide, "Excessive Valve Lash".

## Failure of the Primary Speed/Timing Sensor

If the primary speed/timing sensor fails, the engine will continue to operate using the signal from the secondary speed/timing sensor on the fuel rail pump. The secondary speed/timing sensor is less precise than the primary speed/timing sensor. Timing differences between the secondary speed/timing sensor and the primary speed/timing sensor may cause an increase in fuel consumption.

1. Use the electronic service tool to check for active diagnostic codes that relate to the primary speed/timing sensor.

2. If necessary, replace the primary speed/timing sensor. Refer to Disassembly and Assembly, "Speed/Timing Sensor - Remove and Install".

REFERENCE ONLY

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# Excessive Valve Lash

**Note:** This is not an electronic system fault.

## Probable Causes

- Lubrication
- Valve train components
- Valve lash

## Recommended Actions

### Lubrication

1. Remove the valve mechanism covers. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install" for the correct procedure.
2. Crank the engine and check the lubrication in the valve compartment. Ensure that there is adequate engine oil flow in the valve compartment. The passages for the engine oil must be clean.

**Note:** Do not run the engine without the valve mechanism cover.

### Valve Train Components

1. Inspect the following components of the valve train:
   - Rocker arms
   - Valve bridges
   - Pushrods
   - Valve lifters
   - Camshaft
   - Valve stems
   - Rocker shafts
2. Check the components for the following conditions: abnormal wear, excessive wear, straightness, and cleanliness. If necessary, use new parts for replacement.

**Note:** If the camshaft is replaced, new valve lifters must also be used.

### Valve Lash

Adjust the valve lash of the engine. Refer to Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust" for the correct procedure.

i03447260

# Excessive White Smoke

**Note:** Some white smoke may be present during cold start-up conditions when the engine is operating normally. If the white smoke persists, there may be a fault.

## Probable Causes

- Coolant temperature sensor circuit
- Low coolant temperature
- Glow plugs
- Fuel quality
- Valve lash
- Low compression (cylinder pressure)
- Individual malfunctioning cylinder

## Recommended Actions

### Coolant Temperature Sensor Circuit

1. Connect the electronic service tool to the diagnostic connector.
2. Monitor the display screen on the electronic service tool in order to verify the presence of active diagnostic codes for the coolant temperature. Refer to Troubleshooting, "Engine Temperature Sensor Open or Short Circuit - Test".
3. If the fault has not been eliminated, proceed to "Low Coolant Temperature".

### Low Coolant Temperature

Check that the water temperature regulator is operating correctly. Refer to Systems Operation, Testing and Adjusting, "Water Temperature Regulator - Test".

If the water temperature regulator is operating correctly, refer to "Glow Plugs".

REFERENCE ONLY

### Glow Plugs

1. Check for proper operation of the glow plugs. Refer to Systems Operation, Testing and Adjusting, "Glow Plugs - Test".

2. If the repairs do not eliminate the fault refer to "Fuel Quality".

### Fuel Quality

1. Check the diesel fuel for quality. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".

**Note:** Diesel fuel with a low cetane value is likely to cause white smoke.

2. If the repair does not eliminate the fault refer to "Valve Lash".

### Valve Lash

1. Ensure that the valve lash is correct. Refer to Systems Operation, Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

2. If the repair does not eliminate the fault proceed to "Low Compression (cylinder pressure)".

### Low Compression (cylinder pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".

2. If low compression is noted on any cylinders, investigate the cause and rectify the cause.

   Possible causes of low compression are shown in the following list:

   - Loose glow plugs
   - Faulty piston
   - Faulty piston rings
   - Worn cylinder bores
   - Worn valves
   - Faulty cylinder head gasket
   - Damaged cylinder head

3. Perform all necessary repairs.

4. Ensure that the repairs have eliminated the faults.

5. If the repair does not eliminate the fault refer to "Individual Malfunctioning Cylinder".

### Individual Malfunctioning Cylinder

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated cylinder is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the cylinder is operating below normal performance. Investigate the cause of the fault on any cylinder that is not operating. Investigate the cause of the fault on any cylinder that is operating below normal performance.

2. Rectify any faults.

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## Intake Air Temperature Is Too High

## Probable Causes

- High ambient air temperature
- Intake air restriction and/or high altitude
- Intake air from a heated area
- Intake manifold air temperature sensor and/or circuit
- Insufficient ambient air flow over the engine
- Reduced ambient air flow through the air charge cooler
- Reduced flow of intake air through the air charge cooler

## Recommended Actions

### High Ambient Air Temperature

1. Determine if the ambient air temperature is within the design specifications for the cooling system and the air charge cooler.

2. When the ambient temperature exceeds the capability of the cooling system or the air charge cooler, operate the engine at a reduced load or operate the engine at a reduced speed.

3. When possible, modify the cooling system and the air charge cooler in order to make the system suitable for local conditions.

REFERENCE ONLY

### Intake Air Restriction and/or High Altitude

Low air pressure at the air intake for the turbocharger can be caused by a restriction in the air intake or a high altitude. When the pressure of the intake air is low, the turbocharger (if equipped) works harder in order to achieve the desired intake manifold pressure. This increases intake air temperature.

Measure the intake manifold pressure while the engine is operating under load. For specific data, refer to the Perkins Technical Marketing Information for the engine.

#### Intake Air Restriction

1. Check for blocked air filters. Check for obstructions in the air intake.
2. Replace the air filters or remove the obstruction from the air intake.

#### High Altitude

Make sure that the settings for the engine are correct for the altitude.

### Intake Air from a Heated Area

1. Ensure that the air inlet system is not receiving air from a heated area.
2. If necessary, relocate the air supply to the intake manifold to the outside of the engine enclosure.
3. Check for air leaks in the pipe between the air inlet and the inlet to the turbocharger compressor.

### Intake Manifold Air Temperature Sensor and/or the Circuit

1. Allow the intake manifold air temperature sensor to cool and remove the sensor. Check the reading for the intake air temperature. If the sensor is operating correctly, the reading and the ambient temperature are approximately equal.
2. If the readings are approximately equal, reinstall the sensor.
3. If the reading is not correct, replace the sensor with a sensor that is known to be good. Verify that the fault is rectified.

### Insufficient Ambient Air Flow over the Engine

1. If equipped, check the condition of the cooling fan and the drive belt.
2. If equipped, check that the cooling fan is operating correctly.

### Reduced Ambient Air Flow through the Air Charge Cooler

1. Check that the ambient air flow through the air charge cooler is not obstructed.
2. Inspect the air charge cooler for contamination and/or bent fins or damaged fins.
3. If necessary, clean the air charge cooler.
4. If necessary, carefully straighten any bent fins on the air charge cooler.

### Reduced Flow of Intake Air through the Air Charge Cooler

1. Check for contamination in the air pipe that connects the turbocharger to the air charge cooler.
   a. If dirt is found in the air pipe from the turbocharger to the air charge cooler, check all of the air inlet pipes upstream of the turbocharger for leaks.
   b. Clean any contaminated air inlet pipes or replace all contaminated air inlet pipes.
   c. Service the air cleaner and replace the air cleaner element.
2. If a thick oil film is found in the air pipe, inspect the turbocharger compressor housing. Examine both the inlet to the turbocharger compressor housing and the outlet from the turbocharger compressor for oil.
   a. If oil is found in the inlet to the turbocharger compressor housing, the oil originates from the engine crankcase breather.
   b. If oil is found in the outlet from the turbocharger compressor housing but oil is not found in the inlet to the compressor housing, the oil originates from the seals for the turbocharger bearings.

i03447282

## Intermittent Engine Shutdown

**Note:** Use this procedure only if the engine shuts down completely and the engine must be restarted.

### Probable Causes

- Diagnostic codes
- Air Intake

REFERENCE ONLY

- Electrical connectors
- Fuel supply

## Recommended Actions

### Diagnostic Codes

Check for any event and active diagnostic codes on the electronic service tool. Troubleshoot any active codes or recently logged diagnostic codes before continuing with this procedure.

### Air Intake

1. Check the air filter for blockage or restriction.
2. Check the air intake duct for blockages or restrictions.

### Electrical Connectors

1. Check for correct installation of ECM connectors at the following locations:
   - P1 ECM connector
   - P2 ECM connector
   - P532 Fuel rail pump solenoid connector
2. Refer to Troubleshooting, "Electrical Connectors - Inspect".
3. Inspect the battery wires from the ECM to the battery compartment. Refer to the Schematic Diagram. Inspect the wires and the power relay. Check the power and ground connections to the ECM. Refer to the schematic diagrams for more information.
4. Select the "Wiggle Test" from the diagnostic tests on the electronic service tool.
5. Choose the appropriate group of parameters to monitor.
6. Press the "Start" button. Wiggle the wiring harness in order to reproduce intermittent faults.

**Note:** If an intermittent fault exists, the status will be highlighted and an audible beep will be heard.

7. Repair any faults and ensure that the symptom has been cleared. If the fault is still present, refer to "Fuel Supply".

### Fuel Supply

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.

1. Visually check the fuel tank for fuel. The fuel gauge may be faulty.
2. Ensure that the fuel supply valve (if equipped) is in the full OPEN position.
3. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).
4. Check the primary filter/water separator for water in the fuel.
5. Check for fuel supply lines that are restricted.
6. Check that the low pressure fuel lines are tight and secured properly.
7. Check the fuel filters.
8. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".
9. Check for air in the fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".
10. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".
11. Check the fuel pressure. Refer to Systems Operation, Testing and Adjusting, "Fuel System Pressure - Test".

i03447400

# Intermittent Low Power or Power Cutout

**Note:** Use this procedure only if the engine does not shut down completely.

## Probable Causes

- Diagnostic codes
- Electrical connectors
- ECM connection
- Fuel supply

REFERENCE ONLY

- Intake manifold pressure

## Recommended Actions

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.

### Diagnostic Codes

Check for active diagnostic codes and event codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

### Electrical Connectors

1. Inspect the electrical connectors. Refer to Troubleshooting, "Electrical Connectors - Inspect".
2. Repair any faulty electrical connectors or replaceany faulty electrical connectors.
3. Ensure that all the connector seals are in place and that the connectors have been correctly installed.
4. Ensure that the repairs have eliminated the fault. If the fault has not been eliminated proceed to "ECM Connection".

### ECM Connection

1. If a fault is suspected with the ECM power and ground connections refer to Troubleshooting, "Electrical Power Supply Circuit - Test".
2. Verify that the ECM connections for the power and ground connections at the fuel pump are correctly connected.
3. Repair any faults and ensure that the faults have been eliminated.
4. If the repairs do not eliminate the faults, proceed to "Fuel Supply".

### Fuel Supply

1. Visually check the fuel tank for fuel. The fuel gauge may be faulty.
2. Ensure that the fuel supply valve (if equipped) is in the full OPEN position.
3. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).
4. Check the primary filter/water separator for water in the fuel.
5. Check for fuel supply lines that are restricted.
6. Check that the low pressure fuel lines are tight and secured properly.
7. Check the fuel filters.
8. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".
9. Check for air in the fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".
10. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".
11. Check the fuel pressure. Start the engine and then use the electronic service tool to check that the pressure in the fuel rail is more than 18000 kPa (2610 psi).
12. If the repair does not eliminate the fault refer to "Intake Manifold Pressure".

### Intake Manifold Pressure

1. Use the electronic service tool to verify the intake manifold pressure.
2. Turn the start switch to the ON position.
3. The intake manifold pressure should read 0 ± 0.5 kPa (0 ± 0.07 psi). If the intake manifold pressure is not within the limits, perform the following steps.
4. Check the air filter restriction indicator, if equipped.
5. Ensure that the air filter is clean and serviceable.
6. Check the air intake and the exhaust system for the following defects:
   - Blockages
   - Restrictions
   - Damage to the air intake and exhaust lines and hoses

REFERENCE ONLY

i03447422

# Low Engine Oil Pressure

NOTICE
Do not operate the engine with low oil pressure. Engine damage will result. If measured oil pressure is low, discontinue engine operation until the problem is corrected.

## Probable Causes

- Engine oil level
- Oil specification
- Engine oil pressure gauge
- Engine oil filter
- Engine oil cooler
- Piston cooling jets
- Engine oil suction tube
- Engine oil pump
- Bearing clearance

## Recommended Actions

### Engine Oil Level

1. Inspect the engine oil level. If necessary, add oil.
2. If the fault is still apparent, proceed to "Oil Specification".

### Oil Specification

1. Make sure that engine oil of the correct specification is used. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations".
2. If necessary, drain the oil system and refill the oil system with engine oil of the correct specification. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".
3. If the fault is still apparent, proceed to "Engine Oil Pressure Gauge".

### Engine Oil Pressure Gauge

1. Check the actual engine oil pressure with a calibrated test gauge. Compare the oil pressure reading from the electronic service tool to the pressure on the test gauge.
2. If no difference is noted between the indicated oil pressures, proceed to "Engine Oil Filter".

### Engine Oil Filter

1. Remove the engine oil filter. Refer to the Operation and Maintenance Manual, "Engine Oil and Filter - Change".
2. Inspect the engine oil filter for evidence of blockage.
3. Install a new engine oil filter. Refer to the Operation and Maintenance Manual, "Engine Oil and Filter - Change".
4. If the fault is still apparent, proceed to "Engine Oil Cooler".

### Engine Oil Cooler

1. If oil flow or coolant flow through the oil cooler is suspected of being low, replace the oil cooler. Refer to Disassembly and Assembly, "Engine Oil Cooler - Remove" and Disassembly and Assembly, "Engine Oil Cooler - Install".
2. If the fault is still apparent, proceed to "Piston Cooling Jets".

### Piston Cooling Jets

1. Inspect the piston cooling jets for damage. Replace any piston cooling jet that appears to be cracked, broken or missing. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".
2. If no damage is found, proceed to "Engine Oil Suction Tube".

### Engine Oil Suction Tube

1. Check the inlet screen on the oil suction tube and remove any material that may be restricting oil flow.
2. Check the joints of the oil suction tube for cracks or a damaged joint that may allow air leakage into the supply to the oil pump.
3. If no faults are found, proceed to "Engine Oil Pump".

REFERENCE ONLY

### Engine Oil Pump

1. Inspect the components of the engine oil pump for excessive wear. Repair the oil pump or replace the oil pump, if necessary. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove", Disassembly and Assembly, "Engine Oil Pump - Install" and Disassembly and Assembly, "Engine Oil Relief Valve - Remove and Install".

2. If no faults are found, proceed to "Bearing Clearance".

### Bearing Clearance

Inspect the engine components for excessive bearing clearance or damaged bearings. If necessary, replace the bearings and/or the components. Inspect the following components for excessive bearing clearance:

- Crankshaft main bearings
- Connecting rod bearings
- Camshaft front bearing
- Idler gear bearing

i03447482

## Low Power/Poor or No Response to Throttle

### Probable Causes

- Diagnostic codes
- ECM parameters
- Electrical connectors
- Air intake and exhaust system
- Valve lash
- Turbocharger
- Fuel supply
- Low compression (cylinder pressure)
- Individual malfunctioning cylinder
- Electronic unit injectors

### Recommended Actions

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.

### Diagnostic Codes

Check for active diagnostic codes on the electronic service tool. Troubleshoot any active codes before continuing with this procedure.

### ECM Parameters

1. Use the electronic service tool to make sure that the FLS and FTS parameters have been correctly entered.

2. Use the electronic service tool to ensure that the correct mode was selected.

3. Use the electronic service tool to verify that the correct engine rating has been provided.

4. Use the electronic service tool to verify the maximum engine speed limit.

5. Ensure that the repairs have eliminated the fault.

6. If the repairs have not eliminated the fault proceed to "Electrical Connectors".

### Electrical Connectors

1. Turn the keyswitch to the ON position.

2. Use the electronic service tool to verify that the intake manifold pressure is 0 ± 0.5 kPa (00 ± 0.070 psi). Check the 5 V sensor supply for the intake manifold pressure. Refer to Troubleshooting, "5 Volt Engine Pressure Sensor Supply Circuit - Test".

3. Use the electronic service tool to verify the throttle position status.

4. Run the engine until the speed is equal to the maximum no-load speed.

5. Use the electronic service tool to make sure that the throttle is set to reach the maximum no-load speed.

6. If the maximum no-load speed can not be obtained, refer to Troubleshooting, "Throttle Switch Circuit - Test" and Troubleshooting, "Mode Selection Circuit - Test".

REFERENCE ONLY

7. If the engine speed is erratic refer to Troubleshooting, "Analog Throttle Position Sensor Circuit - Test" or Troubleshooting, "Digital Throttle Position Sensor Circuit - Test".

8. If the fault has not been eliminated, proceed to "Air Intake and Exhaust System".

## Air Intake and Exhaust System

1. Check the air filter restriction indicator, if equipped.

2. Ensure that the air filter is clean and serviceable.

3. Check the air intake and the exhaust system for the following defects:

   - Blockages
   - Restrictions
   - Damage to the air intake and exhaust lines and hoses

4. Make all necessary repairs to the engine.

5. If the fault has not been eliminated, proceed to "Valve Lash".

## Valve Lash

1. Check the valve lash and reset the valve lash, if necessary. Refer to Systems Operation, Testing and Adjusting, "Engine Valve lash - Inspect and Adjust".

2. If the repair does not eliminate the fault proceed to "Turbocharger".

## Turbocharger

**Note:** The turbocharger that is installed on this engine is a nonserviceable item. If any mechanical fault exists, then the turbocharger must be replaced.

1. Ensure that the mounting bolts for the turbocharger are tight.

2. Check that the oil drain for the turbocharger is not blocked or restricted.

3. Check that the compressor housing for the turbocharger is free of dirt and debris.

4. Check that the turbine housing for the turbocharger is free of dirt and debris.

5. Check that the turbine blades rotate freely in the turbocharger.

6. Ensure that the wastegate on the turbocharger is adjusted correctly. Refer to Systems Operation, Testing and Adjusting, "Wastegate - Inspect". If the wastegate actuator or the turbocharger is faulty, replace the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" and Disassembly and Assembly, "Turbocharger - Install".

7. Check that the repairs have eliminated the faults.

8. If the fault has not been eliminated, proceed to "Fuel Supply".

## Fuel Supply

1. Visually check the fuel tank level. The fuel gauge may be faulty.

2. Ensure that the fuel supply valve (if equipped) is in the full OPEN position.

3. If the temperature is below 0 °C (32 °F), check for solidified fuel (wax).

4. Check the primary filter/water separator for water in the fuel.

5. Check for fuel supply lines that are restricted.

6. Check that the low pressure fuel lines are tight and secured properly.

7. Check the fuel filters.

8. Check the diesel fuel for contamination. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".

9. Check for air in the fuel system. Refer to Systems Operation, Testing and Adjusting, "Air in Fuel - Test".

10. Ensure that the fuel system has been primed. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".

11. Check the fuel pressure. Refer to Systems Operation, Testing and Adjusting, "Fuel System Pressure - Test".

12. If the repair does not eliminate the fault refer to "Low Compression (Cylinder Pressure)".

## Low Compression (Cylinder Pressure)

1. Perform a compression test. Refer to Systems Operation, Testing and Adjusting, "Compression - Test ".

2. If low compression is noted on any cylinders, investigate the cause and rectify any faults.

REFERENCE ONLY

Possible causes of low compression are shown in the following list:

- Loose glow plugs
- Faulty piston
- Faulty piston rings
- Worn cylinder bores
- Worn valves
- Faulty cylinder head gasket
- Damaged cylinder head

3. Perform all necessary repairs.
4. Ensure that the repairs have eliminated the faults.
5. If the repair does not eliminate the fault refer to "Individual Malfunctioning Cylinders".

### Individual Malfunctioning Cylinders

1. Use the electronic service tool to perform the "Cylinder Cut-out Test". Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated cylinder is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the cylinder is operating below normal performance. Investigate the cause of the fault on any cylinder that is not operating. Investigate the cause of the fault on any cylinder that is operating below normal performance.
2. If all cylinders have been checked and no faults were detected proceed to "Electronic Unit Injectors".

### Electronic Unit Injectors

1. Use the electronic service tool to perform the "Cylinder Cut-out Test". Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.
2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".
3. Install a new electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".
4. Repeat the test in 1. If the fault is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".
5. If the fault is not eliminated, repeat this test procedure from Step 1.

i02529009

## Mechanical Noise (Knock) in Engine

### Probable Causes

- Accessory equipment
- Valve train components
- Pistons
- Connecting rod and main bearings

### Recommended Actions

#### Accessory Equipment

1. Isolate the source of the noise. Remove the suspect engine accessory. Inspect the suspect engine accessory. Repair the engine accessory and/or replace the engine accessory if any defects are found.
2. If the mechanical noise is still apparent, refer to "Valve Train Components".

#### Valve Train Components

1. Remove the valve mechanism cover. Check the following items for damage: camshaft, valve springs, lifters, pushrods, and bridges. Thoroughly clean the valve train components. If the camshaft is being replaced, also replace the valve lifters. Ensure that all of the valves move freely. Replace any damaged parts.
2. If the mechanical noise is still apparent, refer to "Pistons".

#### Pistons

1. Inspect the pistons for damage and wear. Replace any damaged parts.
2. If the mechanical noise is still apparent, refer to "Connecting Rod and Main Bearings".

REFERENCE ONLY

### Connecting Rod and Main Bearings

Inspect the connecting rod and main bearings. Also, inspect the bearing surfaces (journals) on the crankshaft. Replace any damaged parts.

i03447820

# Noise Coming from Cylinder

## Probable Causes

- Fuel quality
- Valve lash
- Pistons
- Electronic unit injectors

## Recommended Actions

### Fuel Quality

1. Check the fuel quality. Refer to Systems Operation, Testing and Adjusting, "Fuel Quality - Test".
2. If unsatisfactory fuel is found, perform the following procedure.
   a. Drain the fuel system.
   b. Replace the fuel filters. Refer to the Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace" and Operation and Maintenance Manual, "Fuel System Filter - Replace".
   c. Fill the fuel system with fuel that meets the standard in Operation and Maintenance Manual, "Fluid Recommendations".
   d. Prime the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".
3. If the fault is not eliminated, proceed to "Pistons".

### Pistons

1. Inspect the pistons for damage and wear. Replace any damaged parts.
2. If the noise is still apparent, proceed to "Valve Lash".

### Valve Lash

1. Refer to Troubleshooting, "Excessive Valve Lash".
2. If the fault has not been eliminated, proceed to "Electronic Unit Injectors".

### Electronic Unit Injectors

1. With the engine speed at a fast idle, use the electronic service tool to isolate one cylinder at a time. Note if there is any reduction in engine speed. If a reduction in engine speed is not noted, the isolated electronic unit injector is not operating under normal conditions. If the isolation of a particular cylinder results in a reduction of engine speed that is less than normal, this may indicate that the electronic unit injector is operating below normal performance.
2. Remove the electronic unit injector from the suspect cylinder. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".
3. Install a new electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".
4. Repeat the test in 1. If the noise is still apparent, remove the replacement electronic unit injector and install the original electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

REFERENCE ONLY

# Troubleshooting with a Diagnostic Code

i03447840

## Diagnostic Code Cross Reference

Table 51

| CDL Code | Description | 3rd Party Device J1939 | Flash Code |
|---|---|---|---|
| N/A | No Diagnostic Code Detected | N/A | 551 |
| 0001-02 | Cylinder #1 Injector erratic, intermittent, or incorrect | 651-2 | 111 |
| 0001-05 | Cylinder #1 Injector current below normal | 651-5 | 111 |
| 0001-06 | Cylinder #1 Injector current above normal | 651-6 | 111 |
| 0001-07 | Cylinder #1 Injector not responding properly | 651-7 | 111 |
| 0002-02 | Cylinder #2 Injector erratic, intermittent, or incorrect | 652-2 | 112 |
| 0002-05 | Cylinder #2 Injector current below normal | 652-5 | 112 |
| 0002-06 | Cylinder #2 Injector current above normal | 652-6 | 112 |
| 0002-07 | Cylinder #2 Injector not responding properly | 652-27 | 112 |
| 0003-02 | Cylinder #3 Injector erratic, intermitten[illegible] or incorrect | 653-2 | 113 |
| 0003-05 | Cylinder #3 Injector current below normal | 653-5 | 113 |
| 0003-06 | Cylinder #3 Injector current above normal | 653-6 | 113 |
| 0003-07 | Cylinder #3 Injector not responding properly | 653-7 | 113 |
| 0004-02 | Cylinder #4 Injector erratic, intermittent, or incorrect | 654-2 | 114 |
| 0004-05 | Cylinder #4 Injector current below normal | 654-5 | 114 |
| 0004-06 | Cylinder #4 Injector current above normal | 654-6 | 114 |
| 0004-07 | Cylinder #4 Injector not responding properly | 654-7 | 114 |
| 0005-02 | Cylinder #5 Injector erratic, intermittent, or incorrect (1106D engine only) | 655-2 | 115 |
| 0005-05 | Cylinder #5 Injector current below normal (1106D engine only) | 655-5 | 115 |
| 0005-06 | Cylinder #5 Injector current above normal (1106D engine only) | 655-6 | 115 |
| 0005-07 | Cylinder #5 Injector not responding properly (1106D engine only) | 655-7 | 115 |
| 0006-02 | Cylinder #6 Injector erratic, intermittent, or incorrect (1106D engine only) | 656-2 | 116 |
| 0006-05 | Cylinder #6 Injector current below normal (1106D engine only) | 656-5 | 116 |
| 0006-06 | Cylinder #6 Injector current above normal (1106D engine only) | 656-6 | 116 |
| 0006-07 | Cylinder #6 Injector not responding properly (1106D engine only) | 656-7 | 116 |
| 0041-03 | 8 Volt DC Supply voltage above normal | 678-03 | 517 |
| 0041-04 | 8 Volt DC Supply voltage below normal | 678-04 | 517 |
| 0091-02 | Throttle Position Sensor erratic, intermittent, or incorrect | 91-02 | 154 |
| 0091-03 | Throttle Position Sensor voltage above normal | 91-03 | 154 |

(continued)

REFERENCE ONLY

(Table 51, contd)

| CDL Code | Description | 3rd Party Device J1939 Code | Flash Code |
|---|---|---|---|
| 0091-04 | Throttle Position Sensor voltage below normal | 91-04 | 154 |
| 0091-08 | Throttle Position Sensor abnormal frequency, pulse width, or period | 91-08 | 154 |
| 0100-03 | Engine Oil Pressure Sensor voltage above normal | 100-03 | 157 |
| 0100-04 | Engine Oil Pressure Sensor voltage below normal | 100-04 | 157 |
| 0100-10 | Engine Oil Pressure Sensor abnormal rate of change | 100-10 | 157 |
| 0110-03 | Engine Coolant Temperature Sensor voltage above normal | 110-03 | 168 |
| 0110-04 | Engine Coolant Temperature Sensor voltage below normal | 110-04 | 168 |
| 0168-00 | Electrical System Voltage high | [illegible] | 422 |
| 0168-01 | Electrical System Voltage low | 168-01 | 422 |
| 0168-02 | Electrical System Voltage erratic, intermittent, or incorrect | 168-02 | 422 |
| 0172-03 | Intake Manifold Air Temperature Sensor voltage above normal | 105-03 | 133 |
| 0172-04 | Intake Manifold Air Temperature Sensor voltage below normal | 105-04 | 133 |
| 0190-08 | Engine Speed Sensor abnormal frequency, pulse width, or period | 190-08 | 141 |
| 0247-09 | SAE J1939 Data Link abnormal update rate | - | 514 |
| 0247-12 | SAE J1939 Data Link failure | - | 514 |
| 0253-02 | Personality Module erratic, intermittent, or incorrect | 631-02 | 415 |
| 0261-11 | Engine Timing Offset fault | 637-11 | 143 |
| 0262-03 | 5 Volt Sensor DC Power Supply voltage above normal | 1079-03 | 516 |
| 0262-04 | 5 Volt Sensor DC Power Supply voltage below normal | 1079-04 | 516 |
| 0268-02 | Programmed Parameter Fault erratic, intermittent, or incorrect | 630-02 | 527 |
| 0342-08 | Secondary Engine Speed Sensor abnormal frequency, pulse width, or period | 723-08 | 142 |
| 0526-05 | Turbo Wastegate Drive current below normal | 1188-05 | 177 |
| 0526-06 | Turbo Wastegate Drive current above normal | 1188-06 | 177 |
| 0526-07 | Turbo Wastegate Drive not responding properly | 1188-07 | 177 |
| 0774-02 | Secondary Throttle Position Sensor erratic, intermittent, or incorrect | 29-02 | 155 |
| 0774-03 | Secondary Throttle Position Sensor voltage above normal | 29-03 | 155 |
| 0774-04 | Secondary Throttle Position Sensor voltage below normal | 29-04 | 155 |
| 0774-08 | Secondary Throttle Position Sensor abnormal frequency, pulse width, or period | 29-08 | 155 |
| 1743-02 | Engine Operation Mode Selector Switch erratic, intermittent, or incorrect | 2882-02 | 144 |
| 1779-05 | Fuel Rail #1 Pressure Valve Solenoid current below normal | 1347-05 | 162 |
| 1779-06 | Fuel Rail #1 Pressure Valve Solenoid current above normal | 1347-06 | 162 |
| 1785-03 | Intake Manifold Pressure Sensor voltage above normal | 102-03 | 197 |
| 1785-04 | Intake Manifold Pressure Sensor voltage below normal | 102-04 | 197 |
| 1785-10 | Intake Manifold Pressure Sensor abnormal rate of change | 102-10 | 197 |
| 1797-03 | Fuel Rail Pressure Sensor voltage above normal | 157-03 | 159 |
| 1797-04 | Fuel Rail Pressure Sensor voltage below normal | 157-04 | 159 |
| 1834-02 | Ignition Key Switch loss of signal | 158-02 | 439 |

(continued)

REFERENCE ONLY

(Table 51, contd)

| CDL Code | Description | 3rd Party Device J1939 Code | Flash Code |
|---|---|---|---|
| 2246-06 | Glow Plug Start Aid Relay current above normal | 676-06 | 199 |
| | **Event Codes** | | |
| E172-1 | High Air Filter Restriction - Warning | 107-15 | 151 |
| E194-1 | High Exhaust Temperature - Warning | 173-15 | 185 |
| E232-1 | High Fuel/Water Separator Water Level - Warning | 97-15 | - |
| E360-1 | Low Oil Pressure - Warning | 100-17 | 157 |
| E360-2 | Low Oil Pressure - Derate | 100-18 | 157 |
| E360-3 | Low Oil Pressure - Shutdown | 100-1 | 157 |
| E361-1 | High Engine Coolant Temperature - Warning | 110-15 | 168 |
| E361-2 | High Engine Coolant Temperature - Derate | 110-16 | 168 |
| E361-3 | High Engine Coolant Temperature - Shutdown | 110-00 | 168 |
| E362-1 | Engine Overspeed - Warning | 190-15 | 141 |
| E396-1 | High Fuel Rail Pressure - Warning | 157-00 | 159 |
| E398-1 | Low Fuel Rail Pressure - Warning | 157-01 | 159 |
| E539-1 | High Intake Manifold Air Temperature - Warning | 105-15 | 133 |
| E539-2 | High Intake Manifold Air Temperature - Derate | 105-16 | 133 |
| E2143-3 | Low Engine Coolant Level - Shutdown | 111-01 | 169 |

i03449822

## No Diagnostic Codes Detected

**Conditions Which Generate This Code:**

A flash code 0551 indicates that there are no detected faults in the system.

**System Response:**

This code will not appear on the electronic service tool. The indicator lamps will flash the diagnostic code. For more information on flash codes, refer to Troubleshooting, "Indicator Lamps".

**Possible Performance Effect:**

None

There are no faults that require troubleshooting.

**Results:**

- OK – STOP.

i02655551

## CID 0001 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

- Data from the electronic unit injector for the No. 1 cylinder is out of limits.
- Diagnostic code 0168-01 is not active.
- Diagnostic codes 0001-05 and 0001-06 are not active.
- No 0041 diagnostic codes are active.
- No 0262 diagnostic codes are active.
- Diagnostic code 0190-08 is not active.
- No 0110 diagnostic codes are active.

REFERENCE ONLY

**System Response:**

If equipped, the warning light will come on. An active diagnostic code will be generated. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

Perform the following diagnostic procedure: "Injector Data Incorrect - Test"

**Results:**

- OK – STOP.

i02655572

## CID 0001 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector for No. 1 cylinder.

The Electronic Control Module (ECM) detects the following condition:

- A low current condition (open circuit) for each of five consecutive attempts to operate
- Battery voltage is higher than 9 Volts DC for 2 seconds.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. An open circuit in the wiring that is unique to the electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, an open circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, an open circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but an open circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: "Injector Solenoid Circuit - Test"

**Results:**

- OK – STOP.

i02655579

## CID 0001 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector for No. 1 cylinder.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate
- Battery voltage above 9 Volts DC for 2 seconds

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

REFERENCE ONLY

An electrical fault can prevent the electronic unit injector from operating. A short circuit in the wiring or the ECM that is unique to one electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, a short circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, a short circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but a short circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: "Injector Solenoid Circuit - Test"

**Results:**

- OK – STOP.

i03449840

## CID 0001 FMI 07

**Conditions Which Generate This Code:**

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

**System Response:**

If equipped, the warning light will come on. The Electronic Control Module (ECM) will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

Use the electronic service tool to perform the Verification Test for the fuel system. If the diagnostic code is still active, do the following procedure.

Replace the suspect electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

Use the electronic service tool to perform the verification test for the fuel system.

Perform the following diagnostic procedure: "None"

**Results:**

- OK – STOP.

i02655552

## CID 0002 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

- Data from the electronic unit injector for the No. 2 cylinder is out of limits.
- Diagnostic code 0168-01 is not active.
- Diagnostic codes 0001-05 and 0001-06 are not active.
- No 0041 diagnostic codes are active.
- No 0262 diagnostic codes are active.
- Diagnostic code 0190-08 is not active.
- No 0110 diagnostic codes are active.

**System Response:**

If equipped, the warning light will come on. An active diagnostic code will be generated. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

Perform the following diagnostic procedure: "Injector Data Incorrect - Test"

**Results:**

- OK – STOP.

i02655573

## CID 0002 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector for No. 2 cylinder.

REFERENCE ONLY

The Electronic Control Module (ECM) detects the following condition:

- A low current condition (open circuit) for each of five consecutive attempts to operate
- Battery voltage is higher than 9 Volts DC for 2 seconds.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. An open circuit in the wiring that is unique to the electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, an open circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, an open circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but an open circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: "Injector Solenoid Circuit - Test"

**Results:**

- OK – STOP.

i02655580

# CID 0002 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector for No. 2 cylinder.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate
- Battery voltage above 9 Volts DC for 2 seconds

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. A short circuit in the wiring or the ECM that is unique to one electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, a short circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, a short circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but a short circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: "Injector Solenoid Circuit - Test"

**Results:**

- OK – STOP.

i03449880

# CID 0002 FMI 07

**Conditions Which Generate This Code:**

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

**System Response:**

If equipped, the warning light will come on. The Electronic Control Module (ECM) will log the diagnostic code.

REFERENCE ONLY

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

Use the electronic service tool to perform the Verification Test for the Fuel System. If the diagnostic code is still active, do the following procedure.

Replace the suspect electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

Use the electronic service tool to perform the Verification Test for the Fuel System.

Perform the following diagnostic procedure: "None"

**Results:**

- OK – STOP.

i02655554

## CID 0003 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

- Data from the electronic unit injector for the No. 3 cylinder is out of limits.
- Diagnostic code 0168-01 is not active.
- Diagnostic codes 0001-05 and 0001-06 are not active.
- No 0041 diagnostic codes are active.
- No 0262 diagnostic codes are active.
- Diagnostic code 0100-08 is not active.
- No 011 diagnostic codes are active.

**System Response:**

If equipped, the warning light will come on. An active diagnostic code will be generated. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

Perform the following diagnostic procedure: "Injector Data Incorrect - Test"

**Results:**

- OK – STOP.

i02655574

## CID 0003 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector for No. 3 cylinder.

The Electronic Control Module (ECM) detects the following condition:

- A low current condition (open circuit) for each of five consecutive attempts to operate
- Battery voltage is higher than 9 Volts DC for 2 seconds.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. An open circuit in the wiring that is unique to the electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, an open circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, an open circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

REFERENCE ONLY

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but an open circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: “Injector Solenoid Circuit - Test”

**Results:**

- OK – STOP.

i02655581

## CID 0003 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector for No. 3 cylinder.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate
- Battery voltage above 9 Volts DC for 2 seconds

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector current test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. A short circuit in the wiring or the ECM that is unique to one electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, a short circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, a short circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but a short circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: “Injector Solenoid Circuit - Test”

**Results:**

- OK – STOP.

i03449882

## CID 0003 FMI 07

**Conditions Which Generate This Code:**

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

**System Response:**

If equipped, the warning light will come on. The Electronic Control Module (ECM) will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

Use the electronic service tool to perform the Verification Test for the Fuel System. If the diagnostic code is still active, do the following procedure.

Replace the suspect electronic unit injector. Refer to Disassembly and Assembly, “Electronic Unit Injector - Remove” and Disassembly and Assembly, “Electronic Unit Injector - Install”.

Use the electronic service tool to perform the Verification Test for the Fuel System.

Perform the following diagnostic procedure: “None”

**Results:**

- OK – STOP.

REFERENCE ONLY

i02655555

# CID 0004 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

- Data from the electronic unit injector for the No. 4 cylinder is out of limits.
- Diagnostic code 0168-01 is not active.
- Diagnostic codes 0001-05 and 0001-06 are not active.
- No 0041 diagnostic codes are active.
- No 0262 diagnostic codes are active.
- Diagnostic code 0190-08 is not active.
- No 0110 diagnostic codes are active.

**System Response:**

If equipped, the warning light will come on. An active diagnostic code will be generated. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

Perform the following diagnostic procedure: “Injector Data Incorrect - Test”

**Results:**

- OK – STOP.

i02655575

# CID 0004 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector for No. 4 cylinder.

The Electronic Control Module (ECM) detects the following condition:

- A low current condition (open circuit) for each of five consecutive attempts to operate
- Battery voltage is higher than 9 Volts DC for 2 seconds.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. An open circuit in the wiring that is unique to the electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, an open circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, an open circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but an open circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: “Injector Solenoid Circuit - Test”

**Results:**

- OK – STOP.

i02655582

# CID 0004 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector for No. 4 cylinder.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate

REFERENCE ONLY

- Battery voltage above 9 Volts DC for 2 seconds

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. A short circuit in the wiring or the ECM that is unique to one electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, a short circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, a short circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but a short circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure. "Injector Solenoid Circuit - Test"

**Results:**

- OK – STOP.

i03449922

## CID 0004 FMI 07

**Conditions Which Generate This Code:**

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

**System Response:**

If equipped, the warning light will come on. The Electronic Control Module (ECM) will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

Use the electronic service tool to perform the Verification Test for the Fuel System. If the diagnostic code is still active, do the following procedure.

Replace the suspect electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

Use the electronic service tool to perform the Verification Test for the Fuel System.

Perform the following diagnostic procedure. "None"

**Results:**

- OK – STOP.

i02655556

## CID 0005 FMI 02

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

The Electronic Control Module (ECM) detects the following condition:

- Data from the electronic unit injector for the No. 5 cylinder is out of limits.
- Diagnostic code 0168-01 is not active.
- Diagnostic codes 0001-05 and 0001-06 are not active.
- No 0041 diagnostic codes are active.
- No 0262 diagnostic codes are active.
- Diagnostic code 0190-08 is not active.
- No 0110 diagnostic codes are active.

**System Response:**

If equipped, the warning light will come on. An active diagnostic code will be generated. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

REFERENCE ONLY

**Troubleshooting:**

Perform the following diagnostic procedure: “Injector Data Incorrect - Test”

**Results:**

- OK – STOP.

i02655577

## CID 0005 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector for No. 5 cylinder.

The Electronic Control Module (ECM) detects the following condition:

- A low current condition (open circuit) for each of five consecutive attempts to operate
- Battery voltage is higher than 9 Volts DC for 2 seconds.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. An open circuit in the wiring that is unique to the electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, an open circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, an open circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but an open circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: “Injector Solenoid Circuit - Test”

**Results:**

- OK – STOP.

i02655584

## CID 0005 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector for No. 5 cylinder.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate
- Battery voltage above 9 Volts DC for 2 seconds

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. A short circuit in the wiring or the ECM that is unique to one electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, a short circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, a short circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

REFERENCE ONLY

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but a short circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: "Injector Solenoid Circuit - Test"

**Results:**

- OK – STOP.

i03449942

# CID 0005 FMI 07

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

**System Response:**

If equipped, the warning light will come on. The Electronic Control Module (ECM) will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

Use the electronic service tool to perform the Verification Test on the fuel system. If the diagnostic code is still active, do the following procedure.

Replace the suspect electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

Use the electronic service tool to perform the Verification Test on the fuel system.

Perform the following diagnostic procedure: "None"

**Results:**

- OK – STOP.

i02655557

# CID 0006 FMI 02

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

The Electronic Control Module (ECM) detects the following condition:

- Data from the electronic unit injector for the No. 6 cylinder is out of limits.
- Diagnostic code 0168-02 is not active.
- Diagnostic codes 0001-05 and 0001-06 are not active.
- No 0001 diagnostic codes are active.
- No 0262 diagnostic codes are active.
- Diagnostic code 0190-08 is not active.
- No 0611 diagnostic codes are active.

**System Response:**

If equipped, the warning light will come on. An active diagnostic code will be generated. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

Perform the following diagnostic procedure: "Injector Data Incorrect - Test"

**Results:**

- OK – STOP.

i02655578

# CID 0006 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

REFERENCE ONLY

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector for No. 6 cylinder.

The Electronic Control Module (ECM) detects the following condition:

- A low current condition (open circuit) for each of five consecutive attempts to operate
- Battery voltage is higher than 9 Volts DC for 2 seconds.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. An open circuit in the wiring that is unique to the electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, an open circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, an open circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but an open circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: “Injector Solenoid Circuit - Test”

**Results:**

- OK – STOP.

i02655585

# CID 0006 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector for No. 6 cylinder.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate
- Battery voltage above 9 Volts DC for 2 seconds

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

The engine will have low power and/or rough running.

**Troubleshooting:**

When an injector cutout test is performed, a faulty electronic unit injector will indicate a low reading in comparison with the other electronic unit injectors.

An electrical fault can prevent the electronic unit injector from operating. A short circuit in the wiring or in the ECM that is unique to one electronic unit injector will prevent that individual electronic unit injector from operating. On four cylinder engines, a short circuit in common wiring within the ECM can prevent the two electronic unit injectors that share that common wiring from operating. On six cylinder engines, a short circuit in common wiring within the ECM can prevent the three electronic unit injectors that share that common wiring from operating.

The ECM will continue to attempt to operate the electronic unit injector after the diagnostic code has been logged but a short circuit will prevent the operation of the electronic unit injector.

Perform the following diagnostic procedure: “Injector Solenoid Circuit - Test”

**Results:**

- OK – STOP.

i03449944

# CID 0006 FMI 07

**Conditions Which Generate This Code:**

This diagnostic code is applicable to six cylinder engines only.

REFERENCE ONLY

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

**System Response:**

If equipped, the warning light will come on. The Electronic Control Module (ECM) will log the diagnostic code.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

Use the electronic service tool to perform the Verification Test on the fuel system. If the diagnostic code is still active, do the following procedure.

Replace the suspect electronic unit injector. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" and Disassembly and Assembly, "Electronic Unit Injector - Install".

Use the electronic service tool to perform the Verification Test on the fuel system.

Perform the following diagnostic procedure: "None"

**Results:**

- OK – STOP.

i03449960

## CID 0041 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The 8 volt supply is more than 8.8 Volts DC for more than one second.
- The ECM has been powered for more than three seconds.

**System Response:**

The ECM will log the diagnostic code and the check engine lamp will illuminate while this diagnostic code is active.

**Possible Performance Effect:**

The engine may be limited to low idle.

**Note:** If the engine is equipped with a digital throttle, the 8 volt supply provides power to the digital throttle position sensor.

**Note:** The 8 volt supply provides power to the two speed/timing sensors.

**Troubleshooting:**

Perform the following diagnostic procedure: "Digital Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

i03449980

## CID 0041 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The 8 volt supply is less than 7.2 Volts DC for more than one second.
- The ECM has been powered for more than three seconds.
- Diagnostic code 0168-01 is not active.

**System Response:**

The ECM will log the diagnostic code and the check engine lamp will illuminate while this diagnostic code is active. An active diagnostic code may not cause any noticeable effect on engine response unless the voltage drops below 6.5 Volts DC.

**Possible Performance Effect:**

The engine may be limited to low idle.

**Note:** If the engine is equipped with a digital throttle, the 8 volt supply provides power to the digital throttle position sensor.

**Note:** The 8 volt supply provides power to the two speed/timing sensors.

**Troubleshooting:**

Perform the following diagnostic procedure: "Digital Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

REFERENCE ONLY

i03450000

# CID 0091 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) has detected an invalid combination of positions for the multi-position switches.

If the engine is equipped with an analog throttle position sensor then the signal from the idle validation switch is invalid.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

**Possible Performance Effect:**

If a second throttle is installed, the engine will use the second throttle until the fault is repaired.

If a second throttle is not installed or if the second throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

Proceed to "Test Step 1" if the engine is equipped with a throttle switch.

Proceed to "Test Step 2" if the engine is equipped with an analog throttle position sensor.

## Test Step 1.

Perform the following diagnostic procedure: "Throttle Switch Circuit - Test"

**Results:**

- OK – STOP.

## Test Step 2.

Perform the following diagnostic procedure: "Analog Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

i03450160

# CID 0091 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- ECM has been powered for at least 3 seconds.
- A signal voltage for the throttle position is above the diagnostic upper limit that is set for the application.
- The power supply for the throttle sensor is within the expected range.

**System Response:**

If equipped, the warning light will come on. The ECM logs the diagnostic code if the engine is running.

**Possible Performance Effect:**

If a second throttle is installed, the engine will use the second throttle until the fault is repaired.

If a second throttle is not installed or if the second throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.

REFERENCE ONLY

- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

Monitor the configuration screen on the electronic service tool in order to determine the type of throttle position sensor that is used on the engine.

If the engine is equipped with an analog throttle position sensor, proceed to "Test Step 1".

If the engine is equipped with a digital throttle position sensor, proceed to "Test Step 2".

### Test Step 1.

Perform the following diagnostic procedure: "Analog Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

### Test Step 2.

Perform the following diagnostic procedure: "Digital Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

## CID 0091 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects all of the following conditions:

- The ECM has been powered for at least 3 seconds.
- A signal voltage for the throttle position is below the diagnostic lower limit that is set for the application.
- The power supply for the throttle sensor is within the expected range.

**System Response:**

If equipped, the warning light will come on. The ECM logs the diagnostic code if the engine is running.

**Possible Performance Effect:**

If a second throttle is installed, the engine will use the second throttle until the fault is repaired.

If a second throttle is not installed or if the second throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

Monitor the configuration screen on the electronic service tool in order to determine the type of throttle position sensor that is used on the engine.

If the engine is equipped with an analog throttle position sensor, proceed to "Test Step 1".

If the engine is equipped with a digital throttle position sensor, proceed to "Test Step 2".

### Test Step 1.

Perform the following diagnostic procedure: "Analog Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

### Test Step 2.

Perform the following diagnostic procedure: "Digital Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

REFERENCE ONLY

i03450383

# CID 0091 FMI 08

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal frequency from the accelerator pedal position sensor is less than 150 Hz or the signal frequency is greater than 1050 Hz for more than two seconds.
- The ECM has been powered for at least three seconds.
- Diagnostic code 0091-03 is not active.
- Diagnostic code 0091-04 is not active.
- Diagnostic codes for the 8 Volt sensor supplies are not active.

**System Response:**

Limp home mode is activated.

The ECM sets the "Throttle Position" to "0%".

If equipped, the warning light will be on. The diagnostic code will be logged if the engine is running. The diagnostic code will not be logged if the engine is cranking.

**Possible Performance Effect:**

If a second throttle is installed, the engine will use the second throttle until the fault is repaired.

If a second throttle is not installed or if the second throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

This diagnostic code indicates that the frequency of a digital throttle signal is out of the normal range.

Perform the following diagnostic procedure: "Digital Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

i02655609

# CID 0100 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal voltage from the engine oil pressure sensor is greater than 4.95 Volts DC for more than eight seconds.

  The ECM has been powered for at least two seconds.
- The engine is not running or the engine coolant temperature is greater than 38 °C (100 °F).

**System Response:**

The ECM will log the diagnostic code. If equipped, the warning lamp will come on. The ECM will set data for engine oil pressure to the default value.

**Note:** The engine oil pressure that is displayed on the electronic service tool is the default value for engine oil pressure. The default engine oil pressure is 600 kPa (87 psi). The electronic service tool will display "Voltage Above Normal" on the status screens.

**Possible Performance Effect:**

None

**Troubleshooting:**

This diagnostic code can be caused by an open circuit or a short to another power source.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

REFERENCE ONLY

**Results:**

- OK – STOP.

i02655615

## CID 0100 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal voltage from the engine oil pressure sensor is less than 0.1 Volts DC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- The engine is running.

**System Response:**

The ECM will log the diagnostic code. If equipped, the warning lamp will come on. The ECM will set data for engine oil pressure to the default value. The electronic service tool will display "Voltage Below Normal" on the status screens.

**Possible Performance Effect:**

None

**Troubleshooting:**

This code can be caused by a short to ground or a shorted sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03451661

## CID 0100 FMI 10

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- No other codes for the oil pressure sensor are active.
- No 0262 diagnostic codes are active for the 5 Volt supply.
- The engine speed is greater than 600 rpm.
- The engine oil pressure signal is within the limits of 410 kPa (59 psi) to 520 kPa (75 psi) with a pressure variation of less than 1.68 kPa (0.25 psi)for more than 30 seconds.
- The engine oil pressure signal remains constant for 30 seconds.

**System Response:**

If equipped, the warning lamp will be on. The ECM will log the diagnostic code.

The ECM will flag the engine oil pressure as invalid data. The data for engine oil pressure is set to a default value of 500 kPa (72 psi). The electronic service tool will display "Conditions Not Met" on the status screen.

**Possible Performance Effect:**

None

**Troubleshooting:**

This diagnostic code will detect the loss of the 5 Volt supply to the sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03451680

## CID 0110 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal voltage from the engine coolant temperature sensor is greater than 4.95 Volts DC for more than eight seconds.
- The ECM has been powered for at least two seconds.

REFERENCE ONLY

**System Response:**

If equipped, the warning light will be on. An active diagnostic code will be generated after eight seconds. The diagnostic code will be logged if the engine has been operating for more than seven minutes.

The ECM will default to 90 °C (194 °F) for engine coolant temperature. "Voltage Above Normal" will be displayed next to the status for "Engine Coolant Temperature" on the electronic service tool.

**Possible Performance Effect:**

- Poor stability
- Poor cold running
- White smoke

**Troubleshooting:**

The diagnostic code will detect an excessively high voltage from the engine coolant temperature sensor.

Perform the following diagnostic procedure: "Engine Temperature Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03451700

## CID 0110 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal voltage from the engine coolant temperature sensor is less than 0.2 Volts DC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code 0168-01 is not active.

**System Response:**

The ECM will default to 90 °C (194 °F) for engine coolant temperature. "Voltage Below Normal" will be displayed next to the status for "Engine Coolant Temperature" on the electronic service tool.

If equipped, the warning light will come on. An active diagnostic code will be generated after eight seconds. The diagnostic code will be logged if the engine has been operating for more than seven minutes.

**Possible Performance Effect:**

- Poor stability
- Poor cold running
- White smoke

**Troubleshooting:**

The diagnostic code will detect an excessively low voltage from the engine coolant temperature sensor.

Perform the following diagnostic procedure: "Engine Temperature Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03451720

## CID 0168 FMI 00

**Conditions Which Generate This Code:**

The ECM detects the following conditions:

- For 24 Volt DC systems, the battery voltage to the ECM exceeds 32 Volts DC for more than 0.5 seconds.
- For 12 Volt DC systems, the battery voltage to the ECM exceeds 16 Volts DC for more than 0.5 seconds.
- The keyswitch is in the ON mode.
- The engine is not cranking.
- The engine is running for more than 30 seconds.

**System Response:**

The ECM will log the diagnostic code. If equipped, the warning lamp may come on.

**Possible Performance Effect:**

None

**Troubleshooting:**

This diagnostic code will detect excessively high voltage in the battery circuit to the Electronic Control Module (ECM) while the engine is running.

Perform the following diagnostic procedure: "Ignition Keyswitch Circuit and Battery Supply Circuit - Test"

REFERENCE ONLY

**Results:**

- OK – STOP.

i03451721

# CID 0168 FMI 01

**Conditions Which Generate This Code:**

The ECM detects the following conditions:

- The keyswitch is in the ON position.
- The engine is not cranking.
- The engine is running for more than three seconds.
- For 24 Volt DC systems, the battery voltage to the ECM is below 18 Volts DC for more than 0.5 seconds.
- For 12 Volt DC systems, the battery voltage to the ECM is below 9 Volts DC for more than 0.5 seconds.

**System Response:**

If equipped, the warning lamp may come on. The ECM will normally log the diagnostic code. If battery voltage disappears without returning, the ECM will not log this diagnostic code and the engine will shut down.

The engine will derate 100 percent.

**Possible Performance Effect:**

The engine may experience changes in the engine rpm, and intermittent engine shutdowns or complete engine shutdowns.

**Troubleshooting:**

This diagnostic code will detect low voltage in the battery circuit for the Electronic Control Module (ECM) while the engine is running.

Perform the following diagnostic procedure: “Ignition Keyswitch Circuit and Battery Supply Circuit - Test”

**Results:**

- OK – STOP.

i03451741

# CID 0168 FMI 02

**Conditions Which Generate This Code:**

The ECM detects the following conditions:

- Three voltage readings that are below 6 Volts DC in a period of seven seconds will be detected by the ECM. The voltage must subsequently increase to more than 9 Volts DC.
- The keyswitch is in the ON position.
- The engine is running.
- The engine is not cranking.

**System Response:**

The diagnostic code will normally be logged. If the battery voltage disappears without returning, the ECM will not log this diagnostic code and the engine will shut down. This will be dependent on the length of time of the occurrence of the fault.

The check engine lamp and the warning lamp may come on.

**Possible Performance Effect:**

The engine may experience changes in the engine rpm, and intermittent engine shutdowns or complete engine shutdowns while the conditions that cause this diagnostic code are present.

**Troubleshooting:**

This diagnostic code detects intermittent voltage in the battery circuit for the Electronic Control Module (ECM) while the engine is running.

Perform the following diagnostic procedure: “Ignition Keyswitch Circuit and Battery Supply Circuit - Test”

**Results:**

- OK – STOP.

i03451780

# CID 0172 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

REFERENCE ONLY

- The signal voltage from the intake manifold air temperature sensor is greater than 4.95 Volts DC for more than eight seconds.
- Engine coolant temperature is above −10 °C (15.0 °F).
- The ECM has been powered for at least two seconds.
- Diagnostic code 0168-01 is not active.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

The ECM will use the default value of 70 °C (158 °F) for the intake manifold air temperature. "Voltage High" will be displayed next to the status for "Intake Manifold Air Temperature" on the electronic service tool.

**Possible Performance Effect:**

- Poor stability
- Poor cold running
- White smoke
- Black smoke
- Poor acceleration under load

**Troubleshooting:**

This fault can be caused by an open circuit or a short to a power source.

Perform the following diagnostic procedure: "Engine Temperature Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03451782

## CID 0172 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal voltage from the intake manifold air temperature sensor is less than 0.2 Volts DC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code 0168-01 is not active.

**System Response:**

If equipped, the warning light will come on. The ECM will log the diagnostic code.

The ECM will use the default value of 70 °C (158 °F) for the intake manifold air temperature. "Voltage Low" will be displayed next to the status for "Intake Manifold Air Temperature" on the electronic service tool.

**Possible Performance Effect:**

- Poor stability
- Poor cold running
- White smoke
- Black smoke
- Poor acceleration under load

**Troubleshooting:**

This fault can be caused by a sensor that is shorted to ground or a sensor that is internally shorted.

Perform the following diagnostic procedure: "Engine Temperature Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03451783

## CID 0190 FMI 08

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The ECM detected an intermittent loss of signal or a complete loss of signal from the primary speed/timing sensor for 2 seconds.
- The engine has been running for more than three seconds.

**System Response:**

If equipped, the warning light will come on and the diagnostic code will be logged.

REFERENCE ONLY

The ECM will use the signal from the secondary speed/timing sensor.

**Possible Performance Effect:**

The engine will be derated. If the signal from the secondary speed/timing sensor is also lost, the engine will shut down.

**Troubleshooting:**

This diagnostic code will detect a loss of signal from the primary speed/timing sensor.

Perform the following diagnostic procedure: "Engine Speed/Timing Sensor Circuit - Test"

**Results:**

- OK – STOP.

i03451785

## CID 0247 FMI 09

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

- Another controller has incorrectly stopped transmitting a J1939 speed request (TSC1) or another controller has incorrectly started transmitting a J1939 speed request.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

Some system functions may not operate correctly.

**Troubleshooting:**

This diagnostic code detects an abnormal signal from the J1939 data link.

Perform the following diagnostic procedure: "CAN Data Link Circuit - Test"

**Results:**

- OK – STOP.

i03451800

## CID 0247 FMI 12

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- There is an unexpected loss of a continuous J1939 Torque Speed Controller (TSC1) signal on the J1939 data link.
- The expected continuous TSC1 signal has never been received on the J1939 data link.

**System Response:**

If equipped, the warning lamp will come on and the diagnostic code will be logged.

Engine speed functions that are controlled through TSC1 will be disabled until the fault is rectified and the key switch is cycled through the OFF position and the ON position.

If there is no secondary throttle, the engine speed will be reduced to a low idle. If the engine is equipped with a secondary throttle, the engine speed will change to the speed that is demanded by the secondary throttle.

**Troubleshooting:**

This diagnostic code will detect a loss of signal from the J1939 data link.

Check the configuration of the ECM. If the ECM for the engine has been incorrectly configured to expect a continuous TSC1 signal, remove "Continuous" for the TSC1 signal on the main "J1939" screen on the electronic service tool.

Use the OEM information to determine the machine ECM that provides the continuous speed signal. Refer to the troubleshooting procedures from the OEM to diagnose the faulty speed signal.

**Results:**

- OK – STOP.

REFERENCE ONLY

i02527037

## CID 0253 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects incorrect engine software.

**System Response:**

If equipped, the warning light will come on.

This diagnostic code is not logged.

Factory passwords are required to clear this diagnostic code.

**Possible Performance Effect:**

The engine will not start.

**Troubleshooting:**

The flash file in the ECM is from the wrong engine family.

Use the electronic service tool to install the correct flash file into the ECM. Refer to the Troubleshooting Guide, "Flash Programming".

Perform the following diagnostic procedure: "None"

**Results:**

- OK – STOP.

i03451880

## CID 0261 FMI 11

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The outputs from the primary speed/timing sensor and the secondary speed/timing sensor differ by more than 8 crankshaft degrees.
- The engine has been running for more than five seconds.
- Diagnostic code 0190-08 is not active.
- No 0041 diagnostic codes are active.

**System Response:**

If equipped, the warning light will come on. This code will not be logged.

**Possible Performance Effect:**

The pressure in the fuel rail may be unstable and the engine may not run smoothly.

**Troubleshooting:**

Check the timing of the fuel rail pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install".

**Results:**

- OK – STOP.

i03451885

## CID 0262 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The 5 Volt supply is greater than 5.16 Volts DC for more than one second.
- The ECM has been powered for at least three seconds.
- Diagnostic code 0168-01 is not active.

**System Response:**

The ECM sets all of the pressure sensors and temperature sensors to the default values.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

This diagnostic code will detect an excessively high voltage in the 5 Volt supply circuit.

Perform the following diagnostic procedure: "5 Volt Sensor Supply Circuit - Test"

**Results:**

- OK – STOP.

REFERENCE ONLY

i03451888

# CID 0262 FMI 04

**Conditions Which Generate This Code:**

The Engine Control Module (ECM) detects the following conditions:

- The 5 Volt supply is less than 4.84 Volts DC for more than one second.
- The ECM has been powered for at least three seconds.
- Diagnostic code 0168-01 is not active.

**System Response:**

The ECM sets all of the pressure sensors and temperature sensors to the default values.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

This diagnostic code will detect an excessively low voltage in the 5 Volt supply circuit.

Perform the following diagnostic procedure: "5 Volt Sensor Supply Circuit - Test"

**Results:**

- OK – STOP.

i03451930

# CID 0268 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects one or more of the following conditions:

- One or more of the following configuration parameters are not programmed. The effect on the ECM depends on the parameter.
- FLS or FTS
- Trim codes for the injectors
- Engine serial number
- All of the injector trim files are not loaded into the ECM. Engine performance and emissions are affected.

**System Response:**

If equipped, the warning light will come on. The fault is not logged.

The electronic service tool will display a list of the condition(s) on the "Active Diagnostics" screen that must be resolved.

**Possible Performance Effect:**

The ECM may limit the engine to low idle and/or the ECM may derate the power. Engine performance and emissions are affected.

**Troubleshooting:**

Use the electronic service tool to correct parameters that have not been programmed or parameters that have been incorrectly programmed.

Perform the following diagnostic procedure: "Flash Programming"

**Results:**

- OK – STOP.

i03452010

# CID 0342 FMI 08

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal from the secondary speed/timing sensor is lost and/or intermittent.
- The signal from the secondary speed/timing sensor was lost for at least 2 seconds while the signal from the primary speed/timing sensor remained valid and the engine was running.
- Diagnostic code 0168-01 is not active.
- The engine has been running for more than 3 seconds.
- No 0041 diagnostic codes are active.

**System Response:**

If equipped, the warning lamp will come on and the diagnostic code will be logged.

REFERENCE ONLY

**Possible Performance Effect:**

If the signal from the secondary speed/timing sensor is lost and the engine is stopped, the engine will not restart. The performance will not be affected unless both speed signals are lost. The loss of the signals from both speed/timing sensors will cause the ECM to shut down the engine.

**Troubleshooting:**

Perform the following diagnostic procedure: "Engine Speed/Timing Sensor Circuit - Test"

**Results:**

- OK – STOP.

i03452020

# CID 0526 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code will only appear if an electronically controlled wastegate is installed.

The Electronic Control Module (ECM) detects the following conditions:

- A low current condition in the output from the ECM to the solenoid for the wastegate regulator
- No 0168 diagnostic codes are active.

**System Response:**

If equipped, the warning lamp will come on once the diagnostic code has been active for 30 seconds. The diagnostic code will be logged. After the derate has been activated, the electronic service tool will indicate "Turbo Protection Derate Active".

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

This diagnostic code will detect a fault in the circuit for the solenoid in the wastegate regulator that is most likely to be an open circuit.

Perform the following diagnostic procedure: "Wastegate Solenoid - Test"

**Results:**

- OK – STOP.

i03452040

# CID 0526 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code will only appear if an electronically controlled wastegate is installed.

The Electronic Control Module (ECM) detects the following conditions:

- A high current condition in the output from the ECM to the solenoid in the wastegate regulator
- No 0168 diagnostic codes are active.

**System Response:**

If equipped, the warning lamp will come on once the diagnostic code has been active for 30 seconds. The diagnostic code will be logged. After the derate has been activated, the electronic service tool will indicate "Turbo Protection Derate Active".

**Possible Performance Effect:**

The engine will be derated while this diagnostic code is active.

**Troubleshooting:**

This diagnostic code will detect a fault in the circuit for the solenoid in the wastegate regulator. This problem is most likely to be caused by a high side short to ground or a low side short to power.

Perform the following diagnostic procedure: "Wastegate Solenoid - Test"

**Results:**

- OK – STOP.

i03452044

# CID 0526 FMI 07

**Conditions Which Generate This Code:**

This diagnostic code will only appear if an electronically controlled wastegate is installed.

This diagnostic code indicates that the intake manifold pressure is not being controlled correctly.

The Electronic Control Module (ECM) will detect the following conditions:

REFERENCE ONLY

- The ECM has been powered for more than 4 seconds.
- Diagnostic code 0168-01 is not active.
- No 1785 diagnostic codes are active.
- Diagnostic codes 0526-05 and 0526-06 are not active.
- No 0262 diagnostic codes are active.

**System Response:**

If equipped, the warning lamp will come on and the diagnostic code will be logged.

**Possible Performance Effect:**

- The engine may not reach top RPM.
- The engine produces excessive black smoke.
- The engine has low power.

**Troubleshooting:**

This diagnostic code will detect a mechanical problem in the intake air system. The electronic part of the control system will be operating correctly.

Perform the following diagnostic procedure: "System Operation, Testing and Adjusting, "Turbocharger - Inspect""

**Results:**

- OK – STOP.

i03452060

## CID 0774 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects a position for the secondary throttle switch that has not been determined.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

**Possible Performance Effect:**

The engine will use the primary throttle until the fault is repaired.

If the primary throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed until the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

Perform the following diagnostic procedure: "Throttle Switch Circuit - Test"

**Results:**

- OK – STOP.

i03452300

## CID 0774 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects one of the following conditions:

- The ECM has been powered for 3 seconds.
- Diagnostic code 0168-01 is not active.
- No 0262 diagnostic codes are active.
- The setting for the upper diagnostic limit has been exceeded for 1 second.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

**Possible Performance Effect:**

The engine will use the primary throttle until the fault is repaired.

If the primary throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.

REFERENCE ONLY

- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

Monitor the configuration screen on the electronic service tool in order to determine the type of throttle position sensor that is used on the engine.

If the engine is equipped with an analog secondary throttle, proceed to "Test Step 1".

If the engine is equipped with a digital secondary throttle, proceed to "Test Step 2".

### Test Step 1.

Perform the following diagnostic procedure: "Analog Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

### Test Step 2.

Perform the following diagnostic procedure: "Digital Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

i03452340

## CID 0774 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects one of the following conditions:

- The ECM has been powered for 3 seconds.
- Diagnostic code 0168-01 is not active.
- No 0262 diagnostic codes are active.
- The setting for the lower diagnostic limit has been exceeded for 1 second.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

**Possible Performance Effect:**

The engine will use the primary throttle until the fault is repaired.

If the primary throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.

  All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

Monitor the configuration screen on the electronic service tool in order to determine the type of throttle position sensor that is used on the engine.

If the engine is equipped with an analog secondary throttle, proceed to "Test Step 1".

If the engine is equipped with a digital secondary throttle, proceed to "Test Step 2".

### Test Step 1.

Perform the following diagnostic procedure: "Analog Throttle Position Sensor Circuit - Test"

**Results:**

- OK – STOP.

REFERENCE ONLY

### Test Step 2.

Perform the following diagnostic procedure: “Digital Throttle Position Sensor Circuit - Test”

**Results:**

- OK – STOP.

i03454000

## CID 0774 FMI 08

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects one of the following conditions:

- The ECM has been powered for 3 seconds.
- Diagnostic code 0168-01 is not active.
- No 0262 codes are active for the analog sensors.
- No 0041 codes are active for the digital (PWM) sensors.
- Diagnostic codes 0774-03 and 0774-04 are not active.
- The frequency of the signal from the digital (PWM) sensor for the secondary throttle is less than 950 Hz for more than 1 second.
- The frequency of the signal from the digital (PWM) sensor for the secondary throttle is greater than 1050 Hz for more than 1 second.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

**Possible Performance Effect:**

The engine will use the primary throttle until the fault is repaired.

If the primary throttle has a fault, the following conditions will occur:

- The engine will default to the limp home speed.
- If the engine speed is higher than the limp home speed, the engine will decelerate to the limp home speed.
- If the engine speed is lower than the limp home speed, the engine speed will remain at the current speed.
- The engine will remain at this speed while the diagnostic code remains active.
- All inputs from the faulty throttle are ignored by the ECM until the fault is repaired.
- All inputs from the repaired throttle will be ignored by the ECM until the keyswitch has been turned to the OFF position and then back to the ON position.

**Troubleshooting:**

Monitor the configuration screen on the electronic service tool in order to determine the type of throttle position sensor that is used for the secondary throttle on the engine.

If the engine is equipped with an analog throttle position sensor, proceed to “Test Step 1”.

If the engine is equipped with a digital throttle position sensor, proceed to “Test Step 2”.

### Test Step 1.

Perform the following diagnostic procedure: “Analog Throttle Position Sensor Circuit - Test”

**Results:**

- OK – STOP.

### Test Step 2.

Perform the following diagnostic procedure: “Digital Throttle Position Sensor Circuit - Test”

**Results:**

- OK – STOP.

i02527056

## CID 1743 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects a combination of switch positions for the mode switches that has not been defined.

**System Response:**

The ECM will return the engine to the last good mode selection or setting.

REFERENCE ONLY

**Possible Performance Effect:**

The engine will start and the engine will default to the previous mode selection. The engine may operate at reduced speed or reduced power. This will depend on the mode that is selected.

Perform the following diagnostic procedure: "Mode Selection Circuit - Test"

**Results:**

- OK – STOP.

i02527057

## CID 1779 FMI 05

**Conditions Which Generate This Code:**

This diagnostic code indicates that the Electronic Control Module (ECM) has detected an open circuit or low current condition in the solenoid for the fuel rail.

**System Response:**

If equipped, the warning light will come on and the ECM will log the diagnostic code.

**Possible Performance Effect:**

An electrical fault may prevent the provision of pressure to the fuel rail. This may result in the loss of fuel injection. If the solenoid for the fuel rail pump fails, it is likely that fuel will not be pumped into the fuel rail. The engine will stop or the engine will not start.

Perform the following diagnostic procedure: "Fuel Rail Pump Solenoid - Test"

**Results:**

- OK – STOP.

i02527058

## CID 1779 FMI 06

**Conditions Which Generate This Code:**

This diagnostic code indicates that the Electronic Control Module (ECM) has detected a short circuit or high current condition in the solenoid for the fuel rail.

**System Response:**

If equipped, the warning light will come on and the ECM will log the diagnostic code.

**Possible Performance Effect:**

An electrical fault may prevent the provision of pressure to the fuel rail. This may result in the loss of fuel injection. If the solenoid for the fuel rail pump fails, it is likely that fuel will not be pumped into the fuel rail. The engine will stop or the engine will not start.

Perform the following diagnostic procedure: "Fuel Rail Pump Solenoid - Test"

**Results:**

- OK – STOP.

i03454040

## CID 1795 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The ECM has been powered for two seconds.
- The signal voltage from the intake manifold pressure sensor is above 4.95 Volts DC for at least two seconds.
- This diagnostic code can be caused by an open circuit or a short to another power source.

**System Response:**

If equipped, the warning light will be on. The diagnostic code will be logged.

The data for the intake manifold pressure will be set to a maximum valid pressure for two seconds. The ECM will then flag the intake manifold pressure as being invalid. A default value is then used for the intake manifold pressure.

**Possible Performance Effect:**

For engines with an electronically controlled wastegate, the current for the wastegate solenoid will be set to a default value while this code is active. This will cause the engine to have poor acceleration but the default setting will prevent any overpressure in the intake manifold which could be caused by an overspeed of the turbocharger.

REFERENCE ONLY

**Troubleshooting:**

This diagnostic code will detect excessively high voltage from the intake manifold pressure sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03454341

## CID 1785 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- The signal voltage from the intake manifold pressure sensor is less then 0.2 Volts DC for at least two seconds.
- The ECM has been powered for two seconds.
- This code can be caused by a short to ground or a shorted sensor.
- The keyswitch is in the "ON" position so that the ECM is energized.

**System Response:**

If equipped, the warning light will come on. The diagnostic code will be logged.

The data for the intake manifold pressure will be set to a maximum valid pressure for two seconds. The ECM will then flag the intake manifold pressure as being invalid. A default value is then used for the intake manifold pressure.

**Possible Performance Effect:**

For engines with an electronically controlled wastegate, the current for the wastegate solenoid will be set to a default value while this code is active. This will cause the engine to have poor acceleration but the default setting will prevent any overpressure in the intake manifold which could be caused by an overspeed of the turbocharger.

**Troubleshooting:**

This diagnostic code will detect excessively low voltage from the intake manifold pressure sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03454360

## CID 1785 FMI 10

**Conditions Which Generate This Code:**

This diagnostic code is designed to detect the loss of the 5 Volt supply at the sensor connector.

The Electronic Control Module (ECM) detects the following conditions:

- The engine speed is more than 1000 rpm.
- The intake manifold pressure is within the acceptable range.
- No 0262 codes for the 5 Volt supply are active.
- Diagnostic code 0168-01 is not active.

**System Response:**

If equipped, the warning light will come on. The diagnostic code will be logged.

The ECM will flag the intake manifold pressure as being invalid. A default value is used for the intake manifold pressure.

**Note:** Any open circuits or short circuits in the signal wire for the oil pressure may reset this diagnostic.

**Possible Performance Effect:**

For engines with an electronically controlled wastegate, the current for the wastegate solenoid will be set to a default value while this code is active. This will cause the engine to have poor acceleration but the default setting will prevent any overpressure in the intake manifold which could be caused by an overspeed of the turbocharger.

The engine will be derated.

**Troubleshooting:**

This diagnostic code will detect the loss of the 5 Volt supply to the sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

REFERENCE ONLY

i03454381

## CID 1797 FMI 03

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

- The signal voltage for the pressure sensor in the fuel rail is more than 4.8 Volts DC for 0.6 seconds.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

The electronic service tool will display "70000 kPa" next to "Desired Fuel Rail Pressure" and "Actual Fuel Rail Pressure" on the status screens.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

This diagnostic code detects an excessively high voltage from the fuel rail pressure sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03454400

## CID 1797 FMI 04

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following conditions:

- No 262 codes for the 5 Volt supply are active.
- Diagnostic code 0168-01 is not active.
- The signal voltage for the pressure sensor in the fuel rail is less than 0.2 Volts DC for 0.6 seconds.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged.

The electronic service tool will display "70000 kPa" next to "Desired Fuel Rail Pressure" and "Actual Fuel Rail Pressure" on the status screens.

**Possible Performance Effect:**

The engine will be derated.

**Troubleshooting:**

This diagnostic code detects an excessively low voltage from the fuel rail pressure sensor.

Perform the following diagnostic procedure: "Engine Pressure Sensor Open or Short Circuit - Test"

**Results:**

- OK – STOP.

i03454432

## CID 1834 FMI 02

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects the following condition:

The signal from the keyswitch was erratic because the power from the keyswitch was cycled at least three times within the last second.

**Note:** This code can be generated by rapidly cycling the keyswitch. Some control modules on the application may require this action in order to prompt flash codes. If this occurs, clear the logged diagnostic codes in order to prevent future confusion or an incorrect diagnosis.

**System Response:**

If equipped, the warning lamp will come on. The diagnostic code will be logged. The ECM will stop energizing the injector solenoids.

**Possible Performance Effect:**

The engine will shut down.

**Troubleshooting:**

Perform the following diagnostic procedure: "Ignition Keyswitch Circuit and Battery Supply Circuit - Test"

**Results:**

- OK – STOP.

REFERENCE ONLY

i03454605

# CID 2246 FMI 06

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) has detected a high current condition (short circuit) after attempting to activate the glow plug starting aid.

The ECM detects the following conditions:

- The engine is not cranking.
- The ECM has been powered for at least 1 second.
- There is a high current condition (short circuit) for more than 2 seconds.

**System Response:**

If equipped, the warning light will come on. The diagnostic code will be logged. An ECM that was previously blank will require a total of 2 hours of operation before the diagnostic code will be logged.

**Possible Performance Effect:**

The ECM is unable to activate the relay for the glow plug starting aid. The glow plugs will not operate o the glow plugs will operate all the time.

The engine may be difficult to start in co temperatures and the exhaust may e white smok

**Troubleshooting:**

This diagnostic code dete an exce ively high current in the circuit for th starting aid relay.

Perform the follow g diagnos procedure: "Starting Aid (Glow Plug) R y Circuit - Test"

**Results:**

- OK STO

REFERENCE ONLY

# Troubleshooting with an Event Code

i02411237

## Event Codes

The ECM can log events. Events refer to engine operating conditions such as low oil pressure or high coolant temperature. Logged events usually indicate a mechanical problem instead of an electronic system problem.

**Note:** If a diagnostic code has already been logged then any associated event code to that fault will not be logged as well.

i03455720

## E172 High Air Filter Restriction

**Conditions Which Generate This Code:**

This event code will only be generated if the switch for the air filter restriction is installed and the customer programmable feature is enabled.

The Electronic Control Module (ECM) detects a problem with the air flow. If the air flow has been restricted for more than thirty seconds, the ECM will generate this code.

**Note:** This code is generated only when the engine is running. This event code will become inactive when the restriction decreases for more than 5 seconds.

**System Response:**

If equipped, the warning lamp will come on.

The event code will be logged.

**Possible Performance Effect:**

**E172:1**

A blocked filter may cause the engine to experience symptoms such as low power.

**Troubleshooting:**

This event code detects a restriction in the air intake system.

The event code may represent a fault in the electronic system. This event code normally indicates high air filter restriction. Refer to Systems Operation, Testing and Adjusting Manual, "Air Inlet and Exhaust System - Inspect".

**Results:**

- OK – STOP.

i03455721

## E194 High Exhaust Temperature

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) monitors the following parameters in order to estimate the exhaust temperature:

- Intake manifold air temperature
- Barometric pressure
- Engine speed

High intake manifold air temperature, high altitude operation, and high engine loads can cause the exhaust temperature to increase to a level that may damage the components of the exhaust system. When this occurs, the ECM derates the engine in order to reduce the exhaust temperature. This protects the components of the exhaust system from damage.

**System Response:**

If equipped, the warning lamp may come on and the event code will be logged.

**Possible Performance Effect:**

Engine power is reduced.

### Test Step 1. Determine the Operating Conditions

Determine if the engine was under heavy load or the engine is operating at a high altitude.

**Expected Result:**

The event occurred because of abnormal engine operation.

REFERENCE ONLY

**Results:**

- OK – The event occurred because of abnormal engine operation. Clear the logged event and return the engine to service at a reduced load. STOP.
- Not OK – The event indicates an engine fault. If the engine is equipped with an air-to-air aftercooler, proceed to Test Step 2.

### Test Step 2. Check the Air-to-Air Aftercooler (ATAAC) (if equipped)

The intake manifold air temperature can increase if the ATAAC is obstructed. Check the fins of the ATAAC for obstructions.

**Expected Result:**

The fins of the ATAAC are obstructed.

**Results:**

- OK – The fins of the ATAAC are obstructed.

  **Repair:** Clean the fins of the ATAAC. Clear the event. Refer to the OEM manual for the ATAAC. Return the engine to service.

  STOP.

- Not OK – The fins of the ATAAC are clear of obstructions.

  STOP.

i03455801

## E232 High Fuel/Water Separator Water Level

**Conditions Which Generate This Code:**

This event code will only be generated if the switch on the water separator filter is installed and correctly wired to the ECM. The feature must be enabled in the customer programmable parameters on the electronic service tool.

The Electronic Control Module (ECM) detects a high water level in the fuel filter if a water level sensor is installed in the fuel filter. If the water rises above a set level for more than thirty seconds, the ECM will generate this event code. The code will become inactive when the switch has been immersed in fuel for 5 seconds.

**Note:** The code is generated only when the engine is running.

**System Response:**

If equipped, the warning lamp will come on and the event code will be logged.

**Possible Performance Effect:**

**E232-1**

None

**Troubleshooting:**

Refer to Systems Operation, Testing and Adjusting manual, "Fuel System - Inspect".

**Results:**

- OK – STOP.

i03455820

## E360 Low Engine Oil Pressure

**Conditions Which Generate This Code:**

The ECM detects low engine oil pressure under the following conditions:

**360-1**

- The engine has been running for at least ten seconds.
- There are no active diagnostic codes for the oil pressure sensor or for the atmospheric pressure sensor.
- Engine oil pressure is in the "LEVEL 1" area in Illustration 19 for eight seconds.

**360-2**

- The engine has been running for at least ten seconds.
- There are no active diagnostic codes for the oil pressure sensor or for the atmospheric pressure sensor.
- Engine oil pressure is in the "LEVEL 2" area in Illustration 20 for eight seconds.

**360-3**

- The engine has been running for at least ten seconds.
- There are no active diagnostic codes for the oil pressure sensor or for the atmospheric pressure sensor.

REFERENCE ONLY

- Engine oil pressure is in the “LEVEL 3” area in Illustration 21 for four seconds.

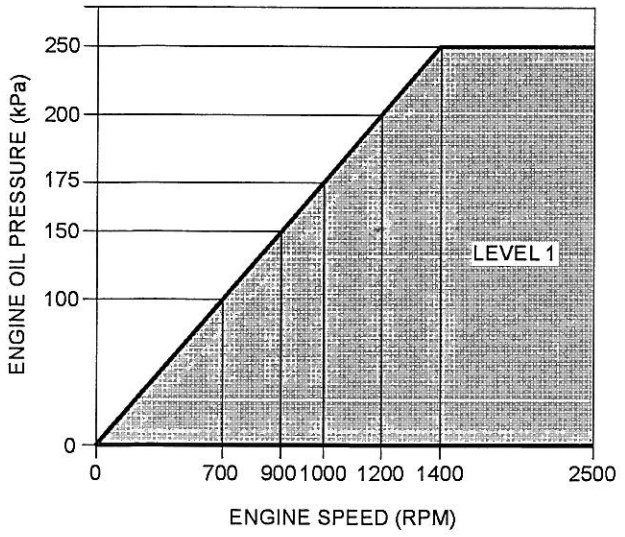



Illustration 19 g01269377

Level 1 engine oil pressure versus engine speed

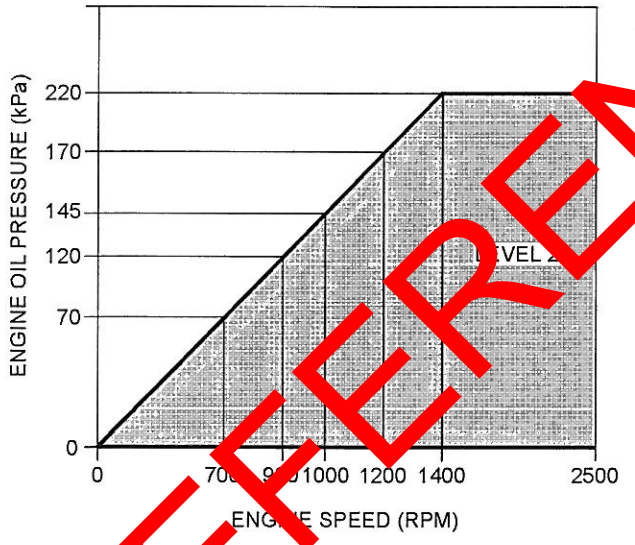



Illustration 20 g01269382

Level 2 engine oil pressure versus engine speed

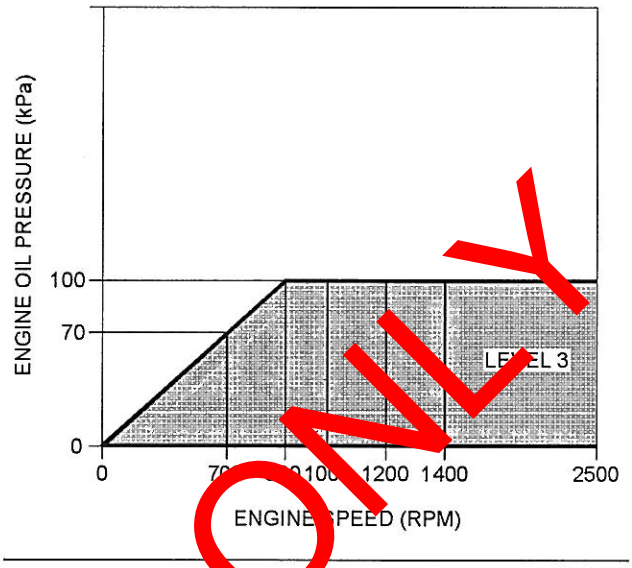



Illustration 21 g01269384

Level 3 engine oil pressure versus engine speed

**System Response:**

**360-1**

The warning lamp will flash while the warning is active.

The Electronic Control Module (ECM) will generate a 46 flash code that will be displayed via the diagnostic lamp.

The ECM will generate a E360-1 event code.

The ECM will generate a SPN 100-FMI 17 event code on the J1939 data link. The event code may be displayed on a receiving device on the J1939 data link.

The warning will be cancelled if the oil pressure rises 21 kPa (3 psi) above the set point for 20 seconds.

**360-2**

The warning lamp will flash while the event code is active.

The ECM will generate a 46 flash code that will be displayed via the diagnostic lamp.

The ECM will generate a E360-2 event code.

The electronic service tool will display “Engine Derate” in the first “Engine Status” box on any status screen.

The ECM will generate a SPN 100-FMI 18 event code on the J1939 data link. The event code may be displayed on a receiving device on the J1939 data link.

REFERENCE ONLY

The derate will be cancelled if the oil pressure rises 21 kPa (3 psi) above the set point for 20 seconds.

**360-3**

The warning lamp will flash while the event code is active.

The ECM will generate a 46 flash code that will be displayed via the diagnostic lamp.

The ECM will generate a E360-3 event code.

The ECM will generate a SPN 100-FMI 01 event code on the J1939 data link. The event code may be displayed on a receiving device on the J1939 data link.

**Possible Performance Effect:**

**360-1**

Engine operation is not affected.

**360-2**

The ECM will derate power by 17.0 percent per second up to a maximum of 100 percent while the derate is active.

**Note:** The derate of the engine will only occur if the "Enable Derate" customer programmable parameter has been enabled.

**360-3**

The engine will shut down.

**Note:** The shutdown of the engine will only occur if the "Enable Shutdown" customer programmable parameter has been enabled.

**Troubleshooting:**

Refer to Troubleshooting, "Low Engine Oil Pressure".

**Results:**

- OK – STOP.

i03455840

# E361 High Engine Coolant Temperature

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects a high engine coolant temperature under the following conditions:

- The engine has been running for more than 185 seconds.
- The trip point for the event code for the temperature of the engine coolant is reached.
- Diagnostic code 0110-03 Engine Coolant Temperature voltage above normal is not active.
- Diagnostic code 0110-04 Engine Coolant Temperature voltage below normal is not active.
- Diagnostic code 0168-01 Electrical System voltage low is not active.

REFERENCE ONLY

Table 52

| Trip Points for the Engine Coolant Temperature | | | |
|---|---|---|---|
| | E361-1 | E361-2 | E361-3 |
| Trip Point | 113 °C (233 °F) | 114 °C (237 °F) | 118 °C (244 °F) |
| Delay to Activation | 10 seconds | 10 seconds | 2 seconds |
| Reset Time | 4 seconds | 20 seconds | 20 seconds |

**System Response:**

If equipped, the warning lamp will come on and the event code will be logged.

**Possible Performance Effect:**

**E361-1**

None

**E361-2**

The ECM will derate the power at one percent per second.

**Note:** The derate of the engine will only occur if the "Enable Derate" customer programmable parameter has been enabled.

**E361-3**

The ECM will shut down the engine after two seconds when the trip point for the engine coolant temperature has been reached.

**Note:** The shutdown of the engine will only occur if the "Enable Shutdown" customer programmable parameter has been enabled.

**Troubleshooting:**

Refer to Troubleshooting, "Coolant Temperature Is Too High".

**Results:**

- OK – STOP.

i03455880

# E362 Engine Overspeed

**Conditions Which Generate This Code:**

The engine speed is above 3000 RPM for more than 0.6 seconds.

**Note:** This event code represents an event. This does not represent an electronic system fault.

**System Response:**

If equipped, the warning lamp will come on and the event code will be logged.

The ECM will reset the event when the engine speed is lower than 2800 RPM for 2 seconds.

**Possible Performance Effect:**

**E362-1**

The fuel injection will be disabled until the event has been reset.

**Troubleshooting:**

This event indicates excessive engine speed. This event does not represent a fault in the Engine Control Module (ECM).

This event does not represent a fault in the Electronic Speed/Timing Sensor.

No troubleshooting is required.

**Results:**

- OK – STOP.

i03455900

# E396 High Fuel Rail Pressure

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects excessive fuel rail pressure under the following conditions:

- The ECM detects fuel rail pressure that is more than the pressure that is required for the operating conditions.
- Diagnostic code 0262-03 5 Volt Sensor DC Power Supply voltage above normal is not active.
- Diagnostic code 0262-04 5 Volt Sensor DC Power Supply voltage below normal is not active.

REFERENCE ONLY

- Diagnostic code 1797-03 Fuel Rail Pressure Sensor voltage above normal is not active.
- Diagnostic code 1797-04 Fuel Rail Pressure Sensor voltage below normal is not active.
- No diagnostic codes are active for the fuel rail pump.
- No diagnostic codes are active for the fuel injectors.

**System Response:**

If equipped, the warning lamp will come on and the event code will be logged.

**Possible Performance Effect:**

The engine will be derated until the keyswitch is turned to OFF and then turned to ON.

**Troubleshooting:**

The event code does not represent a fault in the electronic system. This event indicates high fuel pressure. Refer to Systems Operation, Testing and Adjusting Manual, "Fuel System - inspect".

A failed relief valve, the fuel pump or an electronic unit injector may cause the event code to appear.

**Results:**

- OK – STOP.

i0[illegible]920

## E398 Low Fuel Rail Pressure

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects low fuel rail pressure under the following conditions:

- The ECM determines that the expected fuel rail pressure is lower than the pressure that is requested by the electronic control system.
- Diagnostic code 0262-03 5 Volt Sensor DC Power Supply voltage above normal is not active.
- Diagnostic code 0262-04 5 Volt Sensor DC Power Supply voltage below normal is not active.
- Diagnostic code 1797-03 Fuel Rail Pressure Sensor voltage above normal is not active.
- Diagnostic code 1797-04 Fuel Rail Pressure Sensor voltage below normal is not active.
- No diagnostic codes are active for the fuel rail pump.
- No diagnostic codes are active for the fuel injectors.

**System Response:**

If equipped, the warning lamp will come on and the event code will be logged.

**Possible Performance Effect:**

The engine will be derated until the keyswitch is turned to OFF and then turned to ON.

**Troubleshooting:**

Low fuel pressure may be caused by the following problems:

- A fault in the fuel return system
- A fault in the fuel pressure control
- A leak in the high pressure fuel system
- A failed relief valve, the fuel pump or an electronic unit injector

The event code does not represent a fault in the electronic system. Refer to Systems Operation, Testing and Adjusting, "Fuel System - Inspect".

**Results:**

- OK – STOP.

i03455980

## E539 High Intake Manifold Air Temperature

**Conditions Which Generate This Code:**

The Electronic Control Module (ECM) detects a high air temperature in the intake manifold under the following conditions:

- The engine has been running for more than 3 minutes.
- The temperature of the coolant is more than 99 °C (210 °F) and the intake manifold pressure is more than 30 kPa (4.35 psi).
- The trip level for the intake manifold air temperature is reached.
- Diagnostic code 0172-03 Intake Manifold Air Temperature voltage above normal is not active.

REFERENCE ONLY

- Diagnostic code 0172-04 Intake Manifold Air Temperature voltage below normal is not active.

Table 53

| Intake Manifold Air Temperature Trip Level Table | | |
|---|---|---|
| | **E539-1** | **E539-2** |
| | | |
| Turbocharged Engines (T) | 139 °C (282 °F) | 142 °C (287 °F) |
| Turbocharged Aftercooled Engines (TA) | 82 °C (179 °F) | 86 °C (186 °F) |
| Delay to Activation | 8 seconds | 8 seconds |
| Reset Time | 4 seconds | 4 seconds |

**System Response:**

If equipped, the warning lamp will come on and the event code will be logged.

**Possible Performance Effect:**

**E539-1**

None

**E539-2**

The ECM will derate the power at one percent per second.

The derate of the engine will only occur if the "Enable Derate" customer programmable parameter has been enabled.

**Troubleshooting:**

Refer to Troubleshooting, "Intake Air Temperature Is Too High".

**Results:**

- OK – STOP.

i03455982

## E2143 Low Engine Coolant Level

**Conditions Which Generate This Code:**

**Note:** This event code will only be generated if a coolant level sensor is installed and the customer programmable feature has been enabled.

The ECM detects a low coolant level in the engine for more than thirty seconds.

**System Response:**

If equipped, the shutdown lamp and the warning lamp will come on.

The event code will be logged.

**Possible Performance Effect:**

**E2143-3**

The engine will shut down.

**Note:** Engine shutdown will occur only if the "Enable Shutdown" programmable parameter has been enabled.

**Troubleshooting:**

The event code may represent a fault in the electronic system. This event normally indicates low engine coolant. Refer to Systems Operation, Testing and Adjusting Manual, "Cooling System - Inspect".

**Results:**

- OK – STOP.

REFERENCE ONLY

# Diagnostic Functional Tests

i03456266

## 5 Volt Sensor Supply Circuit - Test

**System Operation Description:**

Use this procedure to troubleshoot the system when one of the following diagnostic codes is active or easily repeated:

- 0262-03 5 Volt Sensor DC Power Supply voltage above normal
- 0262-04 5 Volt Sensor DC Power Supply voltage below normal

Also, use this procedure to troubleshoot the system when you have been directed here by another troubleshooting procedure.

**The following background information is related to this procedure:**

The Engine Control Module (ECM) supplies regulated +5 Volts DC to the following sensors:

- Fuel Rail Pressure Sensor through connector P228
- Intake Manifold Pressure Sensor through connector P200
- Engine Oil Pressure Sensor through connector P201
- Analog Throttle Demand Sensors (if equipped) through P1 OEM connector

The supply for the +5 Volt engine pressure sensor is routed from the ECM through the P2 connector to terminal "A" of each pressure sensor connector. The supply voltage is 5.0 ± 0.16 Volts DC. The +5 Volt supply for the Analog Throttle Demand Sensor is routed from the ECM through the P1 connector to the sensor pins "A".

The +5 Volt diagnostic code is probably caused by a short circuit to ground or a short circuit to another voltage source in the harness.

A diagnostic code can be caused by the following conditions:

- A short circuit in the harness
- A suspect sensor
- A suspect ECM

REFERENCE ONLY

Table 54

| P2 Pin Connections | | | | |
|---|---|---|---|---|
| Sensor Pin | Function | Fuel Rail Pressure Sensor | Intake Manifold Pressure Sensor | Oil Pressure Sensor |
| 1 | Volts (5 Volts) | 48 | 46 | 47 |
| 2 | Ground | 40 | 38 | 39 |
| 3 | Signal | 51 | 55 | 56 |

Table 55

| P1 OEM Connector | | | |
|---|---|---|---|
| Sensor Pin | Function | Analog Throttle Sensor 1 | Analog Throttle Sensor 2 |
| A | 5 Volt Sensor Supply | 41 | 42 |
| B | Ground | 33 | 34 |
| C | Signal | 54 | 55 |

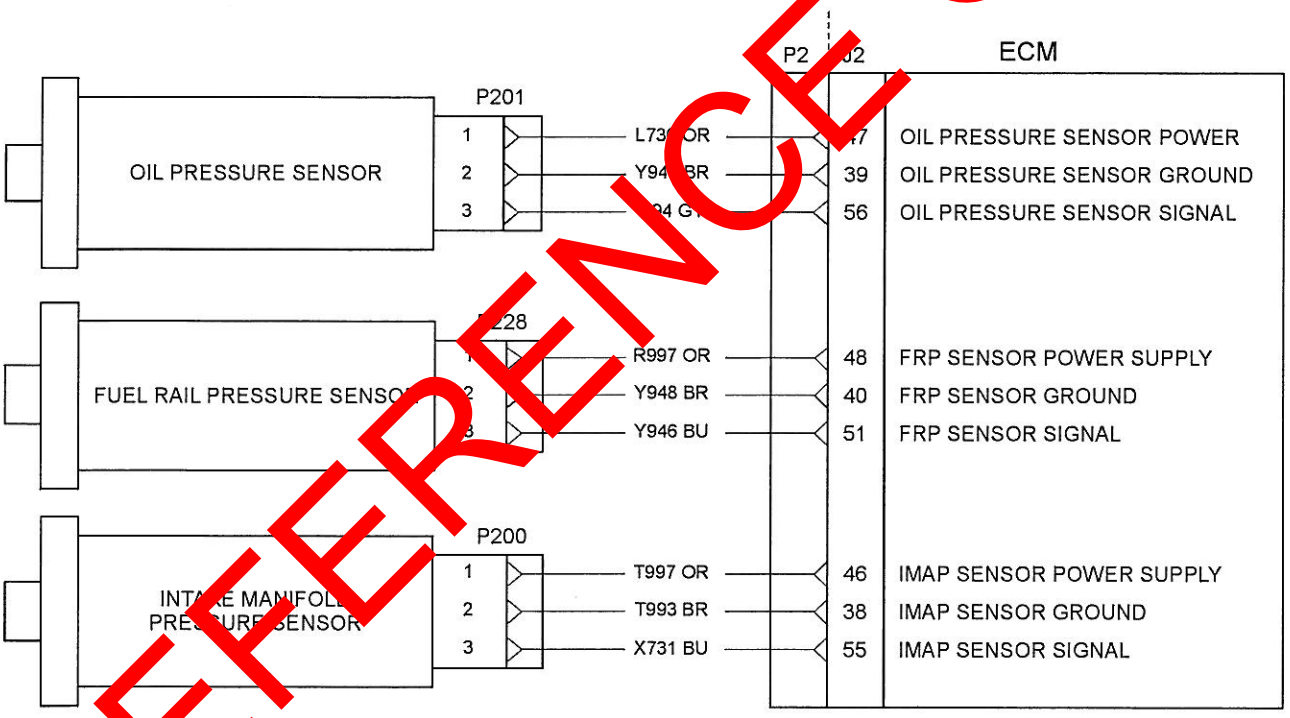
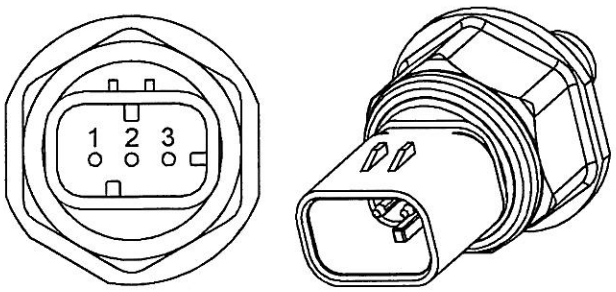



Illustration 2 g01800518

Typical example of the schematic for the sensors

REFERENCE ONLY

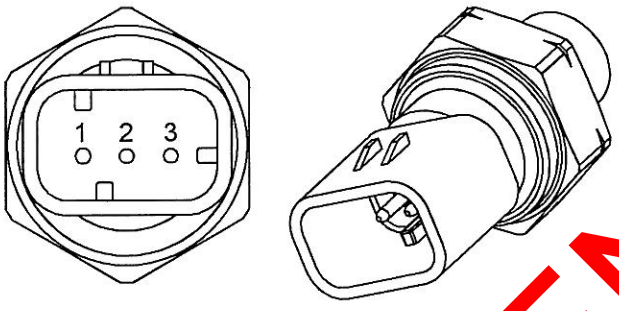



g01173224

Illustration 23

Typical example of the fuel rail pressure sensor

(1) Voltage supply (Vs)
(2) Ground (GND)
(3) Signal (SIG)

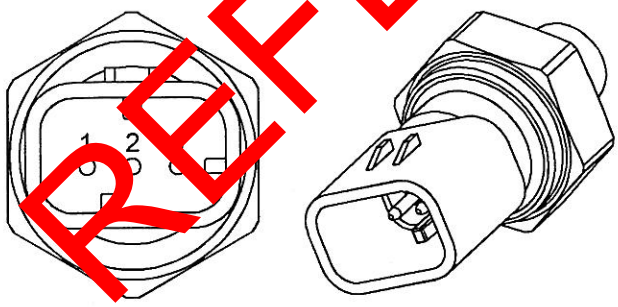



g01173225

Illustration 24

Typical example of the intake manifold pressure sensor

(1) Voltage Supply (Vs)
(2) Ground (GND)
(3) Signal (SIG)




g01173226

Illustration 25

Typical example of the oil pressure sensor

(1) Voltage Supply (Vs)
(2) Ground (GND)
(3) Signal (SIG)

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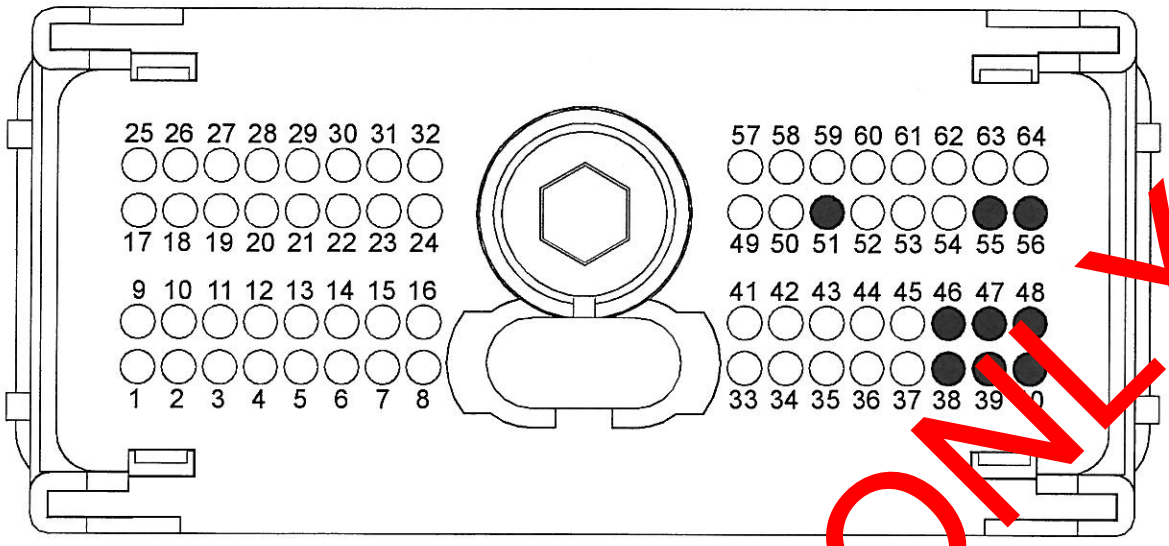



Illustration 26 g01800553

Typical example of the P2 pressure sensor pin locations

(38) Ground (GND) Intake Manifold Pressure Sensor
(39) Ground (GND) Oil Pressure Sensor
(40) Ground (GND) Fuel Rail Pressure Sensor
(46) Voltage supply (5 Volts) Intake Manifold Pressure Sensor
(47) Voltage supply (5 Volts) Oil Pressure Sensor
(48) Voltage supply (5 Volts) Fuel Rail Pressure Sensor
(51) Signal (SIG) Fuel Rail Pressure Sensor
(55) Signal (SIG) Intake Manifold Pressure Sensor
(56) Signal (SIG) Oil Pressure Sensor

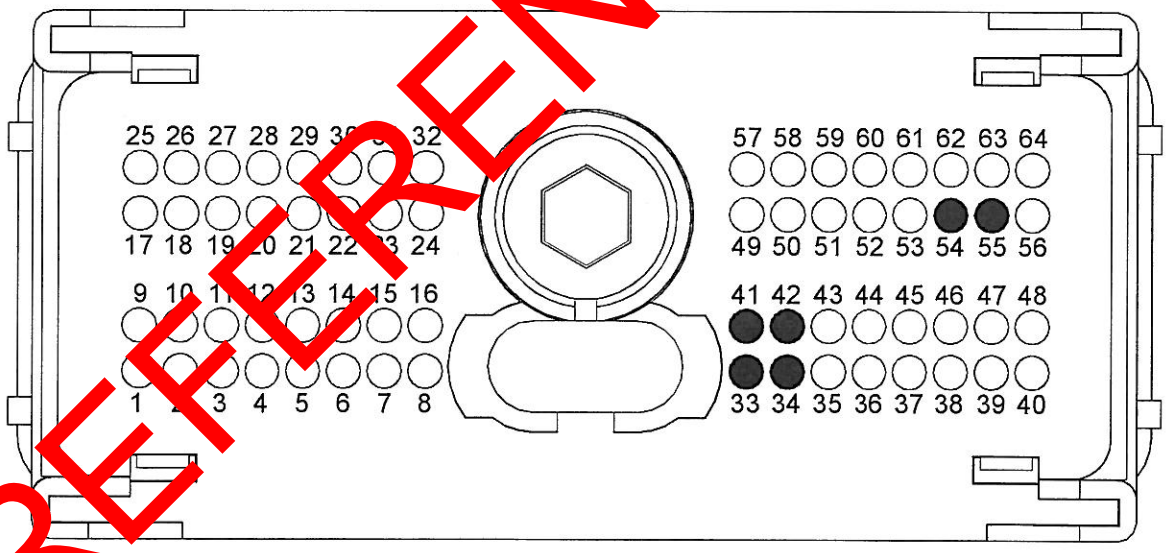
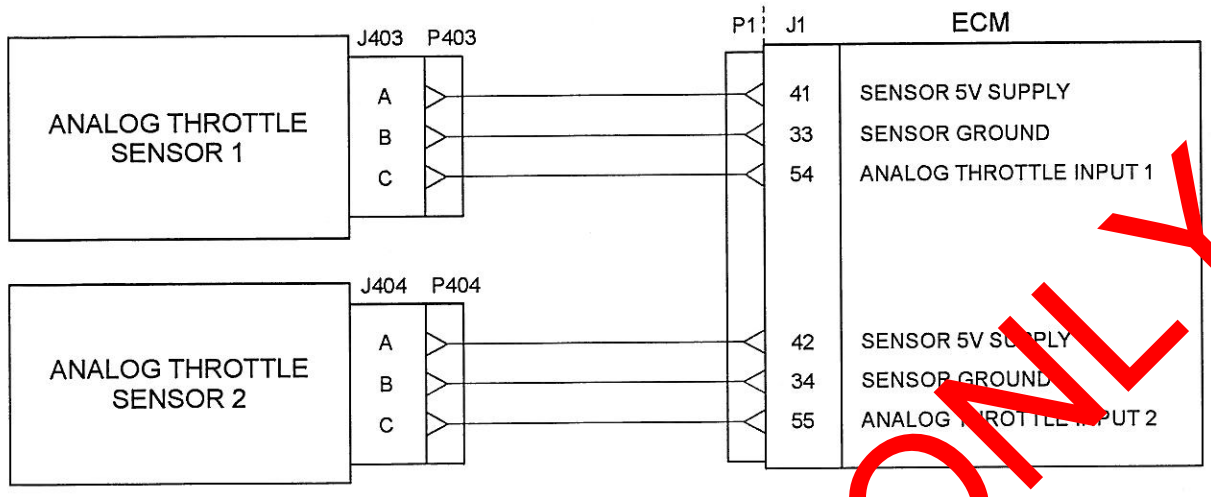



Illustration 27 g01800573

Typical example of the P1 pin locations for the analog throttle demand sensor

(33) Throttle 1 ground (GND)
(34) Throttle 2 ground (GND)
(41) Throttle 1 voltage supply (5 Volts)
(42) Throttle 2 voltage supply (5 Volts)
(54) Throttle 1 position
(55) Throttle 2 position

REFERENCE ONLY




g01800596

Illustration 28

Typical example of the schematic for the P1 OEM connections for the analog throttle demand sensors

REFERENCE ONLY

## Test Step 1. Check for Connector Damage

**A.** Turn the keyswitch to the OFF position.

**B.** Check the connectors and the harness for the following faults:

- Damage
- Abrasion
- Corrosion
- Incorrect attachment

**C.** Refer to Troubleshooting, "Electrical Connectors - Inspect".

**D.** Perform a 45 N (10 lb) pull test on each of the wires in the harness that are associated with the throttle demand sensor. Check the wire connectors at the following positions:

- ECM
- Pressure sensors
- Throttle pedal

The wire connectors are shown in table 54 and table 55.

**E.** Check the screws for the ECM connectors for the correct torque of 5.0 N·m (44 lb in).

**Expected Result:**

The connectors and the harness should be free of the following faults: damage, abrasion, corrosion, and incorrect attachment.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

  **Repair:** Repair the connectors or the harness and/or replace the connectors or the harness.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 2. Check for Active Diagnostic Codes

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Use the electronic service tool in order to monitor the diagnostic codes. Check and record any active diagnostic codes.

**Note:** Wait at least 15 seconds in order for the diagnostic codes to become active.

**Expected Result:**

One of the following diagnostic codes is active:

- 0262-03 5 Volt Sensor DC Power Supply voltage above normal
- 0262-04 5 Volt Sensor DC Power Supply voltage below normal

**Results:**

- OK – Diagnostic code 0262-04 is active. Proceed to Test Step 3.
- OK – Diagnostic code 0262-03 is active. Proceed to Test Step 6.
- Not OK – Diagnostic codes 0262-04 and 0262-03 are not active. Proceed to Test Step 4.

## Test Step 3. Disconnect the Sensors

**A.** Turn the keyswitch to the ON position.

**B.** Use the electronic service tool in order to monitor the diagnostic codes.

**C.** Disconnect the pressure sensors one at a time. If the analog throttle demand sensors are installed, then disconnect the throttle sensors one at a time. Wait for 30 seconds after each of the sensors is disconnected.

**Note:** Diagnostic code 0262-04 will become inactive when the sensor that caused the 5 Volt diagnostic code is disconnected.

**D.** Ensure that all the pressure sensors and the throttle demand sensors (if equipped) are disconnected.

**Expected Result:**

The 5 Volt diagnostic code is not active when all of the sensors are disconnected.

**Results:**

- OK – The 5 Volt diagnostic code is not active when all of the sensors are disconnected.

  **Repair:** Reconnect all of the sensors except the suspect sensor.

  Proceed to Test Step 4.

- Not OK – Diagnostic code 0262-04 is still active.

  **Repair:** Leave all of the sensors disconnected.

  Proceed to Test Step 5.

## Test Step 4. Install a New Sensor

**A.** Remove the connector from the suspect sensor and connect the connector to a replacement sensor. Do not install the replacement sensor to the engine.

**B.** Use the electronic service tool in order to monitor the diagnostic codes.

**Expected Result:**

Diagnostic codes 0262-03 and 0262-04 are not active.

**Results:**

- OK – The 5 Volt diagnostic code is not active.

  **Repair:** Use the electronic service tool in order to clear all logged diagnostic codes. Remove the suspect sensor and then install the replacement sensor. Connect the connector to the sensor.

  Verify that the repair eliminates the fault.

  STOP.

- Not OK – The 5 Volt diagnostic code is still active.

  **Repair:** Do not use the new sensor.

  Proceed to Test Step 5.

## Test Step 5. Disconnect the ECM Connector and Check for Active Diagnostic Codes

**A.** Turn the keyswitch to the OFF position.

**B.** Connect the electronic service tool to the diagnostic connector.

**C.** Check the ECM connectors for corrosion and moisture.

**D.** Disconnect the P2 ECM connector from the ECM.

**E.** If a P1:41 is installed, then temporarily disconnect the pin. If a P1:42 is installed, then temporarily disconnect the pin.

**F.** Reconnect the P1 connector to the ECM.

**G.** Turn the keyswitch to the ON position.

**H.** Check for active diagnostic codes on the electronic service tool.

**Note:** A "voltage high" diagnostic code (open circuit) should be active for all of the following sensors:

- Engine pressure sensors

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- Engine temperature sensors
- Analog throttle demand sensors (if equipped)

**Expected Result:**

Diagnostic code 0262-04 is not active. A "voltage high" diagnostic code (open circuit) is active for all of the engine pressure sensors, temperature sensors and throttle demand sensors (if equipped).

**Results:**

- OK – Diagnostic code 0262-04 is not active.

  **Repair:** Replace all wires to the original configuration.

  Proceed to Test Step 6.

- Not OK – The 5 Volt diagnostic code is still active.

  **Repair:** Perform the following repair:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
  2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
  4. Use the electronic service tool to clear the system for active diagnostic codes.
  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.
  6. If the fault returns with the suspect ECM, replace the ECM.
  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 6. Measure the +5 Volt Supply to the Sensor

**A.** Turn the keyswitch to the ON position.

**Note:** All the pressure sensors and the analog throttle demand sensors (if equipped) should be disconnected.

**B.** Measure the voltage between terminal 1 (Pressure sensor +5 Volts) and the engine ground for each of the pressure sensors.

**C.** Measure the voltage between terminal A (analog throttle demand sensors +5 Volts) and the engine ground for each of the analog throttle demand sensors.

**Expected Result:**

The voltage is 5.0 ± 0.16 Volts DC.

**Results:**

- OK – The +5 Volt supply is within the expected range. Proceed to Test Step 7.
- Not OK – The voltage is greater than 5.16 Volts DC.

  **Repair:** Check the +5 Volt supply wire for a short to a higher voltage source.

  Repair the +5 Volt supply wire and/or replace the +5 Volt supply wire.

  Verify that the repair eliminates the fault.

  STOP.

  Not OK – The voltage is less than 4.84 Volts DC.

  **Repair:** Check the +5 Volt supply wire for a short to ground.

  Repair the +5 Volt supply wire and/or replace the +5 Volt supply wire.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 7. Perform the "Wiggle Test" on the Electronic Service Tool

**A.** Select the "Wiggle Test" from the diagnostic tests on the electronic service tool.

**B.** Choose the appropriate group of parameters to monitor.

**C.** Press the "Start" button. Wiggle the wiring harness in order to reproduce intermittent faults.

If an intermittent fault exists, the status will be highlighted and an audible beep will be heard.

REFERENCE ONLY

**Expected Result:**

No intermittent faults were indicated during the "Wiggle Test".

**Results:**

- OK – No intermittent faults were found. The harness and connectors appear to be OK. If you were sent from another procedure, return to the procedure and continue testing. If this test has resolved the fault, return the engine to service. STOP.
- Not OK – At least one intermittent fault was indicated.

  **Repair:** Repair the harness or the connector.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03456601

# Analog Throttle Position Sensor Circuit - Test

**System Operation Description:**

Use this procedure if another procedure has directed you here. Use this procedure if any of the following diagnostic codes are active:

- 0091-03 Throttle Position Sensor voltage above normal
- 0091-04 Throttle Position Sensor voltage below normal
- 0774-03 Secondary Throttle Position Sensor voltage above normal
- 0774-04 Secondary Throttle Position Sensor voltage below normal

The diagnostic codes above relate to an analog sensor. Use this procedure only if the analog sensor is a variable resistance potentiometer sensor.

The sensor is most likely to be mounted on the throttle pedal. The sensor is attached directly to the throttle assembly. The sensor provides an output voltage to the Electronic Control Module (ECM). The sensor output voltage will vary with the position of the throttle. Foot operated or hand operated throttle assemblies are available.

The sensor receives +5 Volt DC power from the ECM. The sensor will produce a raw signal voltage that will alter between low idle and high idle. The voltage is changed into a throttle position within the range 0% to 100% by the ECM.

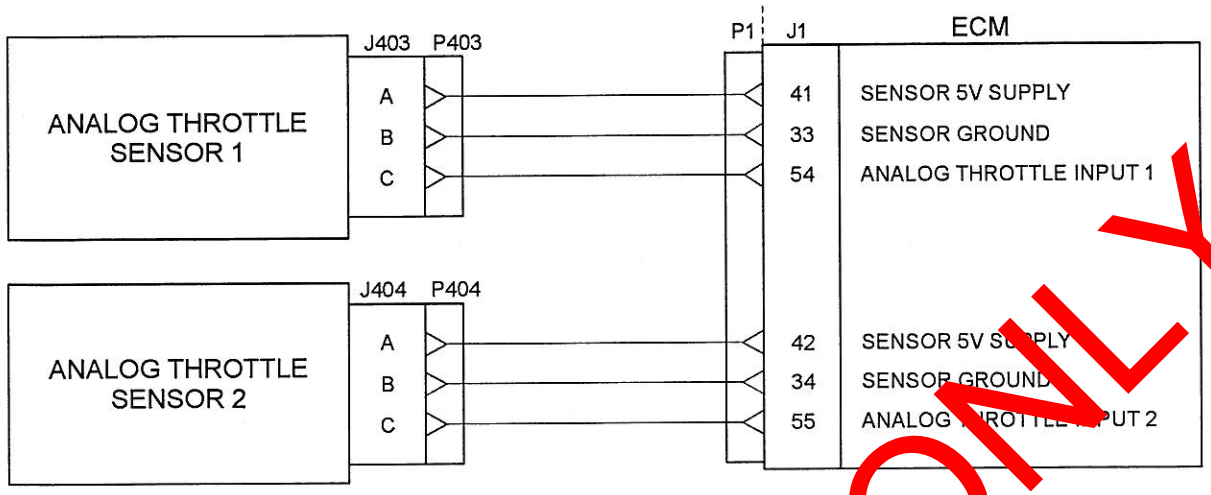
The sensor senses the speed requirement from the throttle position. A second sensor may override this speed requirement from the first sensor. This override will be subject to an input from either the SAE J1939 (CAN), or from the PTO controls.

Use the electronic service tool in order to check the input status.

Table 56

| P1 Pin Connector | | |
|---|---|---|
| **Function** | **Throttle 1** | **Throttle 2** |
| +5 Volt Supply | 41 | 42 |
| Sensor Ground | 33 | 34 |
| Throttle Position Input | 54 | 55 |
| Idle Validation | 45 | 44 |

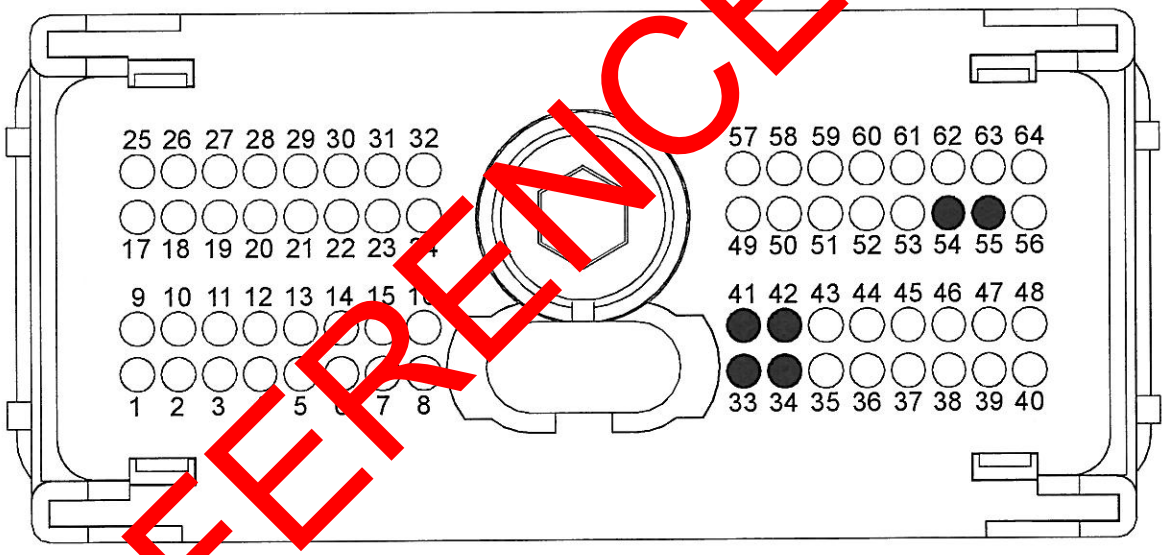
REFERENCE ONLY




g01800755

Illustration 29

Schematic of the analog throttle demand sensors




g01800768

Illustration 30

Typical view of the pin locations on the P1 connector

(33) Sensor Ground (GND)
(34) Sensor Ground (GND)
(41) Sensor supply (5 Volt DC)
(42) Sensor supply (5 Volt DC)
(54) Analog throttle input 1
(55) Analog throttle input 2

REFERENCE ONLY

## Test Step 1. Check for Connector Damage

**A.** Turn the keyswitch to the OFF position.

**B.** Check the connectors and the harness for the following faults: damage, abrasion, corrosion, and incorrect attachment.

**C.** Refer to Troubleshooting, "Electrical Connectors - Inspect".

**D.** Perform a 45 N (10 lb) pull test on each of the wires in the harness that are associated with the throttle demand sensor. Check the wire connectors at the ECM and at the throttle pedal. The wire connectors are shown in table 56.

**E.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**Expected Result:**

The connectors and the harness should be free of the following faults: damage, abrasion, corrosion, and incorrect attachment.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

  **Repair:** Repair the connectors or the harness and/or replace the connectors or the harness.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 2. Check for active Diagnostic Codes.

**A.** Turn the keyswitch to the ON position.

**B.** Use the electronic service tool to check for diagnostic codes.

**Expected Result:**

**RESULT 1** The electronic service tool displays the following active diagnostic codes or recently logged diagnostic codes:

- 91-3 Throttle Position Sensor voltage above normal
- 91-4 Throttle Position Sensor voltage below normal
- 774-3 Secondary Throttle Position Sensor voltage above normal
- 774-4 Secondary Throttle Position Sensor voltage below normal

**RESULT 2** The electronic service tool displays no active diagnostic codes.

**Results:**

- Result 1 – Proceed to Test Step 3.
- Result 2 – Proceed to Test Step 5.

## Test Step 3. Check the Throttle Position with the Electronic Service Tool

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position. Do not start the engine.

**C.** Observe the throttle position reading on the electronic service tool.

**D.** Slowly depress the throttle and release the throttle.

**Expected Result:**

The output should increase when the throttle pedal is depressed.

The output should be between "20 percent" and "27 percent" at the low idle position. The output should be between "80 percent" and "87 percent" at the high idle position.

**Results:**

- OK – The sensor is operating correctly. Proceed to Test Step 4.
- Not OK – The ECM is not receiving a correct signal from the sensor. Proceed to Test Step 5.

## Test Step 4. Check the Throttle Selection Status with the Electronic Service Tool

**A.** Check the status of the throttle selection switch (if equipped). Use the electronic service tool in order to check the status of the throttle selection switch.

**Expected Result:**

If the status of the throttle selection switch is shown in the OFF position, then the throttle 1 has control of the engine speed.

If the throttle selection switch status is shown in the ON position, then the throttle 2 has control of the engine speed.

The throttle may be overridden by using the SAE J1939 (CAN) data link or the set speed control.

**Results:**

- OK – The throttle demand switch is operating correctly.

  **Repair:** There may be an intermittent fault. Refer to Troubleshooting, "Electrical Connectors - Inspect".

  STOP.

- Not OK – The wrong throttle is selected. Change to the other throttle. There may be a fault with the selector switch input.

  **Repair:** Check the connections between the throttle selection switch and P1:47 and P1:35. Refer to Troubleshooting, "Electrical Connectors - Inspect".

  STOP.

REFERENCE ONLY

### Test Step 5. Check the Voltage at the Sensor

**A.** Turn the keyswitch to the OFF position.

**B.** Install a breakout "T" with 3 terminals to the sensor.

**C.** Turn the keyswitch to the ON position.

**D.** Measure the voltage between terminal "A" and terminal "B" on the breakout "T".

**Expected Result:**

The supply voltage should be between 4.84 Volts DC and 5.16 Volts DC.

**Results:**

- OK – The supply voltage is reaching the sensor. Proceed to Test Step 6.
- Not OK – The supply voltage is not reaching the sensor.

  **Repair:** Refer to Troubleshooting, "5 Volt Sensor Supply Circuit - Test".

  STOP.

### Test Step 6. Check the Position of Sensor

**A.** Turn the keyswitch to the OFF position.

**B.** Install a breakout "T" with 3 terminals to the sensor.

**C.** Turn the keyswitch to the ON position.

**D.** Measure the voltage between terminal "C" and terminal "B" on the breakout "T".

**E.** Observe the voltage while the engine speed control is moved from the minimum to the maximum position.

**Expected Result:**

The voltage should vary between 1.5 Volts DC and 4.4 Volts DC when the speed control is moved from the minimum to the maximum position.

**Results:**

- OK – The throttle demand sensor is operating correctly. Proceed to Test Step 7.
- Not OK – The throttle demand sensor is faulty. Proceed to Test Step 8.

### Test Step 7. Check the Sensor at the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Remove the P1 connector.

**C.** Temporarily remove the pin from P1:54.

**D.** Reconnect P1 connector.

**E.** Connect the red probe of a multimeter to the removed pin and the black probe of a multimeter to P1:33.

**F.** Turn the keyswitch to the ON position.

**G.** Use the multimeter to display the output voltage of the sensor while the engine speed control is moved from the minimum position to the maximum position.

**H.** Turn the keyswitch to the OFF position.

**I.** Remove the P1 connector.

**J.** Reconnect P1:54.

**K.** Reconnect the P1 connector.

**Expected Result:**

The output from the throttle demand sensor is 0.5 Volts or less with the sensor slot in the released position.

The output from the throttle demand sensor is 4.5 Volts or more with the sensor slot in the advanced position.

**Results:**

- OK – The ECM terminals have the correct voltage for the sensor.

  **Repair:** Check for the correct supply voltage at the ECM. If the voltage is correct, then perform the following procedure.

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
  2. Contact the Technical Help Desk.

  **Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
  4. Use the electronic service tool to recheck the system for active diagnostic codes.

REFERENCE ONLY

5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

6. If the fault returns with the suspect ECM, replace the ECM.

7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

- Not OK – There is a fault in the harness or the connectors between the sensor and the ECM. Check all of the connections between the ECM and the sensor. Repair the damaged cables or replace the damaged cables. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repairs have eliminated the fault. STOP.

## Test Step 8. Remove the Sensor from the Engine Speed Control Assembly

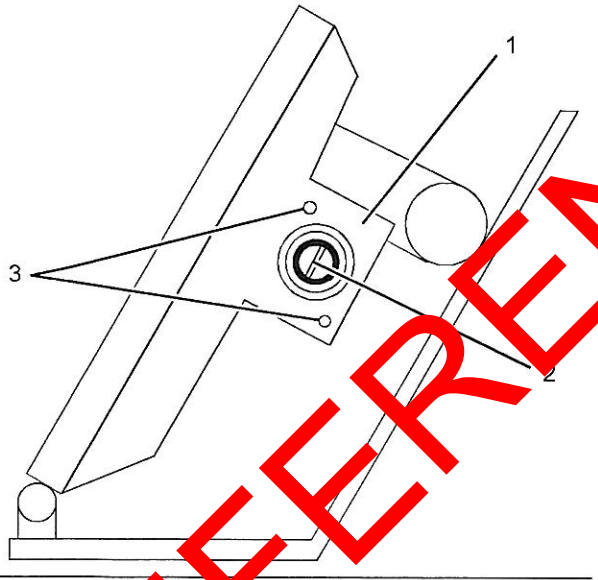



Illustration 31 g01170704

Throttle pedal assembly

(1) Sensor mounting face
(2) Sensor drive key
(3) Mounting screw holes

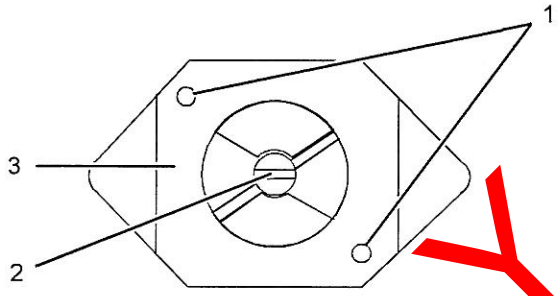



Illustration 32 g01170753

Throttle block assembly

(1) Mounting screw holes
(2) Sensor drive slot
(3) Sensor mounting face

**A.** Turn the keyswitch to the OFF position.

**B.** Record the position of the sensor before removing the sensor.

**C.** Remove the sensor from the housing and inspect the cables for signs of wear.

**D.** Connect a multimeter to terminal "C" and terminal "B" on the breakout "T".

**E.** Turn the keyswitch to the ON position.

**F.** Record the signal voltage of the sensor with the sensor slot in the released position.

**G.** Record the signal voltage of the sensor with the sensor slot in the advanced position.

**Expected Result:**

The output from the sensor is 0.5 Volts DC or less with the sensor slot in the released position.

The output from the sensor is 4.5 Volts DC or more with the sensor slot in the advanced position.

**Results:**

- OK

  **Repair:** The operation of the sensor is correct. The fault is caused by the foot pedal or the lever assembly. Adjust the assembly or replace the assembly.

  Verify that the repairs have eliminated the fault.

  STOP.

- Not OK – The sensor is faulty.

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**Repair:** Replace the sensor.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

STOP.

i03458200

# CAN Data Link Circuit - Test

**System Operation Description:**

**Use this procedure under the following circumstances:**

Use this procedure if another procedure has directed you here. Use this procedure if any of the following diagnostic codes are active:

- 0247-09 SAE J1939 Data Link abnormal update rate
- 0247-12 SAE J1939 Data Link failure

**The following background information is related to this procedure:**

The CAN Data Link is also known as J1939 Data Link. The data link is an industry standard for sending data between different devices in the same application.

High speed data is transfered via the data link. The data link cannot be accurately tested without complicated equipment. The data link requires a resistance of 60 Ohms between the two wires to correctly transmit the data. This resistance is made up of two 120 Ohm resistors. The two resistors are known as "Terminating Resistors". The terminating resistors should be at opposite ends of a data link network. If this resistance is not present, then the data will be intermittent or completely unreadable.

**Note:** The wiring for the J1939 data link is a shielded twisted pair cable. If the wiring is damaged the replacement type must be shielded twisted pair cable.

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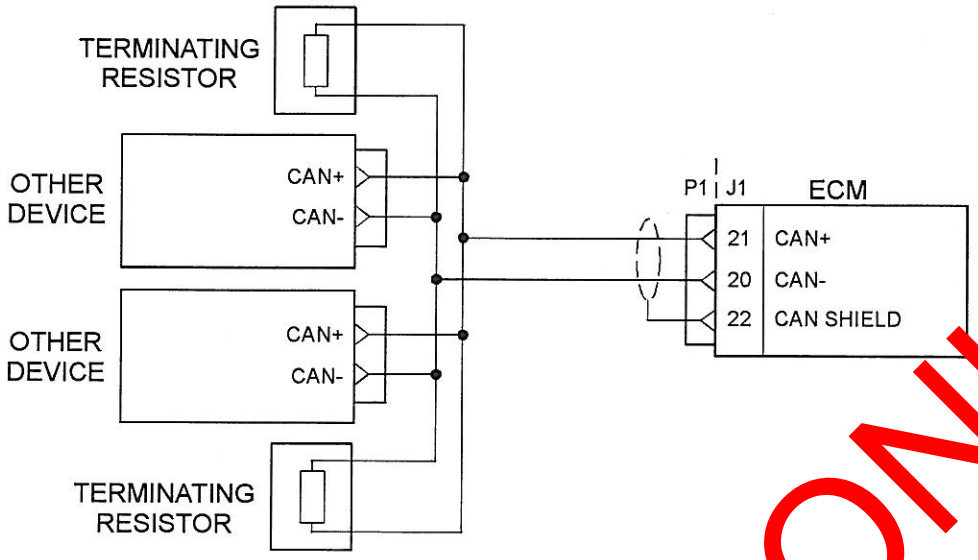



Illustration 33 g01801898

Typical example of the schematic for the CAN data link

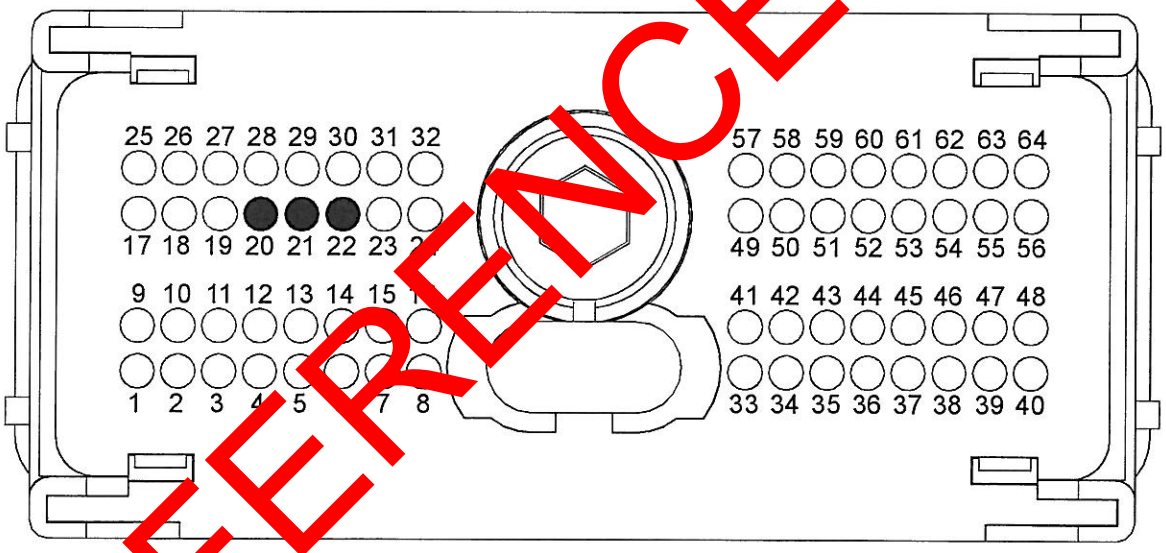



Illustration 34 g01801913

Typical view of the P1 connector pin locations

(20) CAN- (21) CAN+ (22) CAN Shield

REFERENCE ONLY

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Turn the keyswitch to the OFF position.

**B.** Thoroughly inspect the harness connector P1/J1 and any other connectors in the CAN data link circuit.

Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires that are associated with the CAN data link. Refer to Illustration 34.

**D.** Check the harness for abrasion and pinch points from the keyswitch to the ECM.

**Expected Result:**

All connectors, pins and sockets should be completely coupled and/or inserted. The harness should be free of corrosion, abrasion and/or pinch points.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

  **Repair:** Perform the following repair:

  Repair the connectors and/or the wiring, or replace the connectors and/or the wiring. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 2. Check the Data Link Terminating Resistance

**A.** Disconnect the P1 connector from the ECM.

**B.** Measure the resistance between P1:20 and P1:21.

**Expected Result:**

The resistance is between 50 and 70 Ohms.

**Results:**

- Result 1 – The resistance is between 50 and 70 Ohms. This is the correct resistance. The fault may be in the connection to other devices on the data link. Proceed to Test Step 3.
- Result 2 – The resistance is less than 50 Ohms. There is a short circuit in the harness.

  **Repair:** Repair the connectors or the harness and/or replace the connectors or the harness.

  Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.
- Result 3 – The resistance is between 110 and 130 Ohms. One of the terminating resistors may have failed.

  **Repair:** Locate the two terminating resistors and remove the two terminating resistors from the harness. Depending on the application, one or both of the terminating resistors may be located in other ECM's on the data link.

  Measure the resistance of the two terminating resistors.

  If one of the terminating resistors is incorrect, replace the faulty terminating resistor.

  If the two terminating resistors are between 50 and 70 Ohms, proceed to Test Step 4.
- Result 4 – The resistance is greater than 150 Ohms. There may be a break in the harness. Proceed to Test Step 3.

## Test Step 3. Check the Data Link Wiring

**A.** Disconnect each of the connectors that connect other devices on the data link.

**B.** Use a multimeter in order to measure the resistance between P1:20 to each of the CAN+ pins that connect other devices on the data link.

**C.** Use a multimeter in order to measure the resistance between P1:21 to each of the CAN- pins that connect other devices on the data link.

**D.** Use a multimeter in order to measure the resistance between P1:22 to each of the CAN SHIELD pins that connect other devices.

**Expected Result:**

The resistance of each wire is less than 2 Ohms.

**Results:**

- OK – The resistance is less than 2 Ohms. Proceed to Test Step 4.
- Not OK – Some resistances are greater than 2 Ohms.

  **Repair:** Repair the connectors or the harness and/or replace the connectors or the harness.

  Ensure that all seals are correctly in place and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

## Test Step 4. Check the other Devices on the J1939 Data Link

**A.** Use the appropriate service tools in order to diagnose other devices on the data link.

**Expected Result:**

The other devices are working correctly.

REFERENCE ONLY

**Results:**

- OK – The other devices are operating correctly. Restart the diagnostic process. STOP.
- Not OK – The other devices are not working correctly.

  **Repair:** Use the appropriate service tools in order to diagnose other devices on the data link.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03458241

# Data Link Circuit - Test

**System Operation Description:**

**Use this procedure under the following circumstances:**

Use this procedure if the electronic service tool will not communicate with the Electronic Control Module (ECM) through the data link.

**The following background information is related to this procedure:**

The data link is the standard data link that is used by the ECM in order to communicate with the electronic service tool.

The ECM provides multiple connections for the data link. The technician must ensure that the correct connector is being tested. The connection that is used is dependent on the application.

If the diagnostic connector is on the engine, the positive data link signal will be from P2:21 to J23:D. The negative data link signal will be from P2:20 to J23:E.

If the diagnostic connector is off the engine, the positive data link signal will be from P1:23 to "J23:D" of the diagnostic connector. The negative data link signal will be from P1:24 to "J23:E" of the diagnostic connector.

The following information refers to the pin number. Ensure that the correct connector is used.

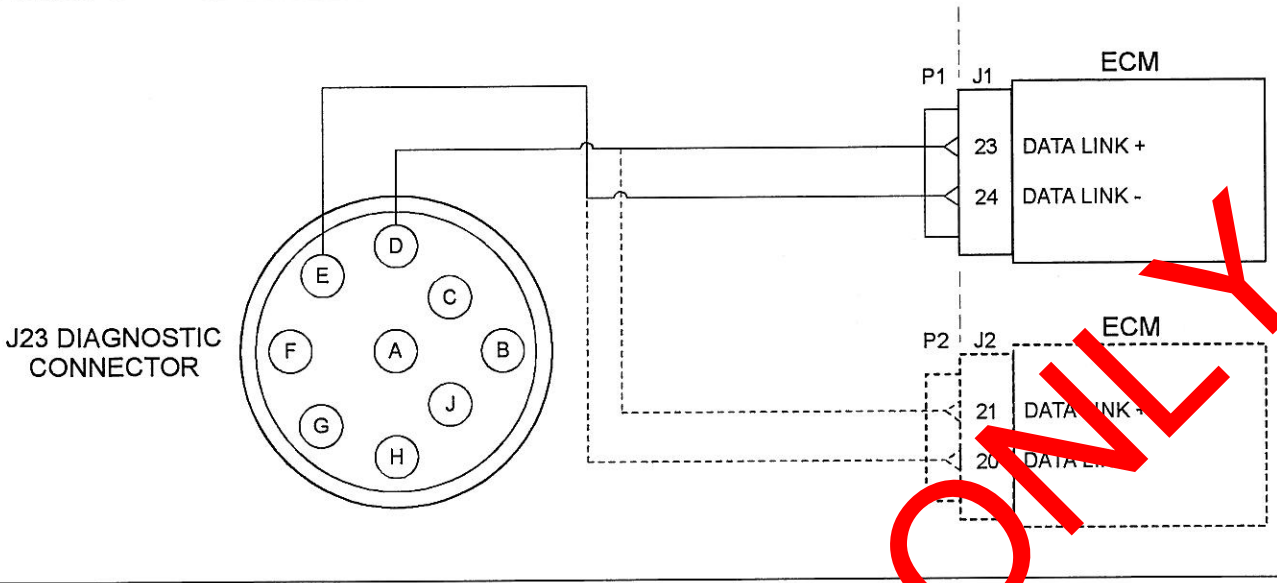
**Communication**

The electronic service tool may indicate the following error message:

The version of the ECM is not recognized and the integrity of the changed parameters and displayed data is not guaranteed.

This message will indicate that the version of the software that is in the electronic service tool is not the same version of the software that is in the ECM. Install the latest version of the electronic service tool software in order to rectify the fault.

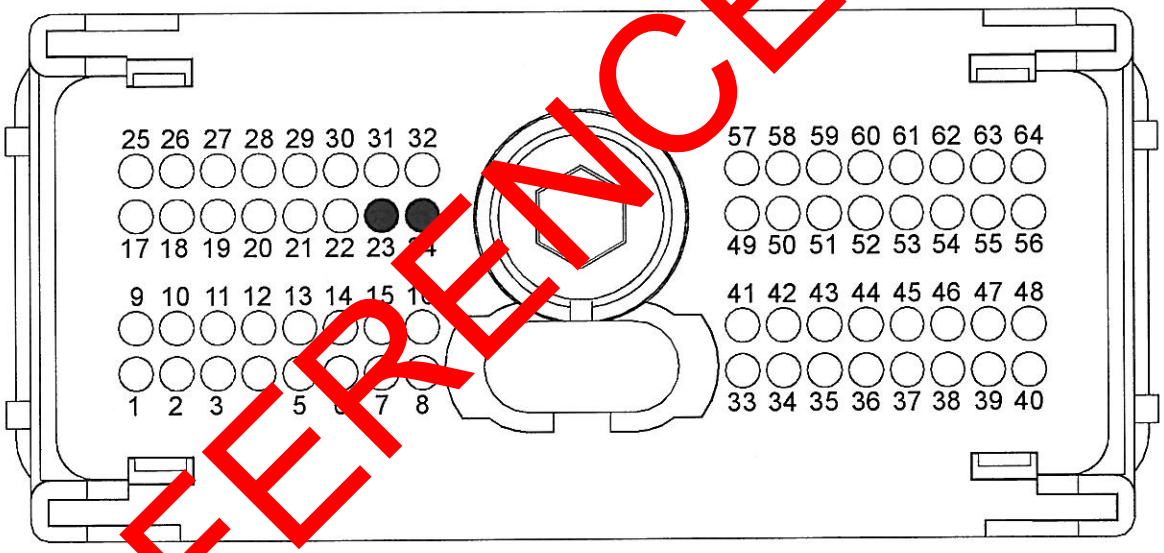
REFERENCE ONLY




g01801933

Illustration 35

Schematic of the diagnostic connector




g01801995

Illustration 36

Typical view of the pin locations on the P1 connector

(23) Data link +

(24) Data link -

REFERENCE ONLY

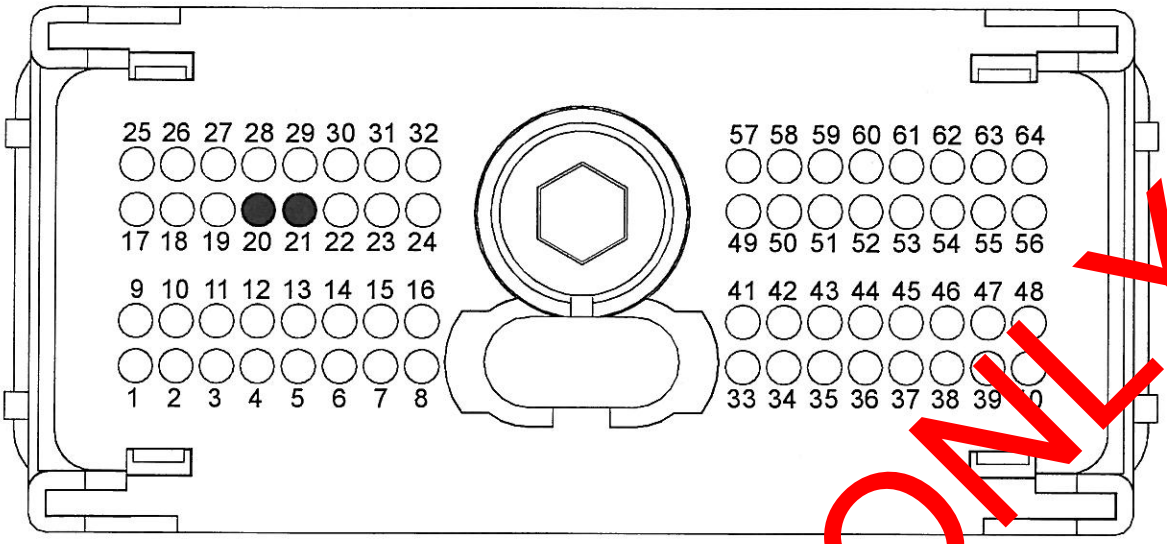



Illustration 37 g01801993

Typical view of the pin locations on the P2 connector

(20) Data link - (21) Data link +

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Thoroughly inspect the following electrical connectors:

- P2/J2 ECM connector
- P1/J1 ECM connector
- J23 diagnostic connector

Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**B.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connectors that are associated with the data lin

**C.** Check the screw for the ECM connectors for correct torque 5.0 N·m (44 lb in).

**D.** Check the harness for abrasion and pinch points from the wires that connect the diagnostic connector to the ECM.

**Expected Result:**

All connectors, pins and sockets should be completely coupled and/or inserted. The harness should be free of corrosion, abrasion and/or pinch points.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

**Repair:** Perform the following repair:

Repair the connectors and/or the harness, or replace the connectors and/or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 2. Determine the Type of Fault on the Data Link

**A.** Connect the electronic service tool to the diagnostic connector that is on the engine harness or on the application.

**B.** Turn the keyswitch to the ON position.

**Expected Result:**

The power lamp should illuminate on the communications adapter. The power lamp on the communications adapter may illuminate when the keyswitch is in any position.

**Results:**

- OK – The communications adapter is currently receiving the correct voltage.

REFERENCE ONLY

**Repair:** If you are redirected to this step from "Check the wiring of the Diagnostic Connector"and if a jumper wire has been installed between pin "A" on the diagnostic connector and the positive terminal on the battery and if a jumper wire has been installed between pin "B" on the diagnostic connector and the negative terminal on the battery, remove the jumper wires and then repair the harness. If the harness cannot be repaired, replace the harness.

Proceed to Test Step 5.

- Not OK – The communications adapter is not receiving the correct voltage. Proceed to Test Step 3.

## Test Step 3. Check the Wiring of the Diagnostic Connector

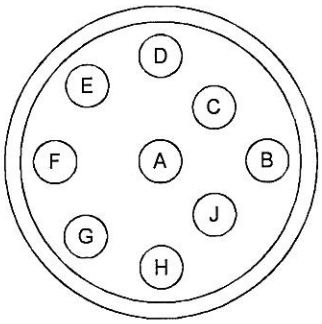



Illustration 38 g01501997

Typical view of the diagnostic connector from the wire side

(A) Switched battery +
(B) Battery ground (GND)
(D) Data link +
(E) Data link -

**A.** If the communications adapter is connected to the diagnostic connector on the engine, ensure that pin "A" and pin "B" are wired on the engine harness side of the connector.

**Expected Result:**

The pins are wired.

**Results:**

- OK – The harness is fully wired. Proceed to Test Step 4.
- Not OK – The data link connector power connections are not wired.

  **Repair:** Fabricate a jumper wire in order to connect pin "A" of the diagnostic connector to battery+ and pin "B" to the battery-.

  Proceed to Test Step 2.

## Test Step 4. Check the Battery Voltage at the Diagnostic Connector

**A.** Turn the keyswitch to the ON position.

**B.** Use a multimeter in order to measure the voltage from pin A (battery+) and pin B (ground) of the diagnostic connector.

**Expected Result:**

The voltage is between 22.0 Volts DC and 27.0 Volts DC for a 24 Volt system and between 11.0 Volts DC and 13.5 Volts DC for a 12 Volt system.

**Results:**

- OK – The diagnostic connector is currently receiving the correct voltage. Proceed to Test Step 5.
- Not OK – The diagnostic connector is not receiving the correct voltage.

  **Repair:** Refer to Troubleshooting, "Engine Wiring Information".

  Proceed to Test Step 2.

## Test Step 5. Check the Data Link Connections

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the communications adapter from the diagnostic connector.

**C.** If the diagnostic connector is installed on the application, disconnect P1 OEM connector from connector J1. Check the resistance between P1:23 and diagnostic pin "D". If the diagnostic connector is installed on the engine, disconnect P2 from connector J2. Check the resistance between P2:21 and diagnostic pin "D".

**D.** If the diagnostic connector is installed on the application, check the resistance between P1:24 and diagnostic pin "E". If the diagnostic connector is installed on the engine, check the resistance between P2:20 and diagnostic pin "E".

**Expected Result:**

The resistance that is measured is less than 10 Ohms.

**Results:**

- OK – The resistance is less than 10 Ohms. Proceed to Test Step 6.

REFERENCE ONLY

- Not OK – The resistance is greater than 10 Ohms.

  **Repair:** Perform the following repair:

  Repair the connectors and/or the harness, or replace the connectors and/or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 6. Change the Components of the Electronic Service Tool

**A.** If another electronic engine is available, connect the electronic service tool to the other engine. Ensure that the same cables are used.

**B.** Turn the keyswitch to the ON position. Determine if the electronic service tool operates correctly on the other engine.

**C.** If another engine is not available, obtain a replacement communications adapter and a replacement set of electronic service tool cables. Ensure that the set of electronic service tool cables are a complete set.

**D.** Install the replacement communications adapter and electronic service tool cables and connect to the diagnostic connector.

**E.** Turn the keyswitch to the ON position.

**F.** If changing the communications adapter or the electronic service tool cables allows the electronic service tool to operate correctly, use the following procedure:

**a.** Replace the components from the old set of electronic service tool cables into the new set of cables that operate. Replace one component at a time.

**b.** Apply power to the electronic service tool after each of the components is replaced. Use this method to find the faulty component.

**G.** If changing the electronic service tool cables does not allow the electronic service tool to operate correctly, connect another electronic service tool.

**H.** Turn the keyswitch to the ON position.

**Expected Result:**

**Result 1** The original electronic service tool works on another engine.

**Result 2** A different electronic service tool works on the original engine while the engine is being tested.

**Results:**

- Result 1 – Proceed to Test Step 7.
- Result 2

  **Repair:** Send the faulty electronic service tool for repairs.

  STOP.

## Test Step 7. Connect the Electronic Service Tool and the ECM to the Other Battery

**WARNING**

**Batteries give off flammable fumes which can explode.**

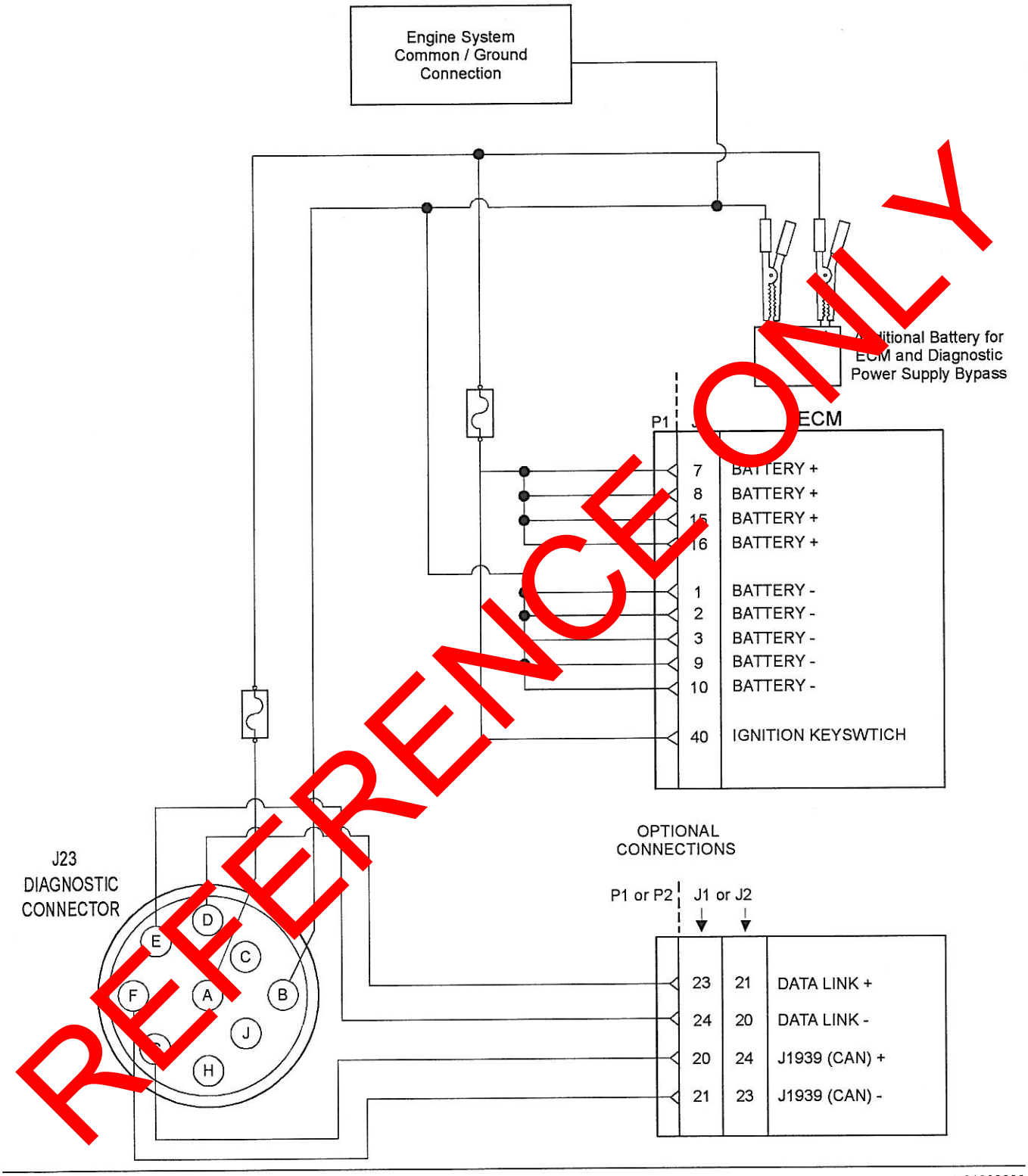
**To avoid injury or death, do not strike a match, cause a spark, or smoke in the vicinity of a battery.**

NOTICE

Do Not connect the Bypass Harness to the battery until the in-line fuse has been removed from the +Battery line. If the fuse is not removed before connection to the battery a spark may result.

**Note:** Refer to Troubleshooting, "Electronic Service Tools" for details of the bypass harness.

REFERENCE ONLY




REFERENCE ONLY

g01802000

Illustration 39

Schematic of the bypass harness connector

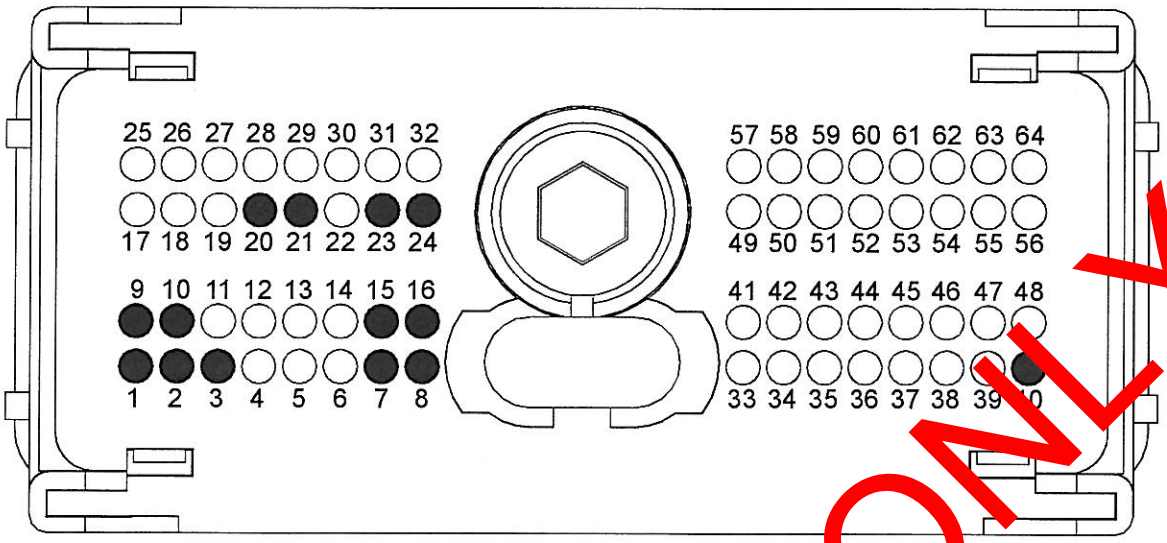



Illustration 40 g01802213

Typical view of the pin locations on the P1 connector for the diagnostic and data link connectors

(1) Battery ground (GND)
(2) Battery ground (GND)
(3) Battery ground (GND)
(7) Battery +
(8) Battery +
(9) Battery ground (GND)
(10) Battery ground (GND)
(15) Battery +
(16) Battery +
(20) J1939 (CAN) +
(21) J1939 (CAN) -
(23) Data link +
(24) Data link -
(40) Keyswitch

**A.** Connect the battery wires from the bypass harness of the electronic service tool to a different battery that is not on the engine.

**Expected Result:**

The electronic service tool is operating correctly.

**Results:**

- Yes

  **Repair:** Refer to Troubleshooting, "Engine Wiring Information".

  STOP.

- No

  **Repair:** Perform the following repair:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

  2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

  4. Use the electronic service tool to recheck the system for active diagnostic codes.

  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

  6. If the fault returns with the suspect ECM, replace the ECM.

  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03458641

# Digital Throttle Position Sensor Circuit - Test

**System Operation Description:**

**Use this procedure under the following situation:**

Use this procedure if any of the following diagnostic codes are indicated:

- 0041-03 8 Volt DC Supply voltage above normal
- 0041-04 8 Volt DC Supply voltage below normal

REFERENCE ONLY

- 0091-08 Throttle Position Sensor abnormal frequency, pulse width, or period

Also, use this procedure if the digital throttle position sensor is suspected of improper operation.

**Digital Throttle Position Sensor**

The digital throttle position sensor is used to provide a digital throttle position signal to the Engine Control Module (ECM). The sensor output is a constant frequency signal with a pulse width that varies with the pedal position. This output signal is referred to as either a duty cycle or a Pulse Width Modulated signal (PWM) and this output signal is expressed as a percentage between 3 and 100 percent.

The digital throttle position sensor is most likely to be attached directly to the throttle pedal assembly. The digital throttle position sensor requires no adjustment.

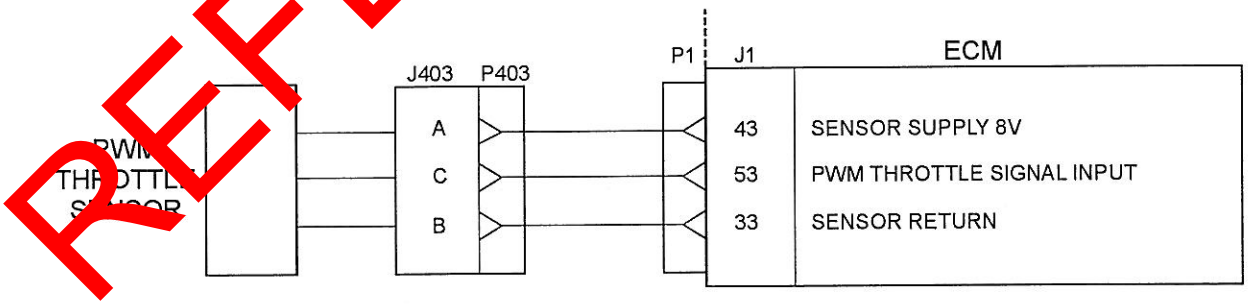
The digital throttle position sensor will produce a duty cycle of 10 to 22 percent at low idle and 75 to 90 percent when the throttle pedal is fully depressed. The percent of duty cycle is translated in the ECM into a throttle position of 3 to 100 percent.

The digital throttle position sensor is powered by the ECM supply voltage (+8 Volts DC). The supply voltage is from the J1:43 to terminal "A" of the digital throttle position sensor connector.

If the application is using the ECM dedicated PTO functions, the digital throttle position sensor will be ignored while the engine is in PTO mode.

The ECM is in PTO mode if the "PTO ON/OFF Switch" is ON. This can be checked with the electronic service tool. Refer to Troubleshooting, "PTO Switch Circuit - Test" for testing if the PTO is being used.

REFERENCE ONLY




g01802294

Illustration 41

Typical schematic of the digital throttle position sensor

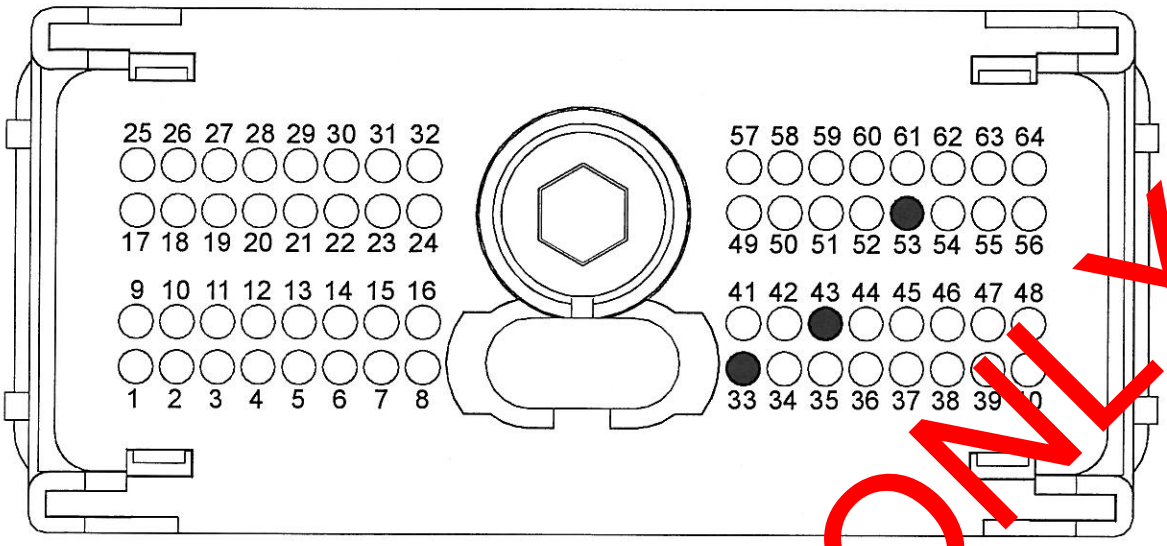



Illustration 42 g01802315

Typical example of the pin locations on the P1 connector

(33) Sensor return (43) Sensor supply (8 Volts) (53) Sensor input

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Inspect the P1/J1 connector, OEM harness and the OEM connectors. Thoroughly inspect the digital throttle position sensor connector. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**B.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connector that are associated with the digital throttle position sensor.

- P1:33
- P1:43
- P1:53

**C.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**D.** Check the harness for abrasion and pinch points from the digital throttle position sensor to the ECM.

**Expected Result:**

All connectors, pins and sockets are completely coupled and/or inserted and the harness is free of corrosion, of abrasion or of pinch points.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

**Repair:** Perform the following repair:

Repair the connectors or the harness and/or replace the connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 2. Check for Active Diagnostic Codes

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Monitor the active diagnostic code screen on the electronic service tool. Check and record active diagnostic codes.

REFERENCE ONLY

**Note:** When the ECM automatically calibrates new duty cycle values for the low idle throttle position and the high idle throttle position, the ECM assumes 22 percent duty cycle at low idle and 75 percent duty cycle at high idle. As a result, you may notice that the throttle position status reaches 100 percent well before the throttle pedal is fully depressed. This is normal. After some cycling of the throttle pedal to the high idle position, the ECM will adjust the calibration automatically. The ECM will adjust the calibration automatically provided that the high idle stop position is within the 75 to 90 percent duty cycle range, and the low idle is in the 10 to 22 percent duty cycle range. During normal operation, you may also notice that more movement of the throttle pedal is required for the throttle position status to increase above three percent. You may also observe that the status reaches the 100 percent value prior to the limit of the high idle position. This is done in order to ensure that the throttle reaches these two critical points for engine operation.

**Expected Result:**

**Result 1** Diagnostic code 0091-08 is active.

**Result 2** Diagnostic code 0041-03 is active.

**Result 3** There are no active diagnostic codes that are related to the digital throttle pedal position sensor circuit at this time, but a fault is suspected with operation of the digital throttle position sensor circuit.

**Results:**

- Result 1 – Proceed to Test Step 3.
- Result 2 – Proceed to Test Step 5.
- Result 3 – Proceed to Test Step 3.

## Test Step 3. Check the Duty Cycle of the Digital Throttle Position Sensor

**A.** Verify that the keyswitch is in the ON position.

**B.** Monitor the duty cycle of the throttle sensor on the "Throttle Display" screen of the electronic service tool.

**Expected Result:**

The duty cycle is between 10 and 22 percent with the throttle pedal assembly in the low idle position, and the duty cycle is between 75 and 90 percent with the throttle pedal assembly in the high idle position.

**Results:**

- OK – The digital throttle position sensor is operating correctly. Proceed to Test Step 6.
- Not OK – The digital throttle position sensor circuit is not operating correctly. Proceed to Test Step 4.

## Test Step 4. Check the Supply Voltage at the Digital Throttle Position Sensor

**A.** Turn the keyswitch to the OFF position.

**B.** Install a breakout "T" with 3 terminals at the digital throttle position sensor connector J403/P403.

**C.** Turn the keyswitch to the ON position.

**D.** Measure the voltage at terminal "A" (+8 Volts DC) with reference to terminal "B" (digital throttle position sensor ground).

**Expected Result:**

The measured voltage is between 7.5 Volts DC and 8.5 Volts DC for the digital throttle position sensor.

**Results:**

- OK – Proceed to Test Step 8.
- Not OK – The sensor is not receiving the correct voltage. Proceed to Test Step 5.

## Test Step 5. Monitor the Electronic Service Tool while the Digital Throttle Position Sensor is Being Disconnected

**A.** Access the active diagnostic code screen on the electronic service tool. Ensure that one of the following diagnostic code is active before proceeding:

- 41-3
- 41-4

**B.** Monitor the active diagnostic code screen while the digital throttle position sensor is being disconnected and reconnected.

**Expected Result:**

One of the following diagnostic codes is still active after the digital throttle position sensor has been disconnected:

- 41-3
- 41-4

**Results:**

- OK – Ensure that the digital throttle position sensor has been reconnected before continuing. Proceed to Test Step 7.
- Not OK

REFERENCE ONLY

**Repair:** Perform the following diagnostic procedure:

Temporarily install another digital throttle position sensor. Use the electronic service tool in order to check for an active +8 Volt diagnostic code. Replace the digital throttle position sensor if both of the following conditions occur:

- The fault is corrected with the new digital throttle position sensor.
- The fault returns after the old digital throttle position sensor has been reconnected.

STOP.

## Test Step 6. Check the Status of the PTO On/Off Switch and the Status of the Power Train Data Link with the Electronic Service Tool

**A.** Check the status of the "PTO ON/OFF Switch" with the electronic service tool in order to verify that the "PTO ON/OFF Switch" is switched OFF. The PTO mode may cause the ECM to ignore the digital throttle position sensor if demand is less than the PTO speed demand.

**B.** Start the engine. Use the electronic service tool in order to monitor the throttle position status. While the throttle position status is being monitored, depress the throttle pedal and release the throttle pedal. The throttle position status and the engine should respond to the change in the throttle pedal position.

**C.** Go to the "Configuration Settings" screen on the electronic service tool and turn on the "Torque Speed Control".

**Note:** The "Torque Speed Control" is an option that may be installed by the OEM.

**D.** While the throttle position status is being monitored, depress the throttle pedal and release the throttle pedal. Also depress the throttle pedal and release the throttle pedal while the engine response is being monitored.

**Expected Result:**

The throttle position status and the engine should respond to the change in the throttle pedal position.

**Result 1** The digital throttle position sensor functions correctly.

**Result 2** The throttle response is limited by a "Torque Speed Control" message.

**Result 3** The PTO limits the throttle response.

**Results:**

- Result 1 – The digital throttle position sensor is operating correctly. Continue troubleshooting until the original condition is resolved. STOP.
- Result 2 – If the engine responds with the "Torque Speed Control Link" in a disabled condition and the engine does not respond with the "Power Train Data Link" in an enabled condition, a component of the "Power Train Data Link" is causing the response fault of the digital throttle position sensor. Refer to the OEM dealer in order to repair the faulty component of the "Power Train Data Link". STOP.
- Result 3 – The ECM is operating in PTO mode.

  **Repair:** If the PTO should not be active, refer to the following diagnostic procedure: Troubleshooting, "PTO Switch Circuit - Test"

  STOP.

## Test Step 7. Disconnect the Power Supply Connections for the Digital Throttle Position Sensor at the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P1 connector. Remove P1:43 (+8 Volts DC). Remove P1:33 (digital throttle position sensor ground) from the P1 connector.

**C.** Reconnect the P1 connector to J1.

**D.** Turn the keyswitch to the ON position.

**E.** Use the electronic service tool to check for active diagnostic codes.

**Expected Result:**

One of the following diagnostic codes is still active after the terminals for sensor power have been disconnected:

- 41-3
- 41-4

**Results:**

- OK

  **Repair:** Perform the following repair:

  Check the battery voltage from P1 connectors at pins 1, 2, 3, 9 and 10 (Battery ground). Check the battery voltage from J1 connectors at pins 7, 8, 15, and 16 (Battery+). The measured voltage should be in one of the following ranges:

REFERENCE ONLY

- For 12 Volt systems, the voltage should be between 11.0 Volts DC and 13.5 Volts DC.
- For 24 Volt systems, the voltage should be between 22.0 Volts DC and 27.0 Volts DC.

If the battery voltage is correct, temporarily connect a test ECM. Use the electronic service tool to verify that the active diagnostic code is resolved. If the fault is corrected with the test ECM, reconnect the suspect ECM. Verify that the active diagnostic code returns. If the active diagnostic code returns with the suspect ECM, replace the ECM.

STOP.

- Not OK

**Repair:** Perform the following repair:

There is a fault in the harness between the ECM and the digital throttle position sensor. While active diagnostic codes are being monitored, connect the removed wires one at a time in order to verify that the active diagnostic codes reappear. ReplaceP1:33 (digital throttle position sensor ground). Replace P1:43 (+8 Volts DC). This procedure is used to find the wire that is causing the fault. Repair the harness or replace the harness, as required.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 8. Check the Duty Cycle of the Accelerator Pedal Position Sensor at the Sensor

**Note:** Performing certain steps within this procedure requires the use of a multimeter that is capable of measuring a PWM duty cycle.

**A.** Turn the keyswitch to the OFF position.

**B.** Remove the signal wire for the digital throttle position sensor (terminal “C”) from P403. Refer to Illustration 11.

**C.** Install a breakout “T” with three terminals at the digital throttle position sensor connector J403/P403.

**D.** Connect the multimeter probes to terminal “B” (digital throttle position sensor signal) and terminal “B” (digital throttle position sensor ground) of the breakout T.

**E.** Turn the keyswitch to the ON position.

**F.** While the duty cycle is being monitored on the multimeter, depress the throttle pedal and release the throttle pedal.

**Expected Result:**

The duty cycle is between 10 and 22 percent with the throttle pedal assembly in the low idle position, and the duty cycle is between 75 and 90 percent with the throttle pedal assembly in the high idle position.

**Results:**

- OK – Reinsert the wire (terminal “C”) into the harness connector of the digital throttle position sensor. The digital throttle position sensor is working correctly. Proceed to Test Step 9.
- Not OK – Leave the PWM probe connected to the breakout “T”. Insert the wire (terminal “C”) into the machine harness connector. The throttle pedal assembly is faulty. Proceed to Test Step 10.

## Test Step 9. Check the Duty Cycle of the Accelerator Pedal Position Sensor at the ECM

**Note:** Performing certain steps within this procedure requires the use of a multimeter that is capable of measuring a PWM duty cycle.

**A.** Turn the keyswitch to the OFF position.

**B.** Remove P1:53. Disconnect the P1 connector in order to remove the terminal for the signal input of the digital throttle position sensor signal.

**C.** Connect the multimeter probes between the removed wire and P1:33 (digital throttle position sensor ground).

**D.** Reconnect the P1 connector to the ECM.

**E.** Turn the keyswitch to the ON position.

**F.** Use the multimeter in order to display the duty cycle output of the digital throttle position sensor. While the duty cycle output of the digital throttle position sensor is being monitored on the multimeter, move the throttle assembly from the low idle position to the high idle position. Record the results.

**G.** Turn the keyswitch to the OFF position.

**H.** Remove the P1 connector from the ECM.

**I.** Install P1:53.

**J.** Connect the P1 connector to the ECM.

REFERENCE ONLY

**Expected Result:**

The duty cycle is between approximately 10 and 22 percent with the throttle pedal assembly in the low idle position, and the duty cycle is between 75 and 90 percent with the throttle pedal assembly in the high idle position.

**Results:**

- OK – A good signal from the digital throttle position sensor is reaching the ECM. Verify that the ECM is receiving the correct battery voltage. If the ECM is receiving the correct battery voltage, temporarily connect a test ECM and verify that the fault is resolved. If the fault is rectified with the test ECM, reconnect the suspect ECM. If the fault returns with the suspect ECM, replace the ECM. STOP.
- Not OK – There is a fault with signal wire in the harness. Proceed to Test Step 11.

## Test Step 10. Remove the Digital Throttle Position Sensor from the Throttle Pedal Assembly

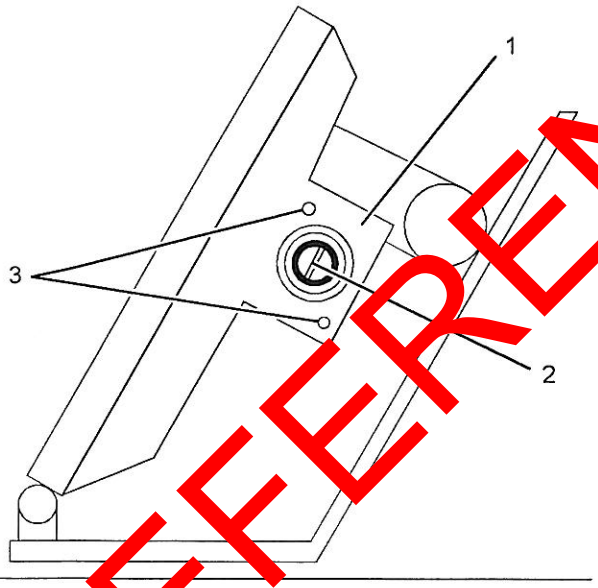



Illustration 43 g01185326

Throttle pedal assembly

(1) Sensor mounting face
(2) Sensor drive key
(3) Mounting screw holes

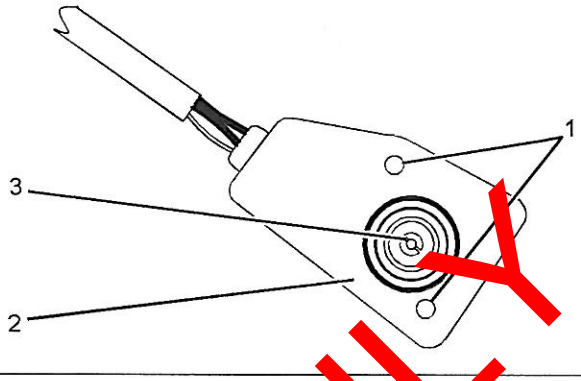



Illustration 44 g01185327

Throttle block assembly

(1) Mounting screw holes
(2) Sensor housing
(3) Sensor drive slot

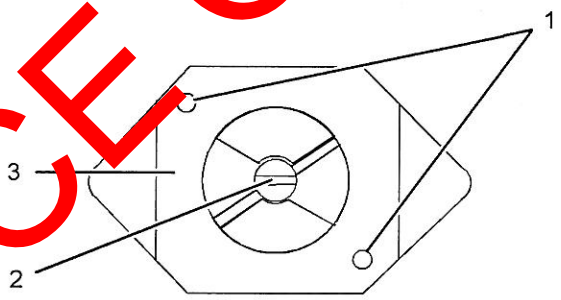



Illustration 45 g01185328

Throttle block assembly

(1) Mounting screw holes
(2) Sensor drive slot
(3) Sensor mounting face

**A.** Verify that the keyswitch is in the OFF position.

**B.** Note the sensor orientation in the throttle pedal assembly and the sensor connector for the harness routing prior to sensor removal. Remove the digital throttle position sensor from the throttle pedal assembly. Thoroughly inspect the connector and the harness for signs of abrasion.

**C.** Connect a multimeter that is capable of measuring a PWM duty cycle to terminal “C” of the breakout “T”.

**D.** Turn the keyswitch to the ON position.

**E.** Display the duty cycle output of the digital throttle position sensor while the sensor slot is released. Use a screwdriver to advance the sensor slot to the maximum position. Refer to Illustration 45.

PREFERENCE ONLY

**Expected Result:**

When the sensor is removed from the accelerator pedal assembly and the sensor slot is released, the duty cycle is 10 percent or less. When the sensor slot is moved to the maximum position, the duty cycle increases to 90 percent or more.

**Results:**

- OK – The digital throttle position sensor is working correctly. Refer to the OEM dealer for correct replacement of the accelerator pedal assembly. STOP.
- Not OK – The digital throttle position sensor is faulty. Check the accelerator pedal assembly in order to ensure that the accelerator pedal assembly is not causing damage to the sensor. If the accelerator pedal assembly is causing damage to the sensor, refer to the OEM dealer for correct replacement of the accelerator pedal assembly. If the accelerator pedal assembly appears OK, replace the digital throttle position sensor. STOP.

### Test Step 11. Route the Supply Bypass Wires to the Digital Throttle Position Sensor

**A.** Turn the keyswitch to the OFF position.

**B.** Temporarily remove the signal wire for the digital throttle position sensor from P1:53.

**C.** Remove terminal "C" (digital throttle position sensor signal) from the digital throttle position sensor connector.

**D.** Route the new wiring from the ECM to the digital throttle position sensor.

**E.** Turn the keyswitch to the ON position.

**F.** Check the duty cycle of the digital throttle position sensor on the electronic service tool while the digital throttle pedal assembly is being moved over the full range.

**Expected Result:**

The duty cycle is between 10 and 22 percent with the throttle pedal assembly in the low idle position, and the duty cycle is between 75 and 90 percent with the throttle pedal assembly in the high idle position.

**Results:**

- OK

  **Repair:** Perform the following repair:

  The wiring from the ECM to the digital throttle position sensor appears faulty. Permanently install new wiring.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – Double check the wiring, the connectors and the digital throttle position sensor connector. If a fault still exists, restart the test procedure. STOP.

i02493833

## ECM Memory - Test

**System Operation Description:**

This procedure covers the following diagnostic codes:

0253-02 Personality Module erratic, intermittent, or incorrect

**Background Information**

0253-02

The flash file in the Electronic Control Module (ECM) is from the wrong engine family. The engine will not start.

### Correct the Condition

Determine the diagnostic code that is active.

**Expected Result:**

A 0253-02 diagnostic code is active.

**Results:**

- A 0253-02 code is active

  **Repair:** Obtain the engine serial number. Use PTMI to determine the latest available flash file for the engine. Verify that the latest available flash file is loaded into the ECM.

  STOP.

REFERENCE ONLY

i03458880

# Electrical Connectors - Inspect

**System Operation Description:**

Most electrical faults are caused by poor connections. The following procedure will assist in detecting faults in connectors and wiring. If a fault is found, correct the condition and verify that the fault is resolved.

Intermittent electrical faults are sometimes resolved by disconnecting and reconnecting connectors. It is very important to check for diagnostic codes immediately before disconnecting a connector. Also check for diagnostic codes after reconnecting the connector. If the status of a diagnostic code is changed due to disconnecting and reconnecting a connector, there are several possible reasons. The likely reasons are loose terminals, improperly crimped terminals, moisture, corrosion, and inadequate mating of a connection.

Follow these guidelines:

- Always use a 27610285 Removal Tool to remove the pins from the P1/P2 connectors.
- Always use a 2900A033 Crimp Tool to service Deutsch HD and DT connectors. Never solder the terminals onto the wires.
- Always use a 28170079 Removal Tool to remove wedges from DT connectors. Never use a screwdriver to pry a wedge from a connector.
- Always use a 2900A033 Crimp Tool to service AMP seal connectors.
- Refer to Troubleshooting, "ECM Harness Connector Terminals" in order to service the connectors for the Electronic Control Module (ECM).
- Always use a breakout harness for a voltmeter probe or a test light. Never break the insulation of a wire in order to access a circuit for measurements.
- If a wire is cut, always install a new terminal for the repair.

**⚠ WARNING**

**The connection of any electrical equipment and the disconnection of any electrical equipment may cause an explosion hazard which may result in injury or death. Do not connect any electrical equipment or disconnect any electrical equipment in an explosive atmosphere.**

## Test Step 1. Check Connectors for Moisture and Corrosion

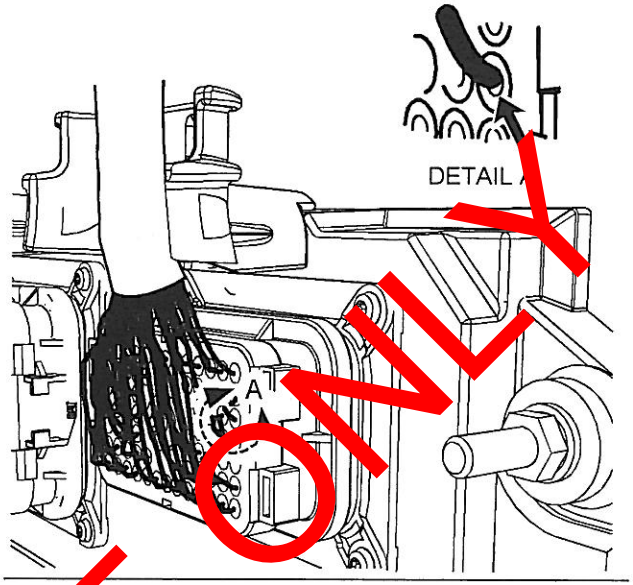



Illustration 46 g01131211

Leaky seal at the connector (typical example)

**A.** Inspect all the harnesses. Ensure that the routing of the wiring harness allows the wires to enter the face of each connector at a perpendicular angle. Otherwise, the wire will deform the seal bore. Refer to Illustration 46. This will create a path for the entrance of moisture. Verify that the seals for the wires are sealing correctly.

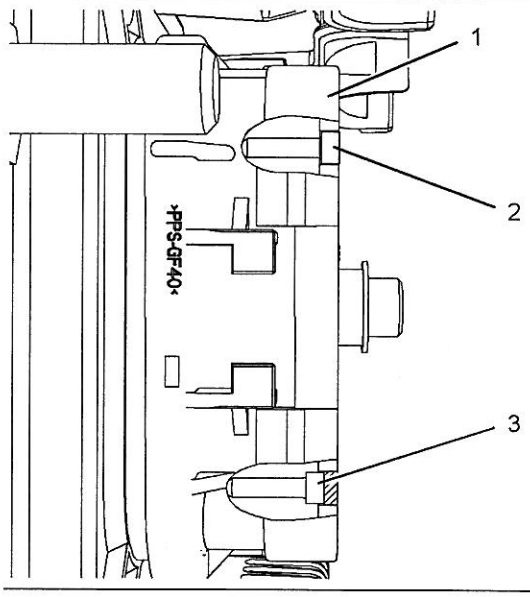



Illustration 47 g01131276

Diagram for the installation of a connector plug (typical example)

(1) ECM connector
(2) Correctly inserted plug
(3) Incorrectly inserted plug

REFERENCE ONLY

**B.** Ensure that the sealing plugs are in place. If any of the plugs are missing, replace the plug. Ensure that the plugs are inserted correctly into the connector. Refer to Illustration 47.

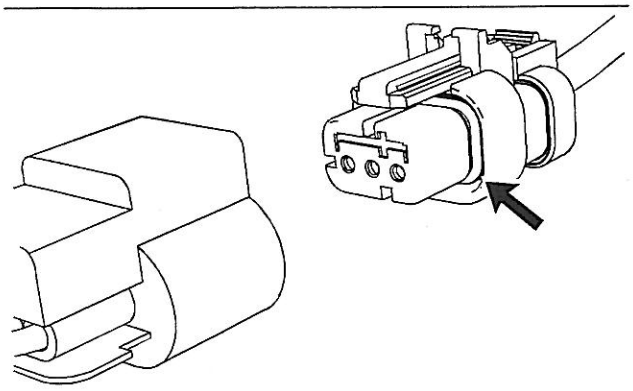


Illustration 48 g01131019

Seal for a three-pin connector (typical example)

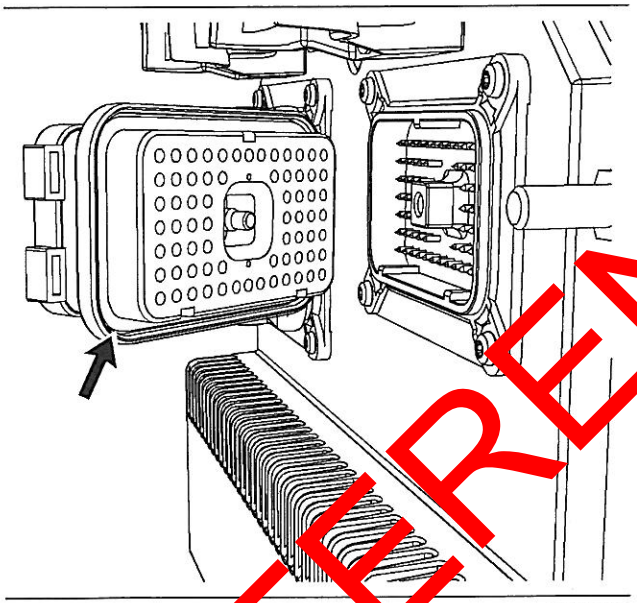


Illustration 49 g01131165

Seal for ECM connector (typical example)

**C.** Disconnect the suspect connector and inspect the connector seal. Ensure that the seal is in good condition. If necessary, replace the connector.

**D.** Thoroughly inspect the connectors for evidence of moisture entry.

**Note:** It is normal to see some minor seal abrasion on connector seals. Minor seal abrasion will not allow the entry of moisture.

If moisture or corrosion is evident in the connector, the source of the moisture entry must be found and the source of the moisture entry must be repaired. If the source of the moisture entry is not repaired, the fault will recur. Simply drying the connector will not fix the fault. Check the following items for the possible moisture entry path:

- Missing seals
- Incorrectly installed seals
- Nicks in exposed insulation
- Improperly mated connectors

Moisture can also travel to a connector through the inside of a wire. If moisture is found in a connector, thoroughly check the connector harness for damage. Also check other connectors that share the harness for moisture.

**Note:** The ECM is a sealed unit. If moisture is found in an ECM connector, the ECM is not the source of the moisture. Do not replace the ECM.

**Expected Result:**

The harness, connectors, and seals are in good condition. There is no evidence of moisture in the connectors.

**Results:**

- OK – The harness, connectors, and seals are in good condition. Proceed to Test Step 2.
- Not OK – A fault has been found with the harness or the connectors.

  **Repair:** Repair the connectors or the wiring, as required. Ensure that all of the seals are correctly installed. Ensure that the connectors have been reattached.

  If corrosion is evident on the pins, sockets or the connector, use only denatured alcohol to remove the corrosion. Use a cotton swab or a soft brush to remove the corrosion.

  If moisture was found in the connectors, run the engine for several minutes and check again for moisture. If moisture reappears, the moisture is wicking into the connector. Even if the moisture entry path is repaired, it may be necessary to replace the wires.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

REFERENCE ONLY

### Test Step 2. Check the Wires for Damage to the Insulation

**A.** Carefully inspect each wire for signs of abrasion, nicks and cuts.

Inspect the wires for the following conditions:

- Exposed insulation
- Rubbing of a wire against the engine
- Rubbing of a wire against a sharp point

**B.** Check all of the fasteners on the harness and the strain relief components on the ECM in order to verify that the harness is correctly secured. Also check all of the fasteners in order to verify that the harness is not compressed. Pull back the harness sleeves in order to check for a flattened portion of wire. A fastener that has been overtightened flattens the harness. This damages the wires that are inside the harness.

**Expected Result:**

The wires are free of abrasion, nicks and cuts and the harness is correctly clamped.

**Results:**

- OK – The harness is OK. Proceed to Test Step
- Not OK – There is damage to the harness.

**Repair:** Repair the wires or replace the wires, as required.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

### Test Step 3. Inspect the Connector Terminals

**A.** Visually inspect each terminal in the connector. Verify that the terminals are not damaged. Verify that the terminals are correctly aligned in the connector and verify that the terminals are correctly located in the connector.

**Expected Result:**

The terminals are correctly aligned and the terminals appear undamaged.

**Results:**

- OK – The terminals are OK. Proceed to Test Step 4.
- Not OK – The terminals of the connector are damaged.

**Repair:** Repair the terminals and/or replace the terminals, as required.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

### Test Step 4. Perform a Pull Test on Each Wire Terminal Connection

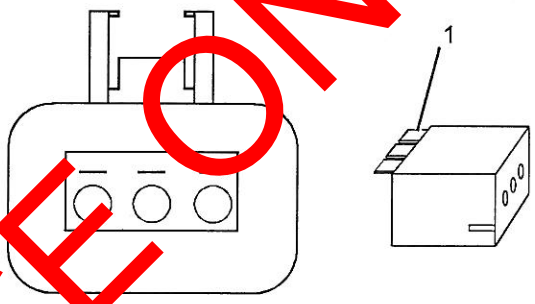



Illustration 50 g01802454

A typical example of the lock wedge.

(1) Lock wedge

**A.** Ensure that the locking wedge for the connector is installed correctly. Terminals cannot be retained inside the connector if the locking wedge is not installed correctly.

**B.** Perform the 45 N (10 lb) pull test on each wire. Each terminal and each connector should easily withstand 45 N (10 lb) of tension and each wire should remain in the connector body. This test checks whether the wire was correctly crimped in the terminal and whether the terminal was correctly inserted into the connector.

**Expected Result:**

Each terminal and each connector easily withstands 45 N (10 lb) of pull and each wire remains in the connector body.

**Results:**

- OK – All terminals pass the pull test. Proceed to Test Step 5.
- Not OK – A wire has been pulled from a terminal or a terminal has been pulled from the connector.

**Repair:** Use the CH11155 Crimp Tool to replace the terminal. Replace damaged connectors, as required.

REFERENCE ONLY

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 5. Check Individual Pin Retention into the Socket

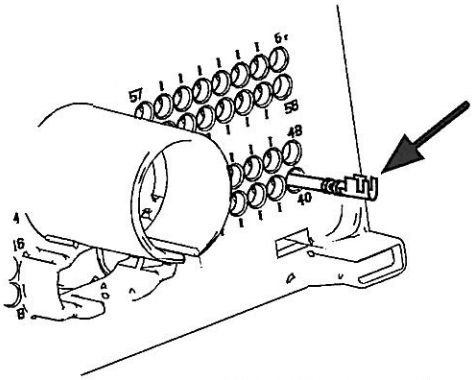


Illustration 51 g01802455

Diagram for testing pin retention

**A.** Verify that the sockets provide good retention for the pins. Insert a new pin into each socket one at a time in order to check for a good grip on the pin by the socket.

**Expected Result:**

The sockets provide good retention for the new pin.

**Results:**

- OK – The terminals are OK. Proceed to Test Step 6.
- Not OK – Terminals are damaged.

  **Repair:** Use the 9H11155 Crimp Tool to replace the damaged terminals. Verify that the repair eliminates the problem.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 6. Check the Locking Mechanism of the Connectors

**A.** Ensure that the connectors lock correctly. After locking the connectors, ensure that the two halves cannot be pulled apart.

**B.** Verify that the latch tab of the connector is correctly latched. Also verify that the latch tab of the connector returns to the locked position.

**Expected Result:**

The connector is securely locked. The connector and the locking mechanism is not cracked or broken.

**Results:**

- OK – The connectors are in good repair. Proceed to Test Step 7.
- Not OK – The locking mechanism of the connectoris damaged or missing.

  **Repair:** Repair the connector or replace the connector, as required.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 7. Check the Screws on the ECM Connectors (64 way)

Visually inspect the screws for the ECM connectors. Ensure that the threads on each screw are not damaged.

A. Connect the ECM connectors.

  **a.** Use a 7 mm Torx screw in order to retain each of the ECM connectors.

  **b.** Tighten the two Torx screws for the ECM connector to the correct torque of 5.0 ± 1.0 N·m (44 ± 9 lb in).

**Note:** If the threaded insert in the ECM is damaged, the ECM must be replaced. Refer to Disassembly and Assembly, “Electronic Control Module - Remove and Install”.

**Expected Result:**

The ECM connectors are secure and the Torx screws are correctly torqued.

**Results:**

- OK – The ECM connectors are secured. Proceed to Test Step 8.
- Not OK – The screws for the ECM connectors are damaged.

  **Repair:** Repair the connectors or replace the connectors or screws, as required.

REFERENCE ONLY

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

### Test Step 8. Perform the "Wiggle Test" on the Electronic Service Tool

**A.** Select the "Wiggle Test" from the diagnostic tests on the electronic service tool.

**B.** Choose the appropriate group of parameters to monitor.

**C.** Press the "Start" button. Wiggle the wiring harness in order to reproduce intermittent faults.

If an intermittent fault exists, the status will be highlighted and an audible beep will be heard.

**Expected Result:**

No intermittent faults were indicated during the "Wiggle Test".

**Results:**

- OK – No intermittent faults were found. The harness and connectors appear to be OK. If this test was required as part of another procedure, return to that procedure and continue testing. If this test has resolved the fault, return the engine to service. STOP.
- Not OK – At least one intermittent fault was indicated.

  **Repair:** Repair the harness or the connector.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03459023

## Engine Pressure Sensor Open or Short Circuit - Test

**System Operation Description:**

**Use this procedure under the following conditions:**

Use this procedure if another procedure has directed you here. Use this procedure if any of the following diagnostic codes are active:

- 0100-03 Engine Oil Pressure Sensor voltage above normal
- 0100-04 Engine Oil Pressure Sensor voltage below normal
- 0100-10 Engine Oil Pressure Sensor abnormal rate of change
- 1785-03 Intake Manifold Pressure Sensor voltage above normal
- 1785-04 Intake Manifold Pressure Sensor voltage below normal
- 1785-10 Intake Manifold Pressure Sensor abnormal rate of change
- 1797-03 Fuel Rail Pressure Sensor voltage above normal
- 1797-04 Fuel Rail Pressure Sensor voltage below normal

**The following background information is related to this procedure:**

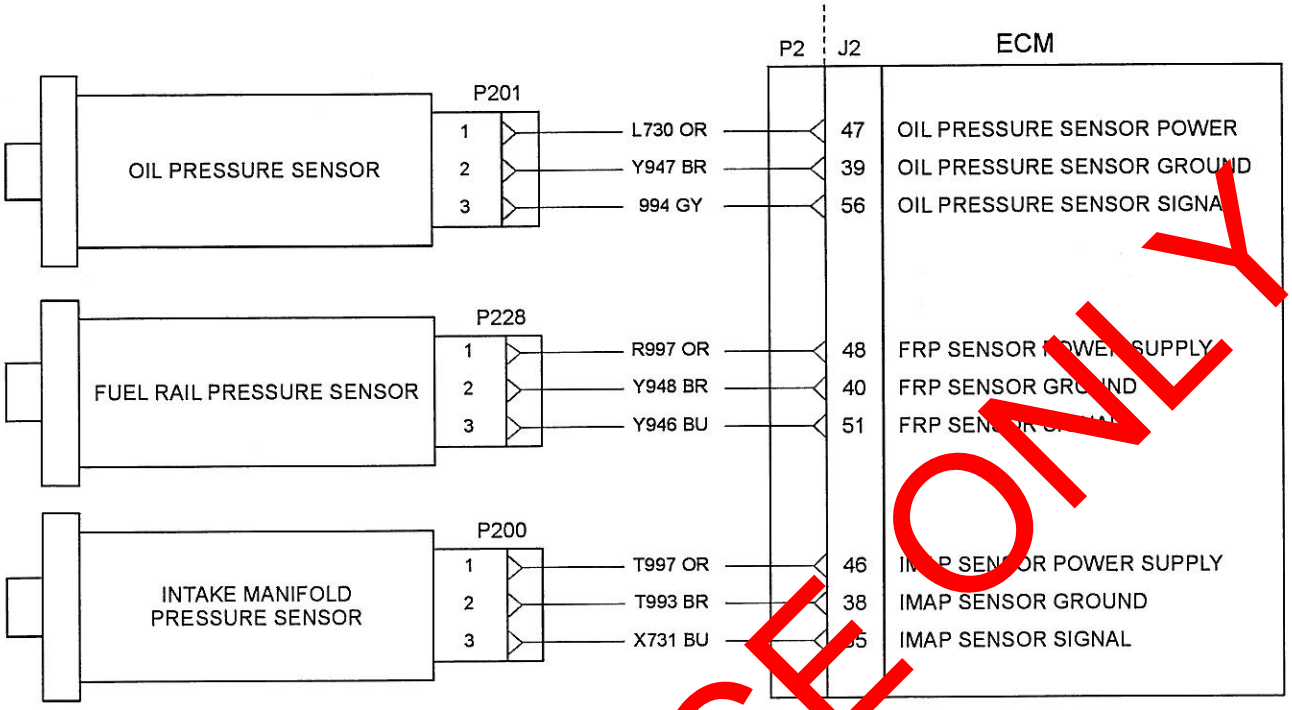
The troubleshooting procedures for the diagnostic codes of each pressure sensor are identical. The 5 volt sensor supply provides power to all 5 Volt sensors. The Electronic Control Module (ECM) supplies 5.0 ± 0.2 Volts DC to terminal "A" of each sensor connector. The sensor common from the ECM connector goes to terminal "B" of each sensor connector. The sensor supply is output short circuit protected. A short circuit to the battery will not damage the circuit inside the ECM.

**Pull-up Voltage**

The ECM continuously outputs a pull-up voltage on the circuit for the sensor signal wire. The ECM uses this pull-up voltage in order to detect an open in the signal circuit. When the ECM detects the presence of a voltage that is above a threshold on the signal circuit, the ECM will generate an open circuit diagnostic code (03) for the sensor.

If the sensor is disconnected at the sensor connector, the presence of pull-up voltage at the sensor connector indicates that the wires from the sensor connector to the ECM are not open or shorted to ground. If the sensor is disconnected at the sensor connector, the absence of pull-up voltage at the sensor connector indicates an open in the signal wire or a short to ground. If the sensor is disconnected at the sensor connector and the voltage at the sensor connector is different from pull-up voltage, the signal wire is shorted to another wire in the harness.

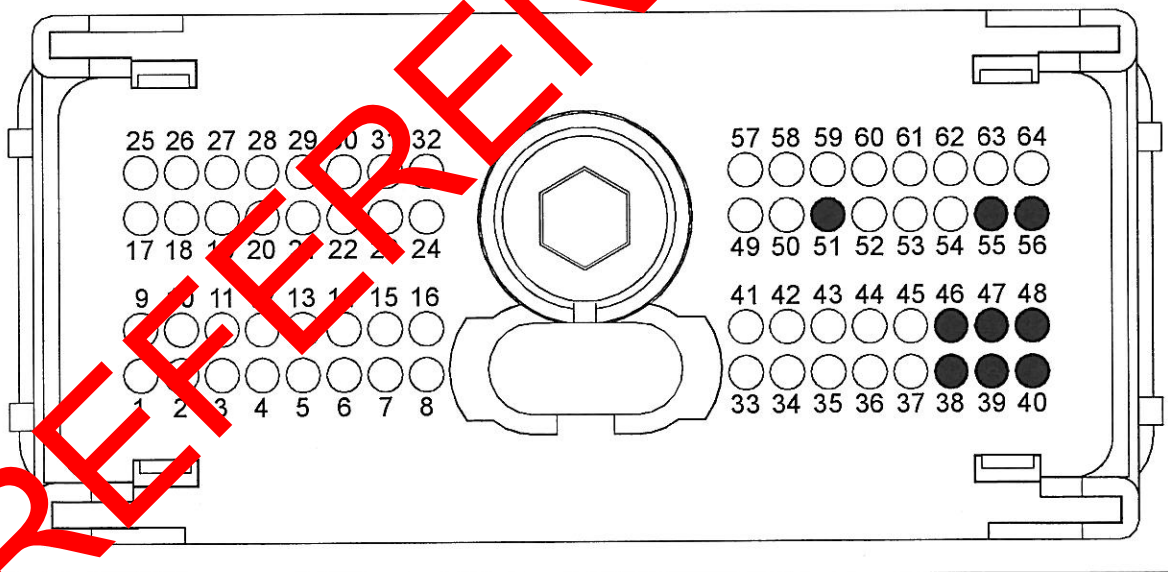
REFERENCE ONLY




g01800518

Illustration 52

Typical example of the schematic for the sensors




g01802515

Illustration 53

Typical view of the P2 pressure sensor pin locations

(38) Ground (GND) Intake Manifold Pressure Sensor
(39) Ground (GND) Oil Pressure Sensor
(40) Ground (GND) Fuel Rail Pressure Sensor
(46) Voltage supply (+5 Volts DC) Intake Manifold Pressure Sensor
(47) Voltage supply (+5 Volts DC) Oil Pressure Sensor
(48) Voltage supply (+5 Volts DC) Fuel Rail Pressure Sensor
(51) Signal (SIG) Fuel Rail Pressure Sensor
(55) Signal (SIG) Intake Manifold Pressure Sensor
(56) Signal (SIG) Oil Pressure Sensor

REFERENCE ONLY

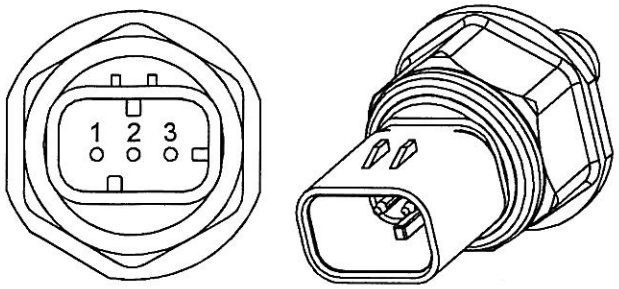



Illustration 54 g01170309

Fuel rail pressure sensor

(1) Voltage supply (+5 Volts DC)
(2) Ground (GND)
(3) Signal (SIG)

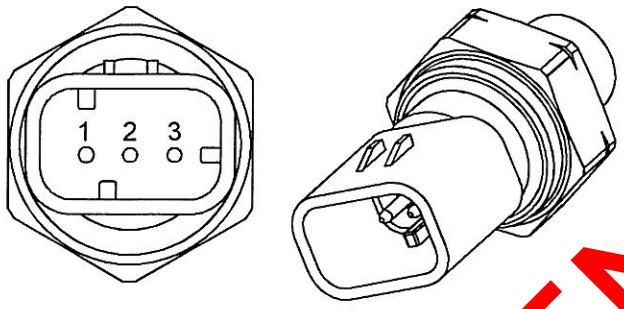



Illustration 55 g01170310

Intake manifold pressure sensor

(1) Voltage Supply (+5 Volts DC)
(2) Ground (GND)
(3) Signal (SIG)

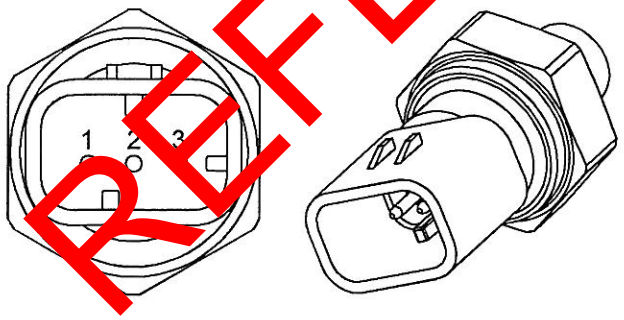



Illustration 56 g01170311

Typical example of the oil pressure sensor

(1) Voltage Supply (+5 Volts DC)
(2) Ground (GND)
(3) Signal (SIG)

The troubleshooting procedures for the diagnostic codes of each pressure sensor are identical. The pressure sensors are active sensors. The pressure sensor has three terminals. Active sensors require supply voltage from the ECM. The ECM connector P2/J2 supplies +5 Volts DC to terminal 1 of each sensor. The common line is connected to each sensor connector terminal 2. The signal voltage from terminal 3 of each sensor is supplied to the appropriate terminal at the ECM connector P2/J2.

## Test Step 1. Verify All Active Diagnostic Codes

**A.** Turn the keyswitch to the ON position. Wait at least 10 seconds for activation of the diagnostic codes.

**B.** Verify if any of the following diagnostic codes are active:

- 0100-03 Engine Oil Pressure Sensor voltage above normal
- 0100-04 Engine Oil Pressure Sensor voltage below normal
- 0100-10 Engine Oil Pressure Sensor abnormal rate of change
- 1785-03 Intake Manifold Pressure Sensor voltage above normal
- 1785-04 Intake Manifold Pressure Sensor voltage below normal
- 1785-10 Intake Manifold Pressure Sensor abnormal rate of change
- 1797-03 Fuel Rail Pressure Sensor voltage above normal
- 1797-04 Fuel Rail Pressure Sensor voltage below normal

**Expected Result:**

One or more of the preceding diagnostic codes are active.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

  **Repair:** Do not use this procedure if 1785-10 or 100-10 diagnostic codes are active. Refer to Troubleshooting, “5 Volt Sensor Supply Circuit - Test”. When this test is complete, return to the start of this test.

REFERENCE ONLY

If the preceding codes are logged, an intermittent condition may be causing the logged codes. Refer to Troubleshooting, "Electrical Connectors - Inspect".

Perform a "Wiggle Test" by using the electronic service tool in order to identify intermittent connections.

STOP.

## Test Step 2. Inspect Electrical Connectors And Wiring

**A.** Thoroughly inspect the terminal connections on the P2/J2 ECM sensor connectors.

**B.** Thoroughly inspect the following engine pressure sensor connectors:

- P201 Engine Oil Pressure Sensor
- P228 Fuel Rail Pressure Sensor
- P200 Intake Manifold Pressure Sensor

**C.** Refer to Troubleshooting, "Electrical Connectors - Inspect".

**D.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connector and the sensor connectors that are associated with the active diagnostic code.

**E.** Check the screw for the ECM connector for the correct torque of 5 N·m (44 lb in).

**F.** Check the harness for abrasions and pinch points from the sensors back to the ECM.

**G.** Use the electronic service tool to perform a "Wiggle Test". The "Wiggle Test" will identify intermittent connections.

**Expected Result:**

All connectors, pins, and sockets should be completely coupled and inserted. The harness should be free of corrosion, abrasions and pinch points.

**Results:**

- OK – Proceed to Test Step 3.
- Not OK

**Repair:** Repair the connectors or the harness and/or replace the connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 3. Verify that the Diagnostic Code is Still Active

**A.** Turn the keyswitch to the ON position. Wait at least 10 seconds for activation of the diagnostic codes.

**B.** Use the electronic service tool to check for active diagnostic codes. Record all active diagnostic codes.

**C.** Determine if the fault is related to an open circuit diagnostic code or a short circuit diagnostic code.

**Expected Result:**

Either a short circuit diagnostic code is active or an open circuit diagnostic code is active.

**Results:**

- OK - SHORT Circuit – A "Voltage Above Normal" diagnostic code is active at this time. Proceed to Test Step 4.

  OK - OPEN Circuit – A "Voltage Below Normal" diagnostic code is active at this time. Proceed to Test Step 5.

- Not OK – A short circuit diagnostic code is not active. An open circuit diagnostic code is not active. An intermittent fault may exist.

  **Repair:** Use the electronic service tool to perform a "Wiggle Test". If faults are indicated then go to the appropriate procedure.

  STOP.

## Test Step 4. Disconnect The Sensor In Order To Create An Open Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the sensor connector of the sensor with the short circuit diagnostic code.

**C.** Turn the keyswitch to the ON position. Wait at least 10 seconds for activation of the diagnostic codes.

**D.** Use the electronic service tool to check the "Active Diagnostic Code" screen. Check for a "Voltage Below Normal" diagnostic code.

REFERENCE ONLY

**Expected Result:**

A "Voltage Below Normal" diagnostic code for the disconnected sensor is now active.

**Results:**

- OK – A "Voltage Above Normal" diagnostic code was active before disconnecting the sensor. An "Voltage Below Normal" diagnostic code became active after disconnecting the sensor. Proceed to Test Step 6.
- Not OK – There is a short circuit between the sensor connector on the harness and the ECM. Leave the sensor disconnected. Proceed to Test Step 8.

## Test Step 5. Measure the Sensor Supply Voltage

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the sensor from the engine harness.

**C.** Turn the keyswitch to the ON position.

**D.** Measure the voltage at the plug for the sensor from the terminal 1 (pressure sensor supply) to terminal 2 (sensor common).

**Expected Result:**

The DC voltage from terminal 1 to terminal 2 measures 4.84 to 5.16 Volts DC.

**Results:**

- OK – The sensor supply voltage is correct. Proceed to Test Step 7.
- Not OK – The sensor supply voltage is out of the nominal range. Continue testing the sensor supply circuit.

  **Repair:** Proceed to the following repair: Troubleshooting, "5 Volt Sensor Supply Circuit - Test"

  STOP.

## Test Step 6. Determine If The Short Circuit Is In The Connector Or In The Sensor

**A.** Thoroughly inspect the connector for moisture.

**B.** Inspect the seals and reconnect the sensor.

**C.** Refer to Troubleshooting, "Electrical Connectors - Inspect".

**D.** If the short circuit diagnostic code reappears, the sensor or the sensor connector has a fault.

  **a.** Temporarily connect a new sensor to the harness, but do not install the new sensor in the engine.

**E.** Use the electronic service tool to check for a short circuit diagnostic code. The new sensor should be connected to the harness at this time.

**Expected Result:**

The short circuit diagnostic code is not present when a new sensor is connected.

**Results:**

- OK – Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault. STOP.
- Not OK – Repair the engine harness connector. Use the electronic service tool to clear the logged diagnostic codes. STOP.

## Test Step 7. Create a Short Circuit Between the Signal and the Common Terminals at the Engine Harness Connector

**A.** Turn the keyswitch to the ON position.

**B.** Fabricate a jumper wire 150 mm (6 inch) long. Crimp a terminal to both ends of the wire.

**C.** Monitor the "Active Diagnostic Code" screen on the electronic service tool before installing the jumper wire and after installing the jumper wire.

**D.** Install the jumper on the engine harness connector. Install one end of the jumper at the sensor signal (terminal 3). Install the other end of the jumper at the common connection for the pressure sensor (terminal 2). Wait at least 30 seconds for activation of the short circuit diagnostic code.

**Expected Result:**

A short circuit diagnostic code is active when the jumper is installed. An open circuit diagnostic code is active when the jumper is removed.

**Results:**

- OK – The engine harness and the ECM are OK.

  **Repair:** Perform the following repair:

  **1.** Temporarily connect the suspect sensor.

REFERENCE ONLY

2. Use the electronic service tool to verify if the diagnostic code remains active.

3. If the diagnostic code is active replace the sensor.

4. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminated the fault.

STOP.

- Not OK – The open circuit diagnostic code remains active when the jumper is installed. The most probable location for the open circuit is in the common wire for the sensor, or in the sensor signal wire of the engine harness between the ECM and the sensor. Remove the jumper. Proceed to Test Step 8.

## Test Step 8. Check the Operation of the ECM by Creating Open and Short Circuits at the ECM Connector

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect connector P2 from the ECM. Thoroughly inspect both halves of the connector for signs of corrosion or moisture. Refer to Troubleshooting, "Electrical Connectors - Inspect".

**C.** Reconnect P2 connector.

**D.** Turn the keyswitch to the ON position. Use the electronic service tool in order to monitor the "Active Diagnostic Code" screen. Wait at least 10 seconds for activation of the code.

An open circuit diagnostic code should be active for the suspect sensor.

**Note:** When the P2 connector is disconnected, all of the open circuit diagnostic codes for the pressure sensors and temperature sensors will be active. This is normal. Disregard the diagnostic codes for the pressure sensors and the temperature sensors that are not suspect. Monitor the diagnostic codes for the suspect sensors only.

**E.** Turn the keyswitch to the OFF position.

**F.** Fabricate a jumper wire 150 mm (6 inch) long. Crimp a terminal to both ends of the wire.

**G.** Install the jumper wire on the P2 connector. Insert the jumper wire between the terminal for the suspect sensor signal and the common connection for the engine's pressure sensor.

Use the electronic service tool to verify that there is a "Voltage Above Normal" diagnostic code.

**Expected Result:**

"Voltage Below Normal" diagnostic codes and "Voltage Above Normal" diagnostic codes were active.

**Results:**

- OK – The ECM is operating correctly. Proceed to Test Step 9.

- Not OK – One of the following conditions exists: The "Voltage Below Normal" diagnostic code is not active when the harness is disconnected. The "Voltage Above Normal" diagnostic code is not active when the jumper wire is installed.

**Repair:** Perform the following repair:

1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

4. Use the electronic service tool to recheck the system for active diagnostic codes.

5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

6. If the fault returns with the suspect ECM, replace the ECM.

7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 9. Bypass the Harness Wiring Between the ECM and the Sensor Connector

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector and disconnect the connector from the suspect sensor.

**C.** Remove the sensor signal wire from the P2 connector.

**D.** Remove the signal wire (terminal 3) from the sensor connector on the engine harness.

REFERENCE ONLY

**E.** Fabricate a jumper wire that is long enough to reach from the ECM to the sensor connector or use an engine sensor harness bypass with 3 terminals.

**Note:** If an engine sensor harness bypass is being made, crimp a socket on one end in order to connect to the ECM. Crimp either a pin or a socket on the other end, as required.

**F.** Insert the one end of the engine sensor harness bypass into P2 connector on the engine harness. Insert the other end of the engine sensor harness bypass into the sensor connector of the engine harness.

**G.** Reconnect the P2 connector and the sensor connector.

**H.** Turn the keyswitch to the ON position.

**I.** Use the electronic service tool to monitor the "Active Diagnostic Code" screen for either the open circuit diagnostic code for the sensor or the short circuit diagnostic code for the sensor.

**Expected Result:**

The diagnostic code disappears when the jumper or the bypass is installed.

**Results:**

- OK – There is a fault in the wiring harness.

  **Repair:** Perform the following repair.

  1. Repair the faulty harness or replace the faulty harness.
  2. Clear all diagnostic codes.
  3. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – The most likely cause is an intermittent fault.

  **Repair:** Use the electronic service tool to perform a "Wiggle Test". If no fault is found, restart this procedure and carefully perform each step.

  STOP.

i03459208

# Engine Speed/Timing Sensor Circuit - Test

**System Operation Description:**

Use this procedure to troubleshoot the system under the following conditions:

- Use this procedure if another procedure has directed you here.
- The engine will not start and the electronic service tool indicates a faulty sensor by displaying "Not Detected" against the faulty sensor on the "No Start Parameters" screen.
- There is an active diagnostic code or a recently logged diagnostic code that is related to the following:
- 0132-08 Engine Speed Sensor abnormal frequency, pulse width, or period
- 0342-08 Secondary Engine Speed Sensor abnormal frequency, pulse width, or period

The engine uses two engine speed/timing sensors. The primary sensor is located on the left hand side of the cylinder block close to the flywheel housing. The secondary speed/timing sensor is mounted on the fuel rail pump. The primary speed/timing sensor that is mounted on the cylinder block generates a signal by detecting the movement of the teeth that are located on the timing ring. The timing ring is mounted on the crankshaft. The signal that is generated by the primary speed/timing sensor is transmitted to the Electronic Control Module (ECM). The ECM uses the signal from the sensor to calculate the position of the crankshaft. The signal is also used to determine the engine speed.

The secondary speed/timing sensor is located in the fuel rail pump . The secondary speed/timing sensor generates a signal that is related to the camshaft position. The fuel rail pump is mechanically connected to the camshaft. The secondary speed/timing sensor detects the movement of the teeth on the timing wheel in the fuel rail pump. The signal that is generated by the speed/timing sensor is transmitted to the ECM. The ECM calculates the speed and the rotational position of the engine by using the signal. The secondary speed/timing sensor is required for starting purposes.

During normal operation, the secondary speed/timing sensor is used to determine the cycle that the engine is on. When the timing has been established, the primary speed/timing sensor is then used to determine the engine speed and the angular position.

REFERENCE ONLY

The loss of signal to the primary sensor and/or the secondary sensor will result in one of the following faults:

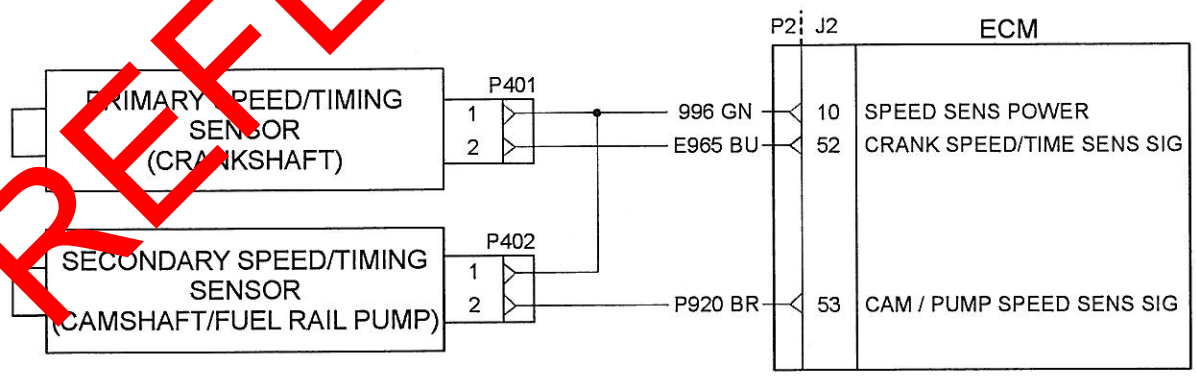
- The loss of signal from the secondary speed/timing sensor during start-up will prevent the engine from starting.
- The engine will continue to run when only one sensor signal is present from either the primary sensor or the secondary sensor.
- The loss of signal from the primary speed/timing sensor during operation of the engine will result in engine operation with a derate.
- Loss of signal from the primary sensor and the secondary sensor during operation of the engine will cause fuel injection to be terminated and the engine will stop.

The primary sensor and the secondary sensor are interchangeable components. If a sensor is suspect the sensors can be exchanged in order to eliminate a fault. If a secondary sensor is suspect and a replacement secondary sensor is not available, then the primary sensor and the secondary sensor can be exchanged. This will allow testing to determine if the secondary sensor is faulty.

Table 57

| P2/J2 Pin Connections | | | |
|---|---|---|---|
| **Function** | **Sensor Pin** | **Primary Sensor** | **Secondary Sensor** |
| +8 Volt Supply | 1 | 10 | 10 |
| Signal | 2 | 52 | 53 |

REFERENCE ONLY




g01803493

Illustration 57

The schematic for the speed/timing sensors

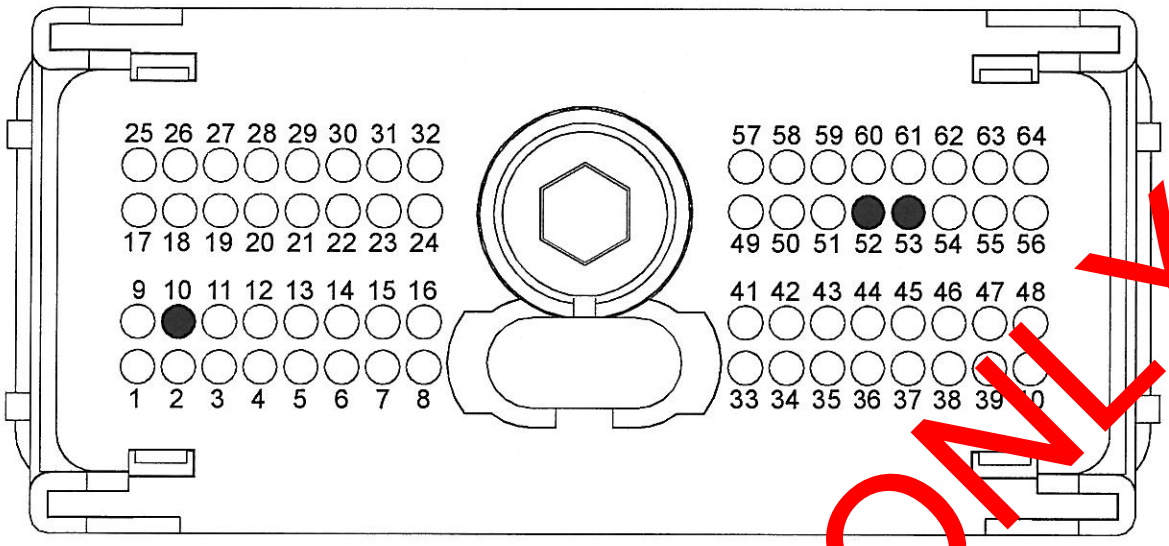
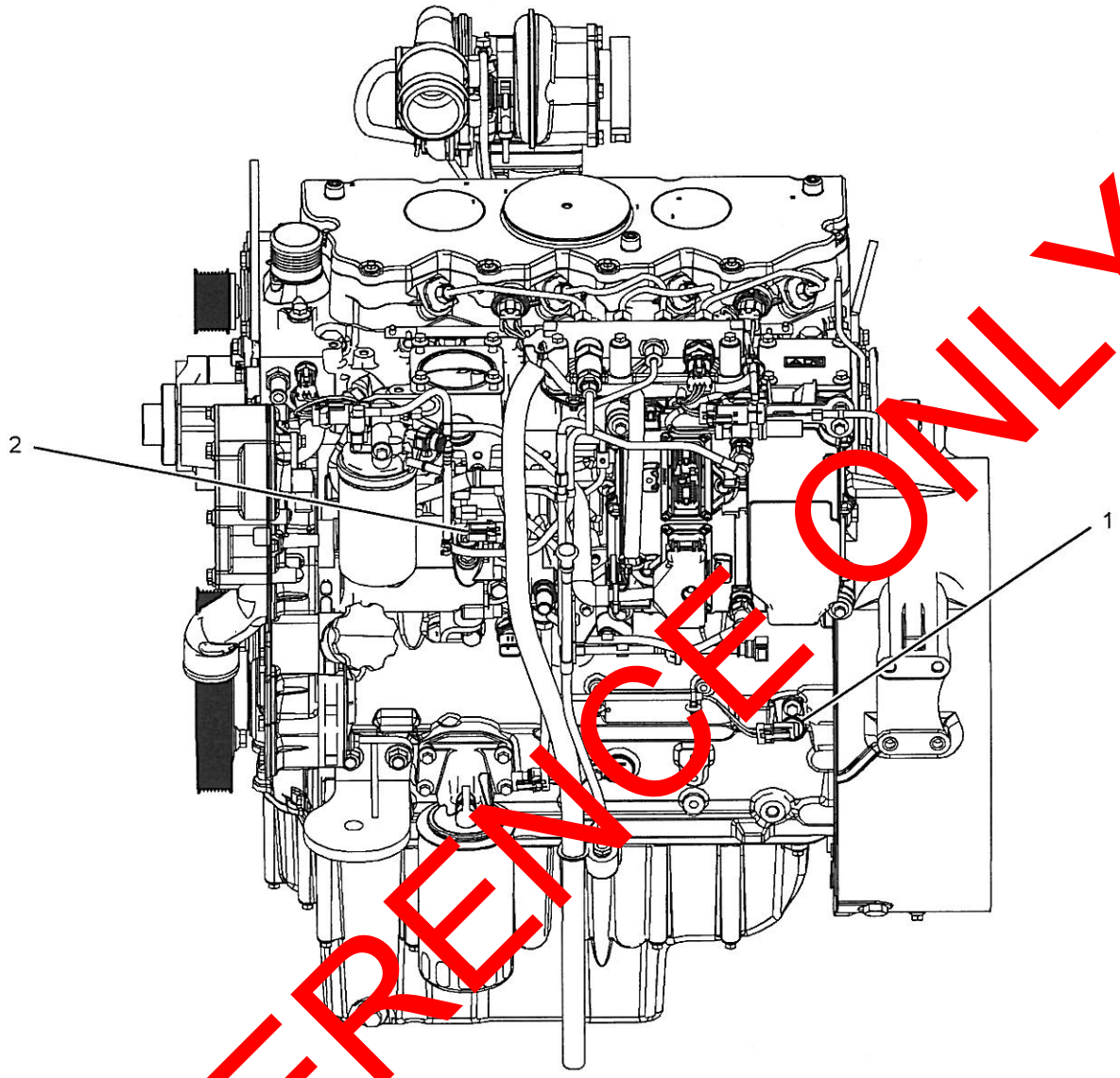



Illustration 58 g01803494

Pin locations on the P1 connector for the speed/timing sensors

(10) Speed/timing sensor supply (+8 Volts DC)
(52) Primary speed/timing sensor signal
(53) Secondary speed/timing sensor signal

REFERENCE ONLY




g01803513

Illustration 59

Typical view of the locations for the speed/timing sensor on the 1104D engine

(1) Primary speed/timing sensor (2) Secondary speed/timing sensor

REFERENCE ONLY

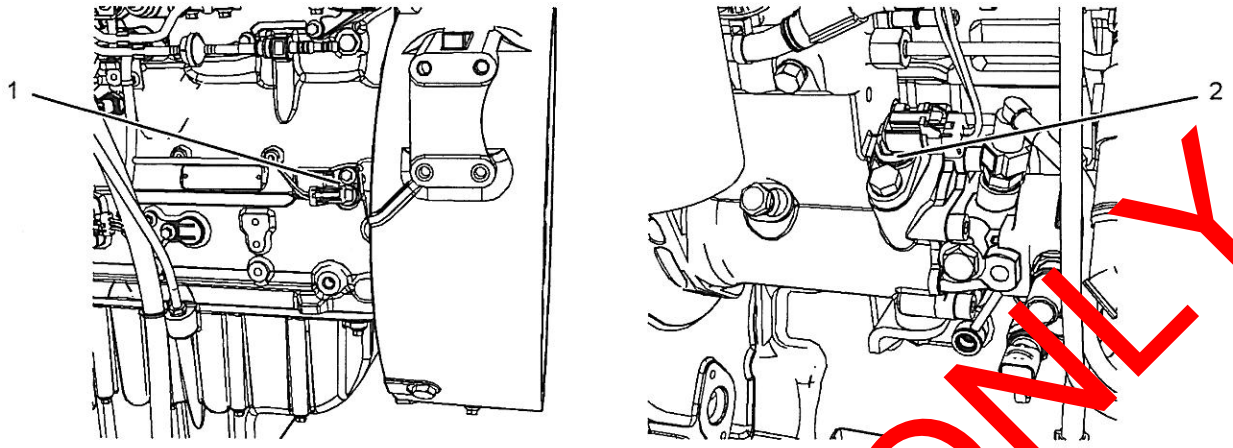



Illustration 60 g01803514

Detailed view of the sensor locations on the 1104D engine

(1) Primary speed/timing sensor (2) Secondary speed/timing sens

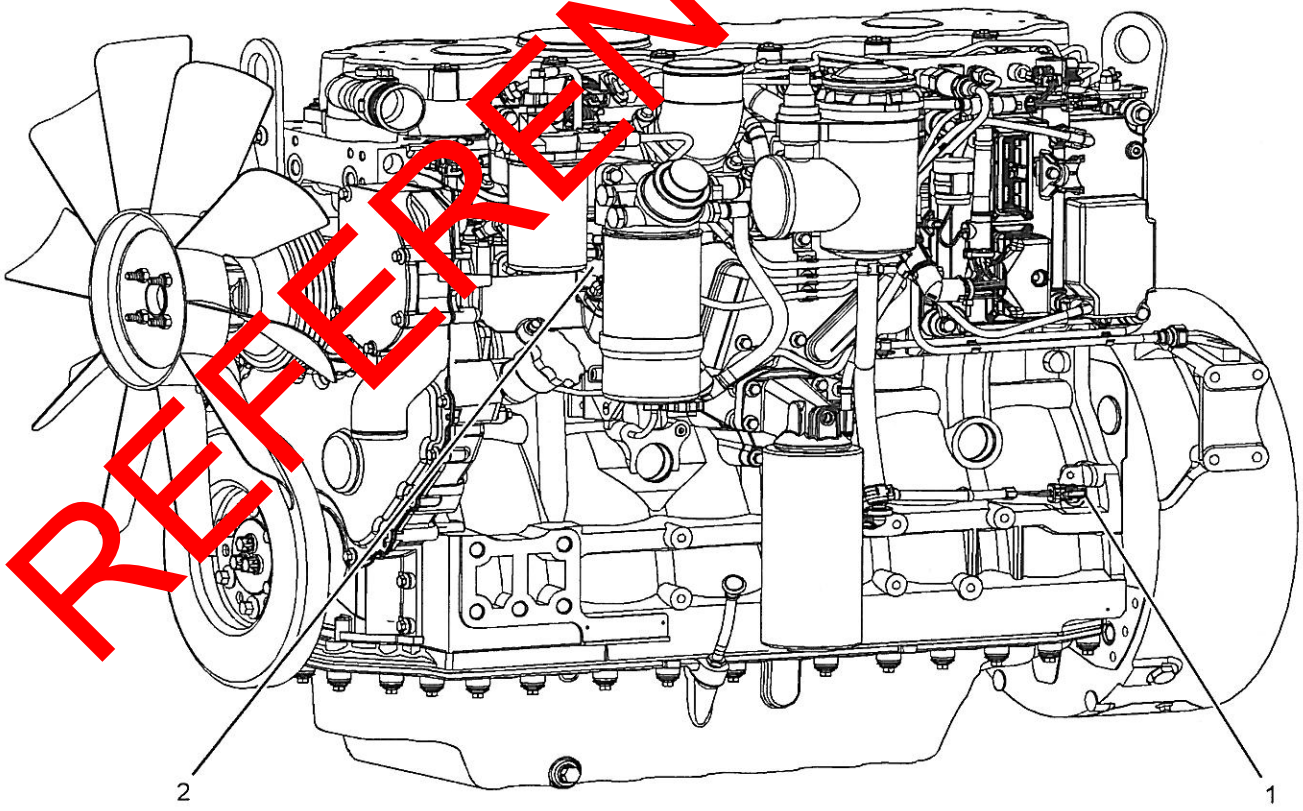
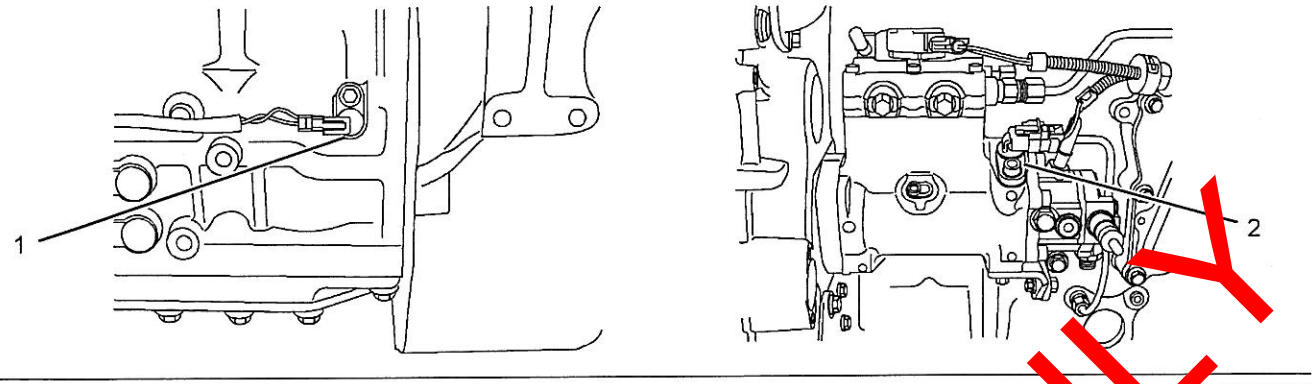



Illustration 61 g01803515

Typical view of the sensor locations on the 1106D engine

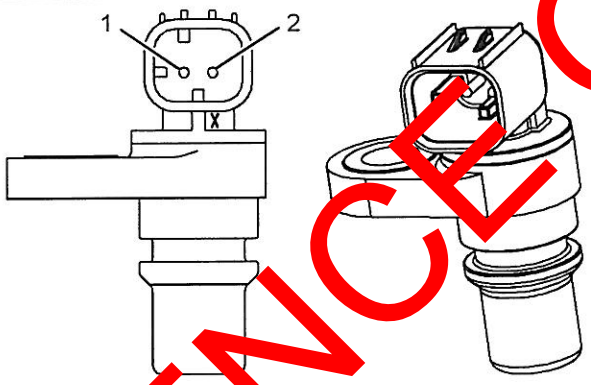
(1) Primary speed/timing sensor (2) Secondary speed/timing sensor

REFERENCE ONLY




g01803516

Illustration 62
Detailed view of the sensor locations on the 1106D engine
(1) Primary speed/timing sensor (2) Secondary speed/timing sensor




g01212995

Illustration 63
Typical example of the speed/timing sensors
(1) Voltage Supply (+8 Volts DC) (2) Sign[illegible] (Si[illegible]

REFERENCE ONLY

## Test Step 1. Inspect the E[illegible]ctrical Connectors and the H[illegible]rness

**A.** Turn the keyswitch to th[illegible] OFF position.

**B.** Thoroughly ins[illegible]ect th[illegible] P2 c[illegible]nector and the suspect sens[illegible]r connections. Refer to Troublesh[illegible]oting, "E[illegible]ctrical Connectors - Inspect".

**C.** Perform [illegible]4[illegible] N (10 lb) pull test on each of th[illegible]s[illegible] in[illegible]he s[illegible]spect sensor connector and [illegible]he se[illegible]sor co[illegible]nections at the ECM. The wire [illegible]onn[illegible]ct[illegible]r[illegible]re shown in illustration 58.

**D.** Chec[illegible] that the ground connection on the ECM and the negative terminal on the battery are correctly installed.

**E.** Check the ground connection on the ECM for abrasions and pinch points.

**F.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**G.** Check the harness for abrasion and pinch points from the suspect sensor to the ECM.

**H.** Check that the suspect sensor is installed correctly. Check that the suspect sensor is fully seated into the engine. Check that the connector on the sensor is securely latched.

**Expected Result:**

The electrical connectors and the cables are correctly installed.

**Results:**

- OK – The harness is OK. Proceed to Test Step 2.
- Not OK

  **Repair:** Repair the faulty connectors or the harness and/or replace the faulty connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are correctly coupled.

  If a sensor must be replaced or the sensor must be reinstalled, complete all of the following tasks:

- Lubricate the "O" ring with clean engine lubricating oil.
- Ensure that the plug for the sensor has a seal inside the connector body. If a seal is damaged or missing, replace the seal.
- Ensure that the sensor is fully seated into the engine before tightening the bracket bolt.
- Ensure that the connector is latched.
- Ensure that the harness is correctly secured, and ensure that the harness is attached to the harness clip.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

STOP.

## Test Step 2. Check for Active Diagnostic Codes and Recently Logged Diagnostic Codes

**A.** Turn the keyswitch to the OFF position.

**B.** Connect the electronic service tool to the diagnostic connector.

**C.** Turn the keyswitch to the ON position. If the engine will start, then run the engine.

**D.** Use the electronic service tool in order to monitor active diagnostic codes or recently logged diagnostic codes.

**Expected Result:**

One or more of the following diagnostic codes are active or recently logged:

- 190-8 Engine Speed Sensor abnormal frequency, pulse width, or period
- 342-8 Secondary Engine Speed Sensor abnormal frequency, pulse width, or period

**Results:**

- 190-8 – Proceed to Test Step 4.
- 342-8 – Proceed to Test Step 3.
- Not OK – No active diagnostic codes or recently logged diagnostic codes are displayed. STOP.

## Test Step 3. Check the Harness Between the Secondary Speed/Timing Sensor and the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector. Disconnect the connector for the primary speed/timing sensor. Disconnect the connector for the secondary speed/timing sensor.

**C.** Check the resistance between P2:53 and terminal 2 on the secondary speed/timing sensor. The resistance should be less than 2.0 Ohms.

**D.** Check the resistance between P2:10 and terminal 1 on the secondary speed/timing sensor. The resistance should be less than 2.0 Ohms.

**Expected Result:**

The readings agree with the values that are listed above.

**Results:**

- OK – The harness does not have an open circuit. Proceed to Test Step 5.
- Not OK – The harness or the connector has an open circuit or high resistance.

  **Repair:** Repair the faulty connectors or the harness. Replace the faulty connectors or the harness. Reconnect all sensor and ECM connectors. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

## Test Step 4. Check the Harness Between the Primary Speed/Timing Sensor and the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector. Disconnect the connector for the primary speed/timing sensor. Disconnect the connector for the secondary speed/timing sensor.

**C.** Check the resistance between P2:52 and terminal 2 on the secondary speed/timing sensor. The resistance should be less than 2.0 Ohms.

**D.** Check the resistance between P2:10 and terminal 1 on the secondary speed/timing sensor. The resistance should be less than 2.0 Ohms.

**Expected Result:**

The readings agree with the values that are listed above.

REFERENCE ONLY

**Results:**

- OK – The harness does not have an open circuit. Proceed to Test Step 6.
- Not OK – The harness has an open circuit.

  **Repair:** Repair the faulty connectors or the harness and/or replace the faulty connectors or the harness. Reconnect all sensor and ECM connectors. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 5. Check that the Connections and the Wiring to the Secondary Speed/Timing Sensor and the ECM are Isolated from Other Power Sources

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector. Disconnect the connector for the primary speed/timing sensor. Disconnect the connector for the secondary speed/timing sensor.

**C.** Measure the resistance from P2:53 to all other pins on the P2 connector. Measure the resistance from P2:53 to the ground and battery+ terminals. The resistance should be more than 20,000 Ohms.

**D.** Measure the resistance from P2:10 to all other pins on the P2 connector. Measure the resistance from P2:10 to the ground and the battery+ terminals. The resistance should be more than 20,000 Ohms.

**Expected Result:**

The readings agree with the values that are listed above.

**Results:**

- OK – There is no short circuit. Proceed to Test Step 7.
- Not OK – The harness has a short circuit.

  **Repair:** Repair the faulty connectors or replace the faulty connectors. Repair the faulty harness or replace the faulty harness. Reconnect all sensor and ECM connectors. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 6. Check that the Connections and the Wiring to the Primary Speed/Timing Sensor and the ECM are Isolated from the Other Power Sources

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector. Disconnect the connector from the primary speed/timing sensor. Disconnect the connector for the secondary speed/timing sensor.

**C.** Check the resistance between P2:52 and each of the other pins on the P2 connector. Check the resistance between P2:52 and the ground and battery+ terminals. The resistance should be more than 20,000 Ohms.

**D.** Check the resistance between P2:10 and each of the other pins on the P2 connector. Check the resistance between P2:10 and the ground and battery+ terminals. The resistance should be more than 20,000 Ohms.

**Expected Result:**

The readings agree with the values that are listed above.

**Results:**

- OK – The wires are not a short circuit. Proceed to Test Step 7.
- Not OK – The sensor wiring has a short circuit.

  **Repair:** Repair the faulty connectors or replace the faulty connectors. Repair the faulty harness or replace the faulty harness. Reconnect all sensor and ECM connectors. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 7. Check if a Replacement Sensor Eliminates the Fault

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the suspect sensor and remove the suspect sensor from the engine.

REFERENCE ONLY

**C.** If a sensor must be replaced or a sensor must be reinstalled, complete all of the following tasks:

- Lubricate the "O" ring with clean engine lubricating oil.
- Ensure that the plug for the sensor has a seal inside the connector body. If a seal is damaged or missing, replace the seal.
- Ensure that the sensor is fully seated into the engine before tightening the bracket bolt.
- Ensure that the connector is latched.
- Ensure that the harness is correctly secured, and ensure that the harness is attached to the harness clip.

**D.** Turn the keyswitch to the ON position.

**E.** Start the engine.

**F.** Use the electronic service tool in order to monitor the diagnostic codes.

**G.** Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the replacement sensor has eliminated the fault.

**Expected Result:**

The fault has been rectified.

**Results:**

- OK – If the fault is eliminated with the replacement sensor, reconnect the suspect sensor. If the fault returns with the suspect sensor, replace the suspect sensor.

  **Repair:** Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – The fault still exists. Proceed to Test Step 8.

## Test Step 8. Check if the Replacement of the ECM Eliminates the Fault

**A.** Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

**B.** Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

**C.** If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

**D.** Connect the electronic service tool to the diagnostic connector.

**E.** Turn the keyswitch to the ON position.

**F.** Start the engine.

**G.** Use the electronic service tool to recheck the system for active diagnostic codes.

**Expected Result:**

The fault is eliminated.

**Results:**

- OK

  **Repair:** If the fault is eliminated with the test ECM, perform the following procedure:

  1. Reconnect the suspect ECM.
  2. If the fault returns with the suspect ECM, replace the ECM.
  3. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – The fault was not eliminated with a test ECM.

  **Repair:** Install the original ECM.

  1. If the fault persists, the fault may be a damaged timing ring. Check the timing ring and/or replace the timing ring.
  2. If the fault is not eliminated, repeat the diagnostic procedure from Step 1.

  STOP.

i03460680

# Engine Temperature Sensor Open or Short Circuit - Test

**System Operation Description:**

**Use this procedure under the following conditions:**

REFERENCE ONLY

This procedure covers open circuit diagnostic codes and short circuit diagnostic codes that are associated with the following sensors:

- Coolant temperature sensor
- Intake manifold air temperature sensor

Use this procedure to troubleshoot the system when one of the following diagnostic codes is an active diagnostic code or a recently logged diagnostic code or when a diagnostic code can easily be activated.

- 0110-03 Engine Coolant Temperature Sensor voltage above normal
- 0110-04 Engine Coolant Temperature Sensor voltage below normal
- 0172-03 Intake Manifold Air Temperature Sensor voltage above normal
- 0172-04 Intake Manifold Air Temperature Sensor voltage below normal

**The following background information is related to this procedure:**

The troubleshooting procedures for the diagnostic codes of each temperature sensor are identical. The temperature sensors are sensors that have two terminals. P2:37 on the Electronic Control Module (ECM) is the common connection for the engine temperature sensors. The sensor common connection is shared between the temperature sensors. The common line is connected to terminal 2 on each sensor connector. Terminal 1 is the sensor output. The signal voltage from terminal 1 of each sensor is supplied to the appropriate terminal at ECM Connector P2/J2.

**Pull-up Voltage**

The ECM continuously outputs a pull-up voltage on the circuit for the sensor signal wire. The ECM uses this pull-up voltage in order to detect an open in the signal circuit. When the ECM detects the presence of a voltage that is above a threshold on the signal circuit, the ECM will generate an open circuit FMI code (-03) for the sensor.

If the sensor is disconnected at the sensor connector, the presence of pull-up voltage at the sensor connector indicates that the wires from the sensor connector to the ECM are not open or shorted to ground. If the sensor is disconnected at the sensor connector, the absence of pull-up voltage at the sensor connector indicates an open in the signal wire or a short to ground. If the sensor is disconnected at the sensor connector and the voltage at the sensor connector is different from pull-up voltage, the signal wire is shorted to another wire in the harness.

REFERENCE ONLY

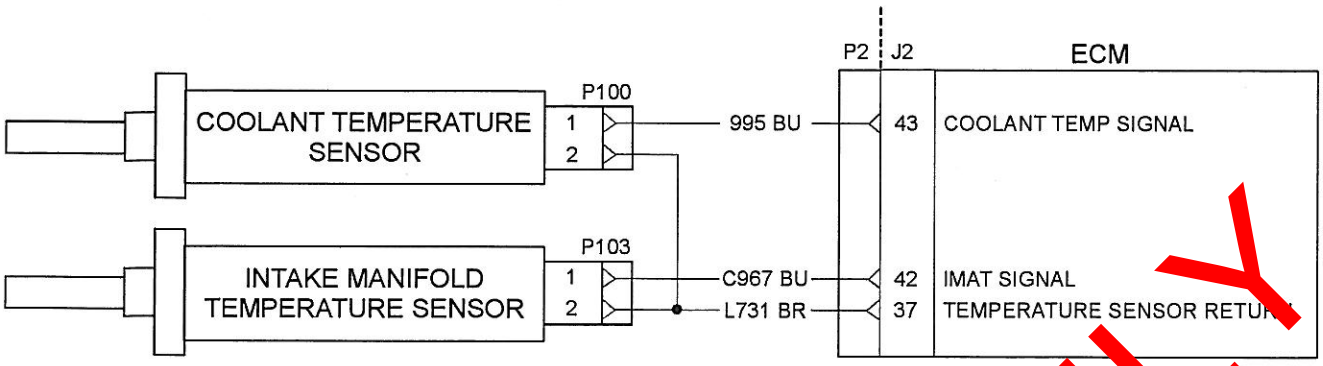



Illustration 64 g01803534

Schematic for engine temperature sensors

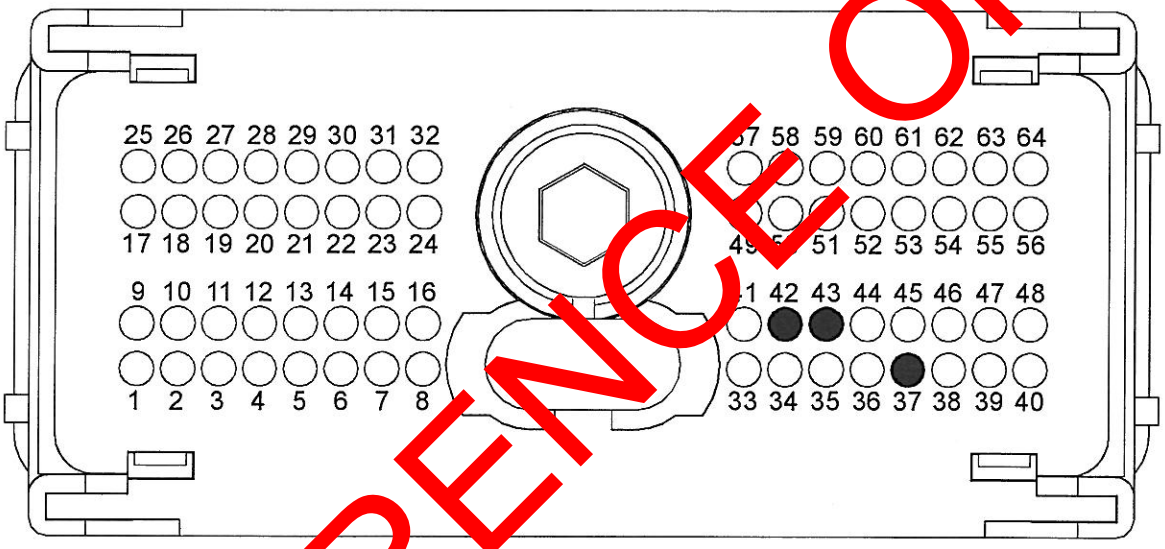



Illustration 65 g01803535

Typical view of the P2 pin locations for the temperature sensors

(37) Ground (GND) Intake Manifold Air Temperature Sensor and Coolant Temperature Sensor
(42) Signal (SIG) Intake Manifold Air Temperature Sensor
(43) Signal (SIG) Coolant Temperature Sensor

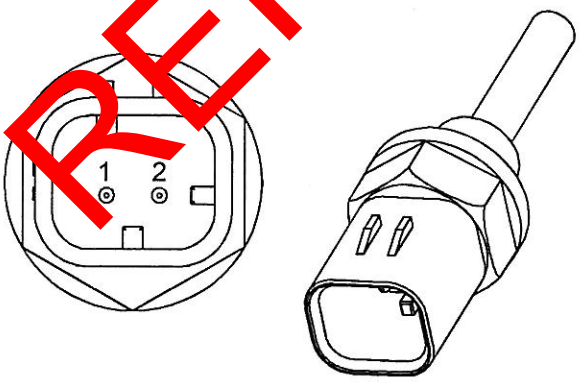



Illustration 66 g01170313

Engine coolant temperature sensor and intake manifold air temperature sensor

(1) Signal (SIG)
(2) Ground (GND)

## Test Step 1. Verify All Active Diagnostic Codes

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**Note:** Wait at least 30 seconds for activation of the diagnostic codes.

**C.** Use the electronic service tool in order to verify if any of the following diagnostic codes are active or recently logged:

- 0110-03 Engine Coolant Temperature Sensor voltage above normal

REFERENCE ONLY

- 0110-04 Engine Coolant Temperature Sensor voltage below normal
- 0172-03 Intake Manifold Air Temperature Sensor voltage above normal
- 0172-04 Intake Manifold Air Temperature Sensor voltage below normal

**Expected Result:**

One or more of the preceding diagnostic codes are active or recently logged.

**Results:**

- Yes – Proceed to Test Step 2.
- No – The fault is intermittent. Proceed to Test Step 8.

## Test Step 2. Inspect Electrical Connectors And Wiring

**A.** Thoroughly inspect ECM engine harness connector P2 and the suspect sensor connector. Refer to Troubleshooting, "Electrical Connectors - Inspect".

**B.** Perform a 45 N (10 lb) pull test on each of the wires in the sensor connector and the ECM connector that are associated with the active diagnostic code.

Refer to illustration 65.

**C.** Verify that the latch tab of the connector is correctly latched. Also verify that the latch tab of the connector has returned to the fully latching position.

**D.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**E.** Check the harness for abrasions and for pinch points from the sensor to the ECM.

**Expected Result:**

All connectors, pins, and sockets should be completely coupled and/or inserted. The harness should be free of corrosion, abrasion, and pinch points.

**Results:**

- OK – Proceed to Test Step 3.
- Not OK – Repair the connectors or the harness and/or replace the connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled. Clear all inactive diagnostic codes. Verify that the repair has eliminated the fault. Proceed to Test Step 3 if the fault has not been eliminated.

## Test Step 3. Verify That The Diagnostic Code Is Still Active

**A.** Turn the keyswitch to the ON position.

**Note:** Wait at least 10 seconds for activation of the diagnostic codes.

**B.** Access the "Active Diagnostic Code" screen on the electronic service tool and check for active diagnostic codes.

**C.** Determine if the fault is related to an "Voltage Above Normal" diagnostic code or a "Voltage Below Normal" diagnostic code.

**Expected Result:**

A "Voltage Below Normal" diagnostic code or an "Voltage Above Normal" diagnostic code is active.

**Results:**

OK - SHORT Circuit – A "Voltage Below Normal" diagnostic code is active at this time. Proceed to Test Step 4.

- OK - OPEN Circuit – A "Voltage Above Normal" diagnostic code is active at this time. Proceed to Test Step 5.
- Not OK – A "Voltage Below Normal" diagnostic code is not active. An "Voltage Above Normal" diagnostic code is not active. An intermittent fault may exist.

  **Repair:** Use the electronic service tool to perform a "Wiggle Test". If faults are indicated then go to the appropriate procedure.

  STOP.

## Test Step 4. Disconnect The Sensor In Order To Create An Open Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the connector for the sensor with the short circuit diagnostic code.

**C.** Turn the keyswitch to the ON position.

**Note:** Wait at least 10 seconds for activation of the diagnostic codes.

REFERENCE ONLY

**D.** Access the "Active Diagnostic Code" screen of the electronic service tool. Check for an active "Voltage Above Normal" diagnostic code.

**Expected Result:**

A "Voltage Above Normal" diagnostic code for the disconnected sensor is now active.

**Results:**

- OK – A "Voltage Below Normal" diagnostic code was active before disconnecting the sensor. An "Voltage Above Normal" diagnostic code became active after disconnecting the sensor.

  **Repair:** Refer to Troubleshooting, "Electrical Connectors - Inspect".

  Inspect the seals in the connectors for damage.

  Connect the sensor and verify that the fault returns. If the fault returns, the sensor is faulty.

  Replace the sensor.

  Clear all logged diagnostic fault codes.

  STOP.

- Not OK – There is a short circuit between the sensor harness connector and the ECM. Leave the sensor disconnected. Proceed to Test Step 5.

## Test Step 5. Create A Short Circuit Between The Signal And The Common Terminals At The Sensor Harness Connector

**A.** Disconnect the suspect sensor connector P100 for the coolant temperature sensor or disconnect P103 for the inlet manifold temperature sensor.

**B.** Turn the keyswitch to the ON position.

**Note:** Wait at least 10 seconds for the activation of any diagnostic fault codes.

**C.** Fabricate a jumper wire 150 mm (6 inch) long. Crimp a terminal to both ends of the wire.

**D.** Monitor the "Active Diagnostic Code" screen on the electronic service tool before installing the jumper wire and after installing the jumper wire.

**E.** Install the jumper on the engine harness connector for the suspect sensor, P100 for the coolant temperature sensor and P103 for the intake manifold temperature sensor. Install one end of the jumper at the sensor signal (terminal 1). Install the other end of the jumper at the common connection (terminal 2).

**Note:** Wait at least 30 seconds for activation of the short circuit diagnostic code.

**Expected Result:**

A "Voltage Below Normal" diagnostic code is active when the jumper is installed. An "Voltage Above Normal" diagnostic code is active when the jumper is removed.

**Results:**

- OK – The engine harness and the ECM are OK.

  **Repair:** Perform the following repair:

  1. Temporarily connect the suspect sensor.
  2. If the diagnostic code remains active, replace the sensor.
  3. Verify that the repair eliminates the fault.
  4. Clear all logged diagnostic codes.

  STOP.

- Not OK – The "Voltage Above Normal" diagnostic code remains active with the jumper in place. The most probable location for the open circuit is in the sensor common or the sensor signal wire in the engine harness between the ECM and the sensor. Remove the jumper. Proceed to Test Step 6.

## Test Step 6. Check The Operation Of The ECM By Creating An Open And A Short Circuit At The ECM Connector

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector.

**C.** Thoroughly inspect both halves of the connector for signs of corrosion or moisture. Refer to Troubleshooting, "Electrical Connectors - Inspect".

**D.** Turn the keyswitch to the ON position. Use the electronic service tool in order to monitor the "Active Diagnostic Code" screen. Wait at least 10 seconds for activation of the code.

An "Voltage Above Normal" diagnostic code should be active for the suspect sensor.

**Note:** When P2 is disconnected, all of the "Voltage Above Normal" diagnostic codes for the pressure sensors and temperature sensors will be active. This is normal. Disregard the diagnostic codes for the pressure sensors and the temperature sensors that are not suspect. Monitor the diagnostic codes for the suspect sensors only.

**E.** Turn the keyswitch to the OFF position.

REFERENCE ONLY

**F.** Fabricate a jumper wire 150 mm (6 inch) long. Crimp a terminal to both ends of the wire.

**G.** Monitor the "Active Diagnostic Code" screen on the electronic service tool before installing the jumper wire and after installing the jumper wire.

**H.** Remove the suspect sensor signal pin from the P2 connector, either pin P2:42 for the intake manifold temperature sensor or pin P2:43 for the coolant temperature sensor. Remove the P2:37 sensor common connector. Install the jumper on the P2 connector. Install one end of the jumper at the suspect sensor signal pin. Install the other end of the jumper to the P2:37 common connection for the sensors. Reassemble the P2 connector to the ECM. Use the electronic service tool in order to check the diagnostic codes. Wait at least 10 seconds for activation of the "Voltage Below Normal" diagnostic code.

**Note:** The "Voltage Above Normal" diagnostic code for the temperature sensor that is not suspect should become active when the sensor common connection is removed from the P2 connector. This code can be disregarded.

**Expected Result:**

A "Voltage Below Normal" diagnostic code is active when the jumper is installed. A "Voltage Above Normal" diagnostic code is active when the jumper is removed.

**Results:**

- OK – Proceed to test step 7.
- Not OK

  **Repair:** The ECM does not operate correctly. Perform the following repair:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
  2. Contact the Technical Help Desk.

**Note:** The consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
  4. Use the electronic service tool to recheck the system for active diagnostic codes.
  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.
  6. If the fault returns with the suspect ECM, replace the ECM.
  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 7. Bypass The Harness Wiring Between The ECM And The Sensor Connector

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P2 connector on the ECM harness, and the suspect sensor connector.

**C.** Remove the sensor signal wire from the P2 connector.

**D.** Remove the signal wire (terminal 1) from the sensor connector on the engine harness.

**E.** Fabricate a jumper wire that is long enough to reach from the ECM to the sensor connector with sockets on both ends.

**F.** Insert one end of the jumper into the ECM connector. Insert the other end of the jumper into the sensor connector of the engine harness.

**G.** Reconnect the connector for the ECM harness and the sensor connector.

**H.** Turn the keyswitch to the ON position.

**I.** Use the electronic service tool in order to monitor the "Active Diagnostic Code" screen for either the "Voltage Above Normal" diagnostic code for the sensor or the "Voltage Below Normal" diagnostic code for the sensor.

**Expected Result:**

The diagnostic code disappears when the jumper is installed.

**Results:**

- OK – There is a fault in the wiring harness.

  **Repair:** Perform the following repair:

  1. Repair the faulty harness or replace the faulty harness.
  2. Clear all diagnostic codes.

REFERENCE ONLY

3. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

- Not OK – The fault is intermittent. Proceed to Test Step 8.

### Test Step 8. Perform the "Wiggle Test" on the Perkins Electronic Service Tool (EST)

**A.** Select the "Wiggle Test" from the diagnostic tests on the electronic service tool.

**B.** Choose the appropriate group of parameters to monitor.

**C.** Press the "Start" button. Wiggle the wiring harness in order to reproduce intermittent faults.

If an intermittent fault exists, the status will be highlighted and an audible beep will be heard.

**Expected Result:**

No intermittent faults were indicated during the "Wiggle Test".

**Results:**

- OK – No intermittent faults were found. The harness and connectors appear to be OK. If this test was required as part of another procedure, return to that procedure and continue testing. If this test has resolved the fault, return the engine to service. STOP.
- Not OK – At least one intermittent fault was indicated.

  **Repair:** Repair the harness or the connector.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03460681

## Fuel Rail Pump Solenoid - Test

**System Operation Description:**

Use this procedure to troubleshoot the system when one of the following diagnostic codes is active or easily repeated:

- 1779-05 Fuel Rail #1 Pressure Valve Solenoid current below normal
- 1779-06 Fuel Rail #1 Pressure Valve Solenoid current above normal

**Note:** The fuel rail pump is installed on the engine at the factory. The fuel rail pump is not serviceable part.

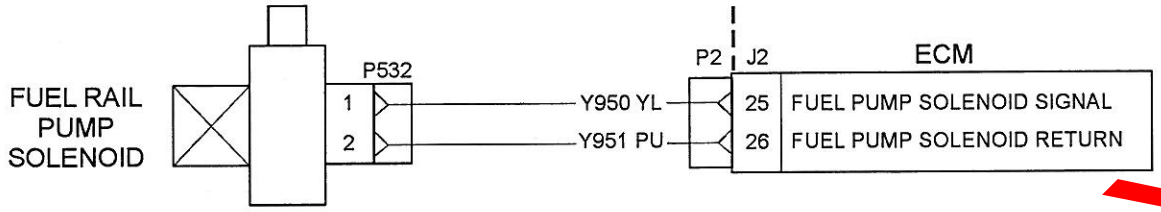
The fuel rail pump solenoid is used to control the output from the fuel rail pump. The solenoid receives an electrical supply from the Electronic Control Module (ECM). The fuel rail pump solenoid is then energized when the fuel is required to be pumped into the fuel rail. Varying the timing of the voltage to the solenoid controls the fuel delivery from the fuel rail pump.

When the fuel rail pump solenoid is deactivated, the fuel that is not sent to the fuel rail is returned to the fuel tank.

The fuel rail pump solenoid forms part of the closed loop control system for the fuel rail pressure in conjunction with the fuel rail pressure sensor, ECM and the software. The fuel rail pressure sensor measures the fuel pressure in the high pressure fuel rail. The signal from the fuel rail pressure sensor is processed by the ECM and software. The measured pressure is compared to the desired fuel rail pressure for the given engine operating conditions.

If the fuel rail pump solenoid fails, it is likely that the fuel will not be pumped into the high pressure fuel rail and engine shutdown or failure to start the engine is expected. Fuel rail pressure can be observed on the status screen of the electronic service tool.

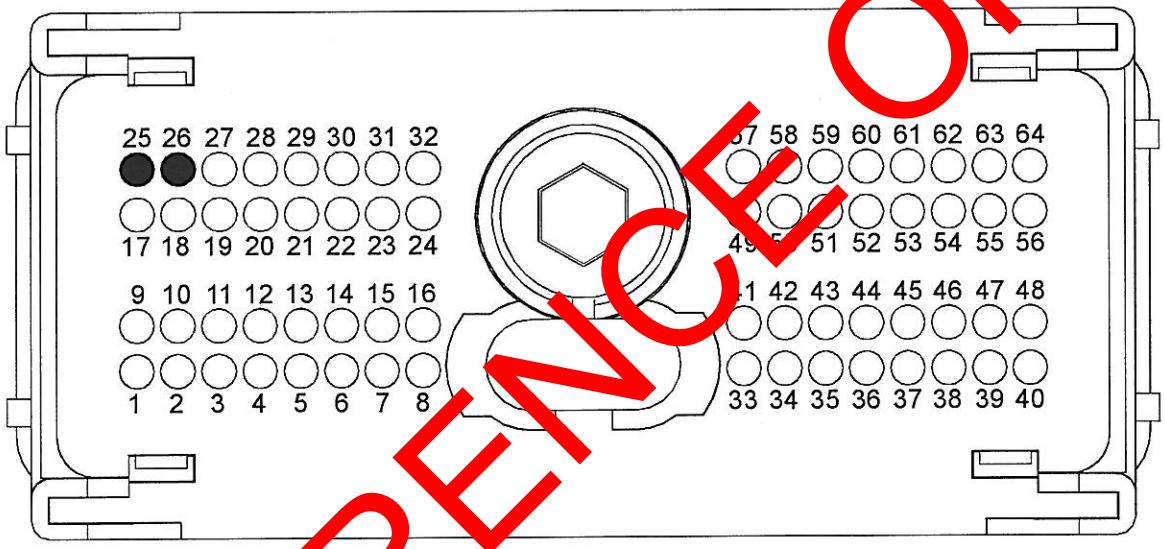
REFERENCE ONLY




g01803553

Illustration 67

Typical schematic of the circuit for the fuel rail pump solenoid




g01803554

Illustration 68

Typical view of the P2 pin locations for the electrical power supply circuit

(25) Fuel rail pump solenoid PWM signal (26) Fuel rail pump solenoid return

REFERENCE ONLY

## Test Step 1. Inspect the Electrical Connectors and the Harness

**WARNING**

**Electrical shock hazard. The fuel rail pump solenoid uses 63 to 73 volts.**

**A.** Turn the keyswitch to the OFF position.

**B.** Thoroughly inspect the harness connector P2/J2 and the suspect connector P532. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the solenoid connector P532 and the connector pins 25 and 26 that are associated with the fuel rail pump solenoid. Refer to illustration 68.

**D.** Check the harness for abrasions and for pinch points from the battery to the ECM. Check the harness for abrasions and for pinch points from the key switch to the ECM.

**E.** Perform a "Wiggle Test" by using the electronic service tool in order to identify intermittent connections.

**Expected Result:**

All connectors, pins, and sockets are completely coupled and/or inserted. The harness is free of corrosion, of abrasion, and of pinch points.

**Results:**

- OK – The connectors and the harness appear to be OK. Proceed to Test Step 2.

- Not OK – There is a fault with the connectors and/or the harness.

  **Repair:** Repair the connectors or the harness and/or replace the connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

## Test Step 2. Check for Active Diagnostic Codes

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Use the electronic service tool to verify if any of the following diagnostic codes are active or recently logged:

- 1779-05 Fuel Rail #1 Pressure Valve Solenoid current below normal
- 1779-06 Fuel Rail #1 Pressure Valve Solenoid current above normal

**Expected Result:**

One or more of the following diagnostic codes are active or recently logged:

- 1779-05 Fuel Rail #1 Pressure Valve Solenoid current below normal
- 1779-06 Fuel Rail #1 Pressure Valve Solenoid current above normal

**Results:**

- 1779-05 – Proceed to Test Step 3.
- 1779-06 – Proceed to Test Step 7.
- Not OK – No active diagnostic codes or recently logged diagnostic codes are displayed. STOP.

## Test Step 3. Check the Harness for an Open Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect P2 from the ECM.

**C.** Measure the resistance between P2:25 and P2:26.

**Expected Result:**

The nominal resistance is less than 2 Ohms.

**Results:**

- OK – The harness and the solenoid do not have an open circuit.

  **Repair:** Check the high pressure fuel system for leaks. A mechanical relief valve is installed in the high pressure fuel rail. Check that there is no flow of fuel from the mechanical relief valve. Refer to Operation and Maintenance Manual, "High Pressure Fuel Lines".

  If the fuel system is Not OK, repair the fuel system and restart the diagnostic process.

  If the fuel system is OK, proceed to Test Step 4.

- Not OK – There is an open circuit. Proceed to Test Step 4.

## Test Step 4. Check the Fuel Rail Pump Solenoid for an Open Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the connector from the fuel rail pump solenoid.

**C.** Measure the resistance of the fuel rail pump solenoid.

**Expected Result:**

The nominal resistance is less than 1 Ohm.

**Results:**

- OK – There is an open circuit or there is an excessive resistance in the harness.

  **Repair:** Repair the connectors or the harness and/or replace the connectors or the harness.

  Ensure that all of the seals are correctly in place and ensure that all connectors are correctly coupled.

  Use the electronic service tool in order to perform the fuel rail pump solenoid test.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminated the fault.

  STOP.

- Not OK – The fuel rail pump solenoid is faulty.

REFERENCE ONLY

**Repair:** Temporarily connect a new fuel rail pump to the harness, but do not install the fuel rail pump to the engine.

Reconnect the P2 to the ECM. Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminated the fault.

Use the electronic service tool in order to perform the fuel rail pump solenoid test.

If the diagnostic code does not reappear, then install the new fuel rail pump to the engine. Refer to Disassembly and Assembly Manual, "Fuel Injection Pump- Install".

STOP.

## Test Step 5. Check the Fuel Rail Pump Solenoid for a Short Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the connector from the fuel rail pump solenoid.

**C.** Turn the keyswitch to the ON position.

**D.** Use the electronic service tool in order to perform the solenoid test for the fuel rail pump.

**Expected Result:**

A "Current Below Normal" diagnostic code is displayed. The "Current Above Normal" diagnostic code is not displayed.

**Results:**

- OK – A "Current Below Normal" diagnostic code is displayed. The harness has no shorts to supply or ground. The fuel rail pump solenoid is faulty.

  **Repair:** Temporarily connect a new fuel rail pump to the harness, but do not install the fuel rail pump to the engine.

  Reconnect P2 to the ECM. Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

  Use the electronic service tool in order to perform the solenoid test for the fuel rail pump.

  Verify that the repair eliminates the fault.

  If the diagnostic code has been cleared, then install the new fuel rail pressure pump to the engine. Refer to Disassembly and Assembly, "Electrical Connectors - Inspect".

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – The harness is a short circuit or the ECM is a short circuit. Proceed to Test Step 6.

## Test Step 6. Check the Harness for the Fuel Rail Pump Solenoid for a Short Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P532 connector from the fuel rail pump solenoid.

**C.** Disconnect the P2 connector from the ECM.

**D.** Measure the resistance between P2:26 and P2:25.

**E.** Measure the resistance between P2:25 and voltage +.

**F.** Measure the resistance between P2:25 and the voltage (-).

**G.** Measure the resistance between P2:26 and voltage +.

**H.** Measure the resistance between P2:26 and voltage (-).

**Expected Result:**

The resistance is greater than 20,000 Ohms.

**Results:**

- OK – The harness has no short circuit to supply or ground. The ECM is suspect. Proceed to Test Step 7.

- Not OK – The harness has a short circuit.

  **Repair:** Repair the harness and connectors or replace the faulty harness and connectors.

  Connect the P532 connector to the fuel rail pump solenoid.

  Connect the P2 connector to the ECM.

  Turn the keyswitch to the ON position.

  Use the electronic service tool in order to perform the solenoid test for the fuel rail pump.

REFERENCE ONLY

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

STOP.

### Test Step 7. Check the ECM and the Harness

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P532 connector from the fuel rail pump solenoid.

**C.** Insert a jumper wire across P532.

**D.** Turn the keyswitch to the ON position.

**E.** Use the electronic service tool in order to perform the solenoid test for the fuel rail pump.

**F.** Use the electronic service tool in order to monitor the status screen.

**Expected Result:**

A 1779-06 diagnostic code is displayed.

**Results:**

- OK – The ECM and the ECM connections function. The solenoid is not an open circuit. Recheck the diagnostic codes. Proceed to Test Step 5.
- Not OK – The ECM is suspect. Proceed to Test Step 8.

### Test Step 8. Check the ECM Function

**A.** Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

**B.** Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

**C.** If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

**D.** Replace all connectors.

**E.** Use the electronic service tool to recheck the system for active diagnostic codes.

**F.** Use the electronic service tool in order to perform the solenoid test for the fuel rail pump.

**Expected Result:**

The fault is eliminated.

**Results:**

- OK

  **Repair:** If the fault is eliminated with the test ECM, perform the following procedure:

  1. Reconnect the suspect ECM.
  2. If the fault returns with the suspect ECM, replace the ECM.
  3. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK

  **Repair:** Repeat the diagnostic procedure from Step 1.

  STOP.

i03460722

## Idle Validation Switch Circuit Test

**System Operation Description:**

Use this procedure if any of the following diagnostic codes are active:

- 0091-02 Throttle Position Sensor erratic, intermittent, or incorrect
- 0774-02 Secondary Throttle Position Sensor erratic, intermittent, or incorrect

The idle validation switch (IVS) may be installed. The IVS is required for mobile applications that use an analog throttle. The IVS is part of the analog throttle demand sensor. The IVS is CLOSED when the low idle is set.

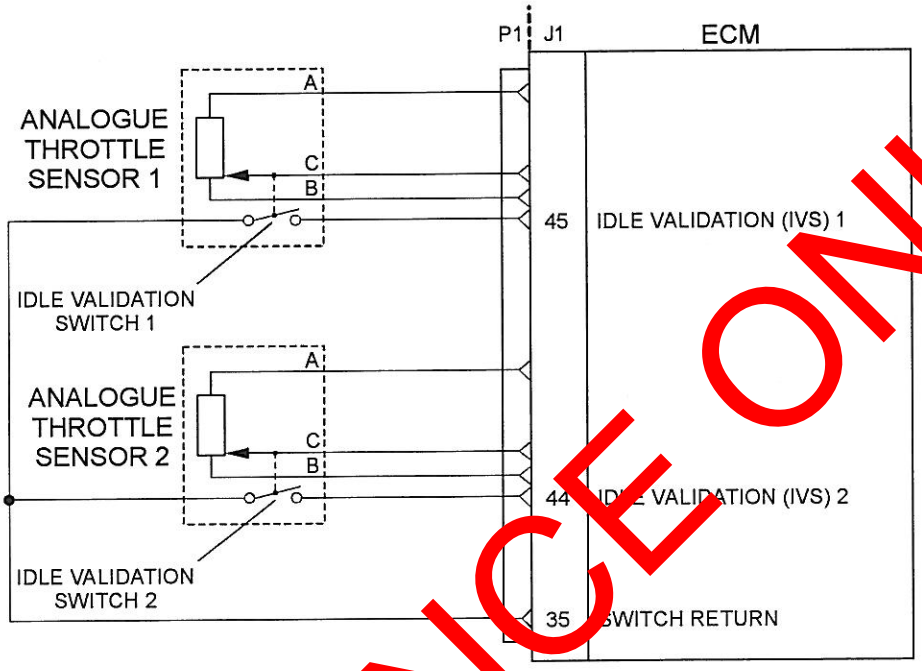
The demand settings for the analog throttle that are valid for the IVS threshold are programmed into the Electronic Control Module (ECM). Use the electronic service tool in order to display the demand settings for the analog throttle.

If the IVS operates outside of the programmed range then the engine speed may not respond to changes in the throttle position for the suspect throttle.

The electronic service tool may be used for the following:

REFERENCE ONLY

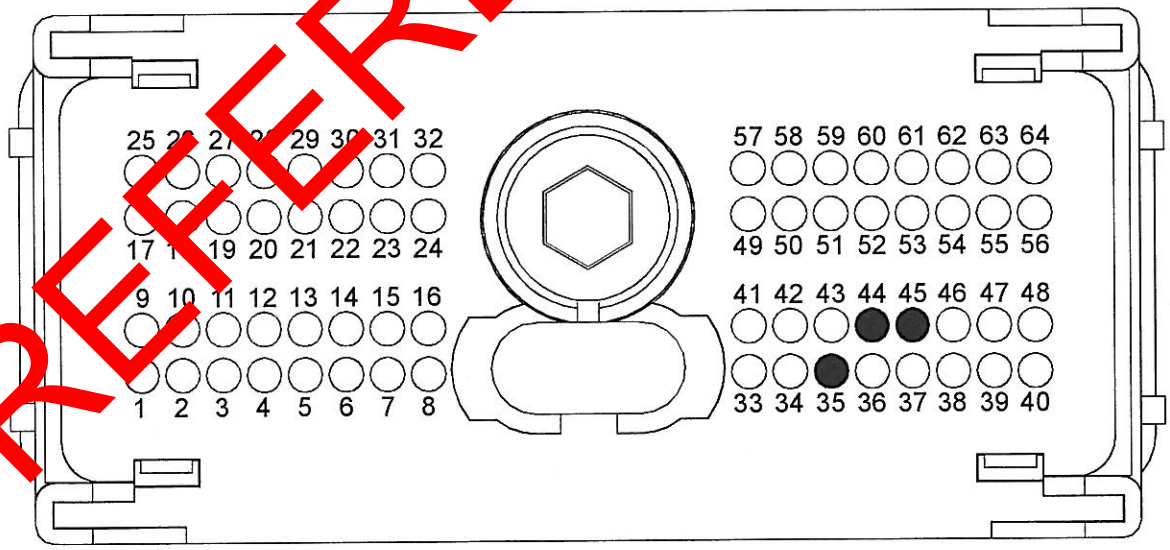
- Reset the IVS threshold for an existing IVS.
- View the IVS change point and reset the IVS thresholds when a new throttle assembly is installed.




g01803633

Illustration 69

Schematic of the idle validation switch (IVS) circuit




g01803694

Illustration 70

Typical view of the pin locations in the P1 connector

(35) Sensor Ground (GND) (44) Idle validation (IVS) 2 (45) Idle validation (IVS) 1

REFERENCE ONLY

### Test Step 1. Check the Operation of the Idle Validation Switch (IVS)

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Use the electronic service tool in order to check the current "Throttle Configuration".

**D.** Select the "SERVICE" option from the drop-down menu on the electronic service tool.

**E.** Select the "Throttle Configuration" option on the electronic service tool. Select the appropriate analog "Throttle Configuration" summary from the menu on the left of the screen. The IVS window for the throttle will indicate "YES" if an IVS is installed. Make a note of the "Idle Validation Min OFF Threshold" parameters that are displayed in the "Throttle Configuration" menu of the electronic service tool. Make a note of the "Idle Validation Max ON Threshold" parameters that are displayed in the "Throttle Configuration" menu of the electronic service tool.

**F.** Select the "Throttle status" function on the electronic service tool. Select "Status" function and then select "Throttles" function.

**G.** The throttle is set in the low idle position.

**H.** Depress the throttle pedal slowly. The IVS status should change from CLOSED (ON) to OPEN (OFF).

**Expected Result:**

The IVS state changes from CLOSED (ON) to OPEN (OFF).

**Results:**

- OK – The IVS state changes from CLOSED (ON) to OPEN (OFF). Proceed to Test Step 2.
- Not OK – The IVS does not operate.

**Repair:**

Proceed to Test Step 3.

### Test Step 2. Check the Idle Validation Switch (IVS) Threshold

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Use the electronic service tool in order to check the current "Throttle Configuration".

**D.** Select the "SERVICE" option from the drop-down menu on the electronic service tool.

**E.** Select the "Throttle Configuration" option on the electronic service tool. Select the appropriate analog "Throttle Configuration" summary from the menu on the left of the screen. The IVS window for the throttle will indicate "YES" if an IVS is installed. Make a note of the "Idle Validation Min OFF Threshold" parameters that are displayed in the "Throttle Configuration" menu of the electronic service tool. Make a note of the "Idle Validation Max ON Threshold" parameters that are displayed in the "Throttle Configuration" menu of the electronic service tool.

**F.** To select the "Throttle status" function on the electronic service tool, select "Status" function and then select "Throttles" function.

**G.** The throttle is set in the low idle position.

**H.** Depress the throttle pedal slowly. The IVS status should change from CLOSED (ON) to OPEN (OFF).

**Expected Result:**

The IVS switch operates between the "Idle Validation Min OFF Threshold" and the "Idle Validation Max ON Threshold" parameters. Use the electronic service tool in order to view the parameters of the IVS switch.

**Results:**

- OK – The IVS switch operates within the "Idle Validation Min OFF Threshold" and the "Idle Validation Max ON Threshold" parameters. Use the electronic service tool in order to view the parameters of the IVS switch. STOP.
- Not OK – The IVS switch cannot operate within the "Idle Validation Min OFF Threshold" and the "Idle Validation Max ON Threshold" parameters. Use the electronic service tool in order to view the parameters of the IVS switch.

**Repair:**

Proceed to Test Step 7.

### Test Step 3. Inspect Electrical Connectors and the Harness

**A.** Inspect the P1/J1 connector, the harness and all of the connectors for the IVS. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**B.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connector that are associated with the suspect analog throttle switch:

REFERENCE ONLY

- P1:35
- P1:44
- P1:45

**C.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**D.** Check the harness for abrasion and pinch points from the analog throttle switch to the ECM.

**Expected Result:**

All connectors, pins and sockets are completely coupled and/or inserted and the harness is free of corrosion, abrasion and pinch points.

**Results:**

- OK – Proceed to Test Step 4.
- Not OK

  **Repair:** Perform the following repair:

  Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly installed and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 4. Check the Location of the Fault

**A.** Disconnect the IVS harness connector.

**B.** Install a jumper wire between the IVS connections on the harness.

**C.** Turn the keyswitch to the ON position.

**D.** Install a jumper wire between the IVS connections on the harness. Use the electronic service tool in order to check for diagnostic codes.

**E.** Remove the jumper wire that is between the IVS connections on the harness. Use the electronic service tool in order to check for diagnostic codes.

**Expected Result:**

When the jumper wire is installed, the IVS state on the "Throttle Status" screen of the electronic service tool will display "ON".

When the jumper wire is removed, the IVS state on the "Throttle Status" screen of the electronic service tool will display "OFF".

**Results:**

- OK – The jumper wire is connected. The electronic service tool displays the IVS state as "ON". The jumper wire is disconnected. The electronic service tool displays the IVS state as "OFF". The IVS is suspect. Proceed to Test Step 6.
- Not OK – The harness and/or the ECM are suspect. Proceed to Test Step 5.

## Test Step 5. Check the ECM function

**A.** Disconnect the P1 connector.

**B.** If the IVS 2 is suspect, temporarily remove connector P1:35. If the IVS 1 is suspect, temporarily remove P1:44.

**C.** Fabricate a jumper wire.

**D.** Turn the keyswitch to the ON position.

**E.** Install the jumper wire between the removed connector pin on the P1 connector and P1:35.

**F.** Use the electronic service tool in order to monitor the IVS status. Record the status of the IVS.

**G.** Disconnect the jumper wire.

**H.** Use the electronic service tool in order to monitor the IVS status. Record the status of the IVS.

**Expected Result:**

When the jumper wire is installed, the IVS state on the "Throttle Status" screen of the electronic service tool will display "ON".

When the jumper wire is removed, the IVS state on the "Throttle Status" screen of the electronic service tool will display "OFF".

**Results:**

- OK – The jumper wire is connected. The electronic service tool displays the IVS state as "ON". The jumper wire is disconnected. The electronic service tool displays the IVS state as "OFF".

  **Repair:**

  1. Inspect the harness between the ECM and IVS.
  2. Locate the fault.
  3. Repair the harness and/or replace the harness.

REFERENCE ONLY

4. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

STOP.

- Not OK – The ECM is suspect.

**Repair:** Perform the following repair:

1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

4. Use the electronic service tool to recheck the system for active diagnostic codes.

5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

6. If the fault returns with the suspect ECM, replace the ECM.

7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 6. Check the Idle Validation Switch (IVS) at the Sensor

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the IVS.

**C.** Set the throttle to low idle.

**D.** Check the resistance of the IVS.

**E.** Set the throttle to high idle.

**F.** Check the resistance of the IVS.

**Expected Result:**

The IVS reading should be more than 20,000 Ohms at high idle.

The IVS reading should be less than 10 Ohms at low idle.

**Results:**

- OK – The IVS indicates the resistance that is shown in the test. No fault is indicated at this time. Recheck the harness for intermittent connections. STOP.

- Not OK – The IVS is not functioning correctly.

**Repair:** Replace the IVS or replace the sensor assembly for throttle demand. Refer to documentation for the machine for information on the throttle demand sensor. Check the IVS calibration.

Refer to Test Step 7.

- Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault. – STOP.

## Test Step 7. Check the Idle Validation Switch (IVS) Calibration

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Select the "Throttle Configuration" option on the electronic service tool. Select the appropriate analog "Throttle Configuration" summary from the menu on the left of the screen. The IVS window for the throttle will indicate "YES" if an IVS is installed. Make a note of the "Idle Validation Min OFF Threshold" parameters that are displayed in the "Throttle Configuration" menu of the electronic service tool. Make a note of the "Idle Validation Max ON Threshold" parameters that are displayed in the "Throttle Configuration" menu of the electronic service tool.

**D.** Select the "Throttle status" function on the electronic service tool. Select "Status" function and then select "Throttles" function.

**E.** The throttle is set in the low idle position.

**F.** Depress the throttle pedal slowly. The raw percentage values for the throttle that are shown on the electronic service tool should increase and the IVS status should change from "CLOSED" (ON) to "OPEN" (OFF). Make a note of the raw reading for the throttle when the IVS reading changes from "CLOSED" to "OPEN". Repeat this step in order to obtain accurate raw percentage values for the throttle. The noted value should be within the previously noted "Idle Validation Min OFF Threshold" and "Idle Validation Max ON Threshold" limits.

**G.** The throttle pedal is set to the full throttle position or the high idle position.

REFERENCE ONLY

**H.** Release the throttle pedal slowly. The raw percentage values for the throttle that are shown on the electronic service tool should decrease and the IVS status should change from "OPEN" (OFF) to "CLOSED" (ON). Make a note of the raw reading for the throttle when the IVS reading changes from the OPEN position to the CLOSED position. Repeat this step in order to obtain accurate raw percentage values for the throttle. The noted value should be within the previously noted "Idle Validation Min OFF Threshold" and "Idle Validation Max ON Threshold" limits.

**Expected Result:**

The IVS operates within the "Idle Validation Min OFF Threshold" and the "Idle Validation Max ON Threshold" values that are shown on the "Configuration" menu of the electronic service tool.

**Results:**

- OK – The IVS operates within the "Idle Validation Min OFF Threshold" and the "Idle Validation Max ON Threshold" values that are shown on the "Configuration" menu of the electronic service tool. STOP.
- Not OK – Proceed to Test Step 8.

### Test Step 8. Reset the Idle Validation Switch (IVS) Threshold Limits by Using the Electronic Service Tool

The electronic service tool can be used to reset the "Idle Validation Min OFF Threshold" and the "Idle Validation Max ON Threshold" limits that are shown in the current throttle configuration summary.

**A.** Calculate the new "Idle Validation Min OFF Threshold" limit. The "Idle Validation Min OFF Threshold" limit is 5% below the lowest raw values that are noted in the previous Test Step.

**Note:** The default value for the "Idle Validation Min OFF Threshold" is 10%. The lowest value that should be set is 5%.

**B.** Calculate the new "Idle Validation Max ON Threshold" limit. The "Idle Validation Max ON Threshold" is 3% above the raw values that was noted for the "Idle Validation Max ON Threshold" limit. The "Idle Validation Max ON Threshold" is 3% above the highest raw % value that was noted in the previous Test Step.

**Note:** The default value for the "Idle Validation Max ON Threshold" is 25%. The maximum value that is expected is 28%.

**C.** Enter the new threshold limits into the electronic service tool.

**D.** Turn the keyswitch to the OFF position. Turn the keyswitch to the ON position.

**E.** Repeat the previous Test Step. Check that the IVS operates within the newly set threshold limits.

**Expected Result:**

The fault is cleared.

**Results:**

- OK – STOP.
- Not OK

  **Repair:** Repeat the procedure from Test Step 1.

  STOP.

i03460880

## Ignition Keyswitch Circuit and Battery Supply Circuit - Test

**System Operation Description:**

This procedure tests that the correct voltage is being supplied to the Electronic Control Module (ECM).

Use this procedure to troubleshoot the system when one of the following diagnostic codes is active or easily repeated:

- 0168-00 Electrical System Voltage high
- 0168-01 Electrical System Voltage low
- 0168-02 Electrical System Voltage erratic, intermittent, or incorrect
- 1834-02 Ignition Keyswitch loss of signal

The ECM receives electrical power (battery voltage) through the wiring that is supplied by the manufacturer of the application. Unswitched battery voltage is supplied through P1: 7, 8, 15, 16. The negative battery is supplied through P1: 1, 2, 3, 9, 10. The ECM receives the input from the keyswitch at P1:40 when the keyswitch is in the ON position or in the START position. When the ECM detects battery voltage at this input, the ECM will power up. When battery voltage is removed from this input, the ECM will power down.

The cause of an intermittent power supply to the ECM can occur on either the positive side or on the negative side of the battery circuit. The connections for the unswitched battery+ may be routed through a dedicated protection device (circuit breaker).

REFERENCE ONLY

Some applications may be equipped with an engine protection shutdown system or an idle timer shutdown system that interrupts electrical power to the keyswitch. The engine protection shutdown system can be an aftermarket device and the idle timer shutdown system can be external to the ECM. Some of these systems will not supply power to the ECM until one of the following conditions is met:

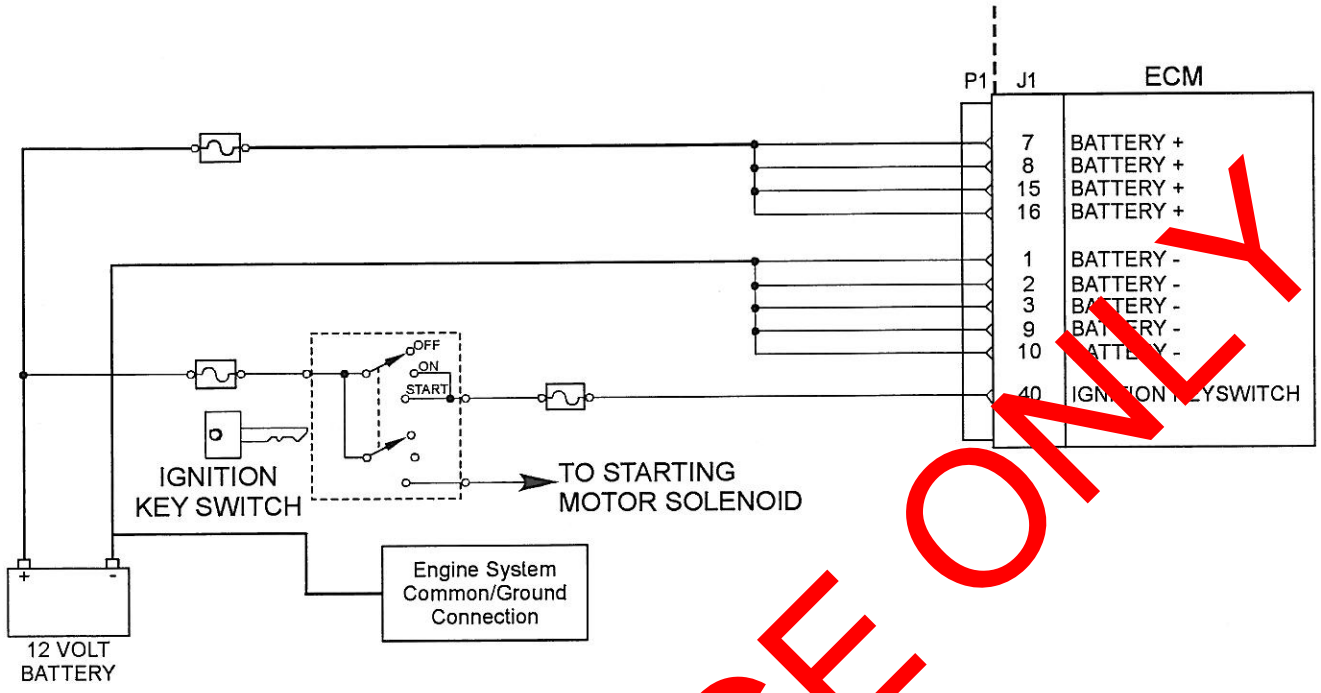
- The engine is cranked.
- The engine oil pressure achieves acceptable limits.
- An override button is pressed.

Keep in mind that these devices may be the cause of intermittent power to the ECM. These devices may also shut down the engine.

Usually, battery power to the diagnostic connector is available and the battery power to the data link connector is independent of the keyswitch. Therefore, you will be able to power up the electronic service tool, but you may not be able to communicate with the engine ECM. The engine ECM requires the keyswitch to be in the ON position in order to maintain communications. The ECM may power down a short time after connecting the electronic service tool if the keyswitch is in the OFF position. This is normal.

For intermittent faults such as intermittent shutdowns that could be caused by the application wiring, temporarily bypassing the application wiring may be an effective means of determining the root cause. If the symptoms disappear with the bypass wiring, the application wiring is the cause of the fault. A means of bypassing the application wiring is explained in this test procedure. This is especially important for applications that do not provide dedicated circuits for the unswitched battery and the connections for the keyswitch.

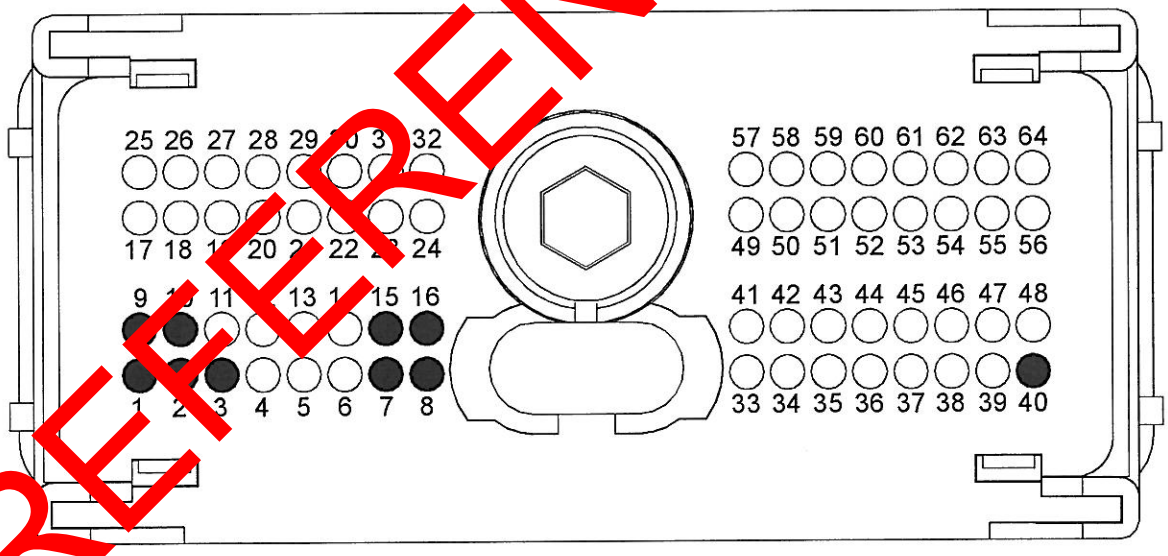
REFERENCE ONLY




g01803755

Illustration 71

Schematic for the ignition keyswitch and battery supply circuit




g01803934

Illustration 72

Typical view of the pin locations on the P1 connector for the ignition keyswitch and battery supply circuit

(1) Battery ground (GND)
(2) Battery ground (GND)
(3) Battery ground (GND)
(7) Battery (+)
(8) Battery (+)
(9) Battery ground (GND)
(10) Battery ground (GND)
(15) Battery ground (+)
(16) Battery ground (+)
(40) Ignition key switch

REFERENCE ONLY

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Thoroughly inspect the P1 connector, the battery connections and the connections to the keyswitch. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**B.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connector that are associated with the following connections:

- P1: 7, 8, 15, 16 (Unswitched Battery+)
- P1: 1, 2, 3, 9, 10 (Battery-)
- P1:40 (keyswitch)

**C.** Use the electronic service tool to perform a "Wiggle Test". Special attention must be paid to the following connections:

- P1: 7, 8, 15, 16
- P1: 1, 2, 3, 9, 10
- P1:40

**D.** Check the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**E.** Check the harness for abrasion and for pinch points from the battery to the ECM, and from the keyswitch to the ECM.

**Expected Result:**

All connectors, pins and sockets are completely coupled and/or inserted and the harness is free of corrosion, of abrasion or of pinch points.

**Results:**

- OK – The harness and connectors appear to be OK. Proceed to Test Step 2.
- Not OK – There is a fault with the connectors and/or the harness.

  **Repair:** Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly installed and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 2. Check for Active Diagnostic Codes or Logged Diagnostic Codes

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Monitor the active diagnostic code screen on the electronic service tool. Check and record any active diagnostic codes or logged diagnostic codes.

**Note:** Wait at least 30 seconds in order for the diagnostic codes to become active.

**Expected Result:**

One of the following diagnostic codes is active or logged:

- 168-0 Electrical System Voltage high
- 168-1 Electrical System Voltage low
- 168-2 Electrical System Voltage erratic, intermittent or incorrect
- 1834-2 Ignition Keyswitch loss of signal

**Note:** Diagnostic code 1834-2 can be generated by rapidly cycling the keyswitch. If diagnostic code 1834-2 is logged but not active, this may be the cause.

**Results:**

- OK – A 168 or a 1834-02 diagnostic code is active or logged. Proceed to Test Step 3.
- Not OK – No diagnostic code is active.

  **Repair:** The fault is no longer present. If the fault is intermittent, refer to Troubleshooting, "Electrical Connectors - Inspect".

  STOP.

## Test Step 3. Check the Battery Voltage at the ECM Connector

**A.** Disconnect the connector P1 from the ECM connector.

**B.** Turn the keyswitch to the ON position.

**C.** Measure the voltage between P1:7 (Unswitched Battery+) and P1:1 (Battery-).

**D.** Measure the voltage between P1:8 (Unswitched Battery+) and P1:2 (Battery-).

REFERENCE ONLY

**E.** Measure the voltage between P1:15 (Unswitched Battery+) and P1:9 (Battery-).

**F.** Measure the voltage between P1:16 (Unswitched Battery+) and P1:10 (Battery-).

**G.** Measure the voltage between P1:40 (keyswitch) and P1:3 (Battery-).

**H.** Turn the keyswitch to the OFF position.

**Expected Result:**

For 12 Volt systems, the measured voltage is a constant 11.0 to 13.5 Volts DC with no suspected intermittent faults at this time.

For 24 Volt systems, the measured voltage is a constant 22.0 to 27.0 Volts DC with no suspected intermittent faults at this time.

**Results:**

- OK – The ECM is receiving the correct voltage.

  **Repair:** If an intermittent condition is suspected, refer to Troubleshooting, "Electrical Connectors - Inspect".

  STOP.

- Not OK – The ECM is not receiving the correct voltage.

  **Repair:** Check for continuity in the harness for the keyswitch from P1:40 through the keyswitch circuit to the batteries. Check the circuit protection for the circuit. Refer to the service manual for the instructions on troubleshooting the circuit for the keyswitch.

  For intermittent problems such as intermittent shutdowns that could be caused by the application wiring, temporarily bypassing the application wiring may be an effective means of determining the root cause.

  Proceed to Test Step 5.

- Not OK – No voltage is present on P1: 7, 8, 15, 16.

  **Repair:** Check for continuity in the harness for the unswitched Battery+ from the ECM to the batteries. Check the circuit protection for the circuit. Check for continuity in the harness for the Battery- from the ECM to the batteries.

  For intermittent faults such as intermittent shutdowns that could be caused by the application wiring, temporarily bypassing the application wiring may be an effective means of determining the root cause.

  Proceed to Test Step 5.

- Not OK – The battery voltage is out of limits. Proceed to Test Step 4.

## Test Step 4. Check the Batteries

**A.** Measure the no-load battery voltage at the battery terminals.

**B.** Load test the batteries using a suitable battery load tester.

**Expected Result:**

The batteries pass the load test. For 12 Volt systems, the measured voltage is at least 11.0 Volts DC. For 24 Volt systems, the measured voltage is at least 22.0 Volts DC.

**Results:**

- OK – The batteries pass the load test. For 12 Volt systems, the measured voltage is at least 11.0 Volts DC. For 24 Volt systems, the measured voltage is at least 22.0 Volts DC.

  **Repair:** Refer to the service manual for the application for instructions on troubleshooting the application harness. Troubleshoot the application harness and repair the application harness, as required.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repairs eliminate the fault.

  STOP.

- Not OK – The batteries do not pass the load test. For 12 Volt systems, the measured voltage is less than 11.0 Volts DC. For 24 Volt systems, the measured voltage is less than 22.0 Volts DC.

  **Repair:** Recharge or replace the faulty batteries.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

REFERENCE ONLY

## Test Step 5. Bypass the Application Harness

**⚠ WARNING**

**Batteries give off flammable fumes which can explode.**

**To avoid injury or death, do not strike a match, cause a spark, or smoke in the vicinity of a battery.**

NOTICE

Do not connect the bypass harness to the battery until all of the in-line fuses have been removed from the Battery+ line. If the fuses are not removed before connection to the battery, a spark may result.

**Note:** The bypass harness is only for test applications. This bypass harness must be removed before the application is released to the customer. The bypass harness can be used in order to determine if the cause of the intermittent fault is an interruption in battery power to the ECM or to the keyswitch circuit.

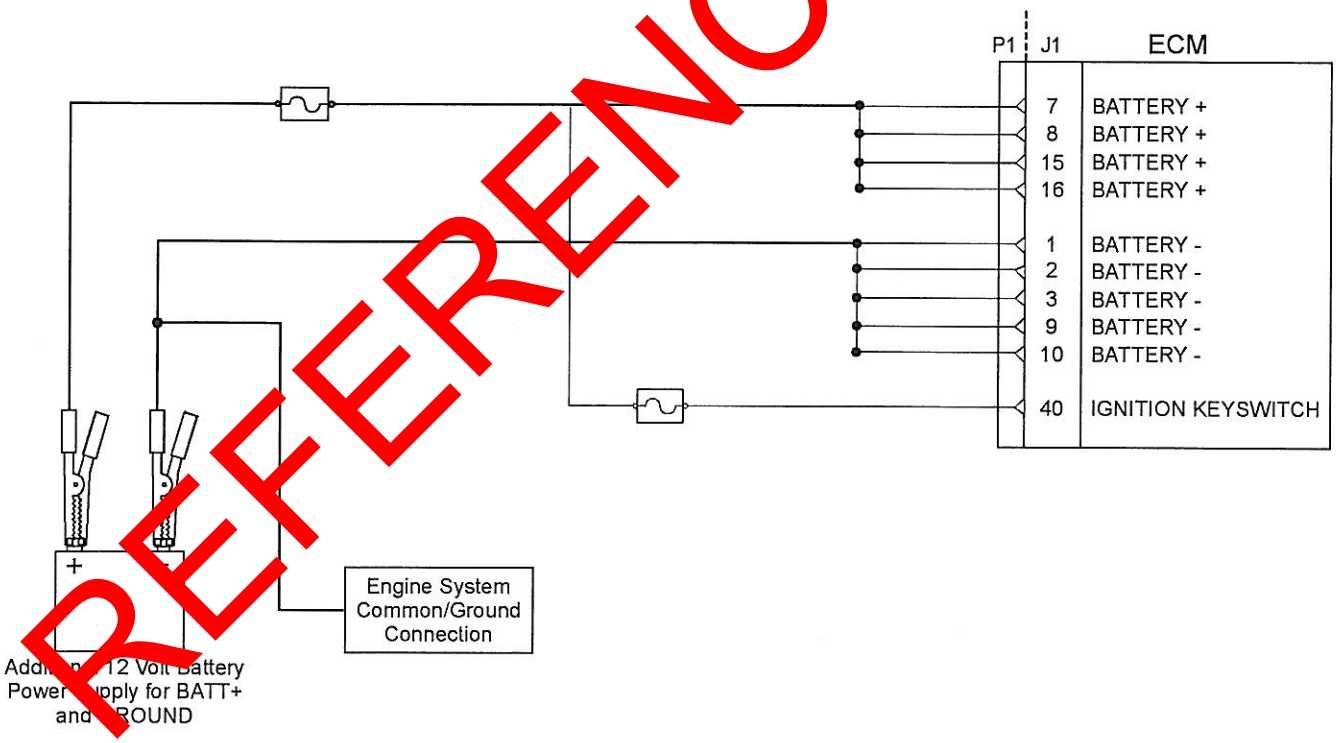



Illustration 73 g01803954

Schematic for the bypass application harness

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P1 connector from the ECM connector.

**C.** Connect a bypass harness to the ECM.

**D.** Remove the fuses from the Battery+ wire of the bypass harness and connect the Battery+ and the Battery- wires directly to the battery terminals.

REFERENCE ONLY

**Note:** This bypass directly connects the circuit for the keyswitch to the ECM. The ECM will remain powered until the connection to the unswitched battery+ line is disconnected. Remove the fuses from the in-line fuse holder to power down the ECM. Do not connect the bypass to the battery terminals or do not remove the bypass from the battery terminals without first removing the in-line fuses.

**E.** Connect the electronic service tool to the diagnostic connector of the bypass harness and verify that communication can be established.

**Note:** Remove the bypass harness and restore all wiring to the original condition after testing.

**Expected Result:**

Installing the bypass eliminates the fault.

**Note:** The status of the "Ignition Keyswitch" will always indicate ON while the bypass harness is installed.

**Results:**

- OK – The symptom disappears when the bypass harness is installed. The symptom returns when the bypass harness is removed. The fault is in the wiring for the application that supplies power to the ECM. Check for aftermarket engine protection switches that interrupt power. Send the application to the OEM dealer to repair. STOP.
- Not OK – The symptom is still present when the bypass harness is installed.

  **Repair:** Connect the bypass to another battery and verify if the fault is resolved. If the fault is resolved, the fault is with the batteries on the application.

  If the fault still exists, perform the following procedure:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
  2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
  4. Use the electronic service tool to recheck the system for active diagnostic codes.
  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.
  6. If the fault returns with the suspect ECM, replace the ECM.
  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

03461205

# Indicator Lamp Circuit - Test

**System Operation Description:**

Use this procedure under the following circumstances:

- The lamps are not receiving battery voltage.
- The lamps are not operating correctly.

Also use this procedure if another procedure has directed you here.

The following diagnostic lamps are available:

- Power Take Off (PTO) lamp
- Stop lamp
- Warning lamp
- Cold start (wait to start lamp)
- Low oil pressure lamp

The electronic service tool can be used as a diagnostic aid in order to switch the individual lamps ON and OFF.

**Note:** The diagnostic function that switches the lamps is contained in the "Override" section in the "Diagnostics" menu of the electronic service tool.

REFERENCE ONLY

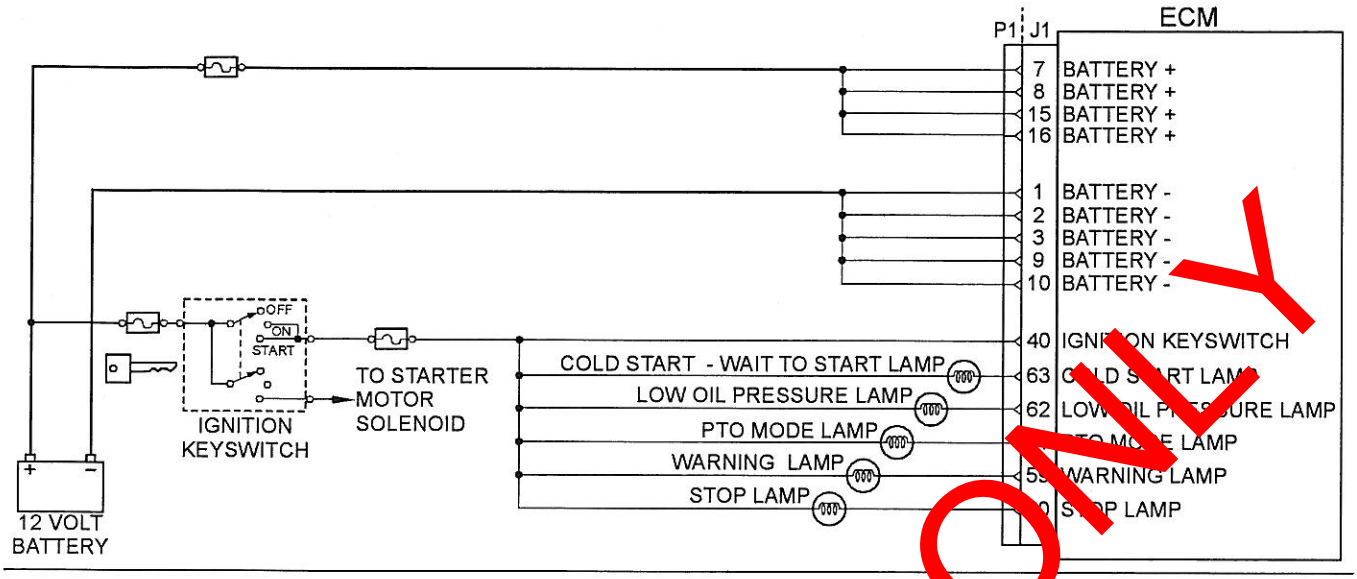



Illustration 74 g01804053

Typical schematic of the indicator lamp circuit

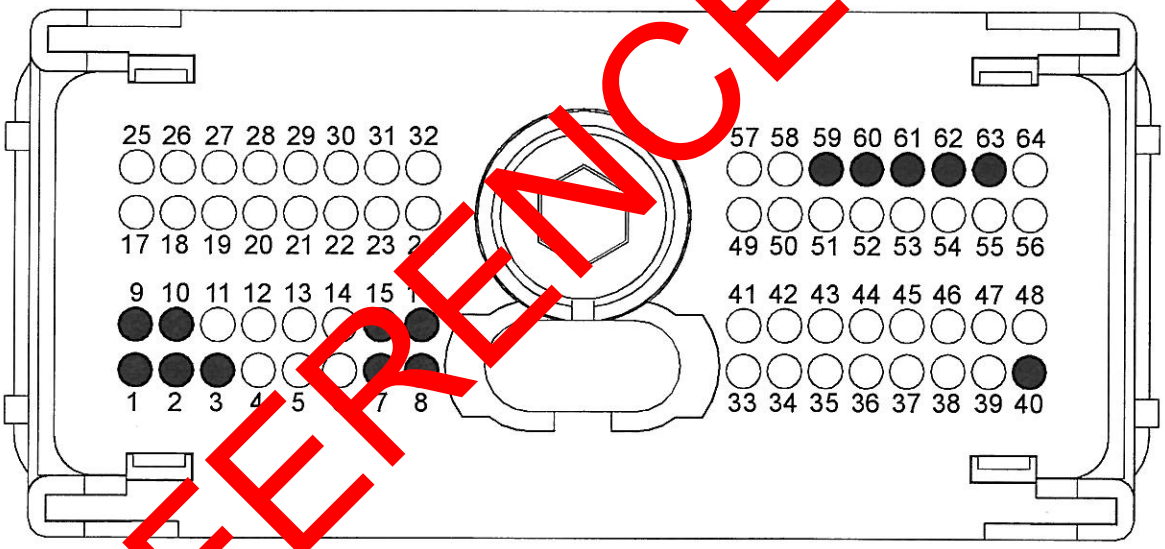



Illustration 75 g01804073

Typical example of the pin locations on the P1 connector

(1) Ground
(2) Ground
(3) Ground
(9) Ground
(10) Ground
(7) Battery+
(8) Battery+
(15) Battery+
(16) Battery+
(40) Keyswitch
(59) Warning lamp
(60) Stop lamp
(61) PTO lamp
(62) Low oil pressure lamp
(63) Cold start lamp

REFERENCE ONLY

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Turn the keyswitch to the OFF position.

**B.** Thoroughly inspect P1 connector and the lamp connections. Refer to Troubleshooting, “Electrical Connectors - Inspect” for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the customer connector and the Electronic Control Module (ECM) connector that is associated with the diagnostic lamp.

**D.** Check the screw for the P1 connector for the correct torque of 5.0 N·m (44 lb in).

**E.** Check the harness for abrasions and for pinch points from the battery to the ECM.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

  **Repair:** Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly installed and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 2. Inspect the Lamp, the Fuse, and the Power Supply

**A.** Disconnect the lamp from the harness. Inspect the lamp in order to determine if the lamp has failed.

**B.** Measure the resistance across the two terminals of the lamp. If the resistance is more than 2000 Ohms, the bulb has failed.

**C.** Check the battery by connecting a test lamp across the terminal of the battery.

**Expected Result:**

The lamp has less than 2000 Ohms and the power supply is OK.

**Results:**

- OK – The lamp appears to be operating correctly at this time. Proceed to Test Step
- Not OK

  **Repair:** Replace the suspect component or repair the suspect component.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

## Test Step 3. Measure the Input to the Lamp at the Lamp Socket

**A.** Turn the keyswitch to the ON position.

**B.** Use the electronic service tool to select the "Override" function in order to switch individual lamps ON and OFF.

**Note:** The "Override" function is contained in the "Diagnostics" menu of the electronic service tool.

**C.** Measure the voltage at the lamp socket.

**Expected Result:**

The voltage should be between 12.0 Volts DC and 24.0 Volts DC.

**Results:**

- OK – The voltage is between 12.0 Volts DC and 24.0 Volts DC.

  **Repair:** Replace the bulb.

  Verify that the repair eliminates the fault.

  If the fault persists, measure the resistance across the 2 terminals of the lamp. If the resistance is more than 2000 Ohms, the replacement bulb has failed. Replace the bulb and repeat the test.

  If the fault persists, proceed to Test Step 4.

- Not OK – The voltage is not in the range that is expected. Proceed to Test Step 5.

## Test Step 4. Test the Individual Lamp Circuits

**A.** Disconnect the P1 connector.

**B.** Temporarily disconnect the wire from the P1 connector socket that supplies the suspect lamp.

**C.** By using a jumper wire, connect the removed wire to the battery-.

**D.** Turn the keyswitch to the ON position and observe the lamp.

**Expected Result:**

The diagnostic lamp turns ON while the jumper is connected. Also, the diagnostic lamp turns OFF when the jumper is removed.

**Results:**

- OK – The circuit for the diagnostic lamp is functioning correctly. Proceed to Test Step 5.
- Not OK – The lamp did not turn ON. The lamp circuit is not functioning correctly. There is a fault in the harness between the lamp and the ECM.

  **Repair:** Repair the lamp circuit.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminated the fault.

  STOP.

REFERENCE ONLY

### Test Step 5. Check the Voltage at the ECM

**A.** Disconnect the P1 connector.

**B.** Temporarily disconnect the wire from the P1 connector that supplies the suspect lamp.

**C.** Fabricate the jumper wire with a suitable pin for the P1 connector.

**D.** Install one end of the jumper wire into the P1 connector that supplies the suspect lamp. Connect a test lamp between the battery+ and the jumper wire.

**E.** Reinstall the P1 connector to the ECM.

**F.** Turn the keyswitch to the ON position. Use the electronic service tool to select the override function in order to switch individual lamps ON and OFF.

**Note:** The "Override" function is contained in the "Diagnostics" menu of the electronic service tool.

**Expected Result:**

The lamp should illuminate.

**Results:**

- OK – The ECM is operating correctly. There is a fault in the wiring or the lamp. Repair the wiring or the lamp, as required. Verify that the repair eliminates the fault.

  STOP.

- Not OK – There is a suspected fault in the ECM.

  **Repair:** Perform the following procedure:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

  2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

  4. If the fault is resolved with the test ECM, reconnect the suspect ECM.

  5. If the fault returns with the suspect ECM, replace the ECM.

  STOP.

i03462462

# Injector Data Incorrect - Test

**System Operation Description:**

**Use this procedure under the following situation:**

Use this procedure for any of the following diagnostic codes:

- 0001-02 Cylinder #1 Injector erratic, intermittent, or incorrect
- 0002-02 Cylinder #2 Injector erratic, intermittent, or incorrect
- 0003-02 Cylinder #3 Injector erratic, intermittent, or incorrect
- 0004-02 Cylinder #4 Injector erratic, intermittent, or incorrect
- 0005-02 Cylinder #5 Injector erratic, intermittent, or incorrect (1106D engine only)
- 0006-02 Cylinder #6 Injector erratic, intermittent, or incorrect (1106D engine only)

**The following background information is related to this procedure:**

The engine has electronic unit injectors that are electronically controlled by the Electronic Control Module (ECM). The ECM sends a 70 Volt pulse to each injector solenoid. The pulse is sent at the correct time and for the correct duration for a given engine load and engine speed. Use this procedure to identify the cause of the diagnostic code. Use this procedure to repair the system.

If an injector is replaced, then the correct injector trim files must be programmed into the ECM. The injector trim files allow each individual injector to be fine tuned for optimum performance. The ECM will generate the following diagnostic code if the injector trim files are not programmed:

- 0268-02 Programmed Parameter Fault erratic, intermittent, or incorrect

Refer to Troubleshooting, "Injector Trim File" for further information.

If the ECM is replaced then the replacement ECM must be correctly programmed. Refer to Troubleshooting, "Replacing the ECM" for further information.

REFERENCE ONLY

Use the electronic service tool in order to perform the "Fuel System Verification Test". The "Fuel System Verification Test" is used to check that the system operates correctly after a repair has been made.

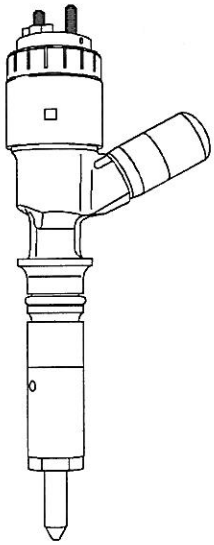


Illustration 76 g01336666

Typical example of the electronic unit injector

## Test Step 1. Check for Diagnostic Codes That Are Related to this Procedure

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Check for logged diagnostic codes that are related to this procedure.

**D.** Make a note of the logged diagnostic codes.

**Expected Result:**

**Expected Result 1**

One or more of the following diagnostic codes are logged:

- 1-2 Cylinder #1 Injector erratic, intermittent, or incorrect
- 2-2 Cylinder #2 Injector erratic, intermittent, or incorrect
- 3-2 Cylinder #3 Injector erratic, intermittent, or incorrect
- 4-2 Cylinder #4 Injector erratic, intermittent, or incorrect
- 5-2 Cylinder #5 Injector erratic, intermittent, or incorrect (1106D engine only)
- 6-2 Cylinder #6 Injector erratic, intermittent, or incorrect (1106D engine only)

**Expected Result 2**

On four cylinder engines, two injectors that share a common supply indicate a diagnostic code.

**Note:** Injectors 1 and 4 share a common injector driver circuit in the ECM. Injectors 2 and 3 share a common driver circuit in the ECM. If two injectors that share a common supply indicate a diagnostic code then this is probably caused by a faulty ECM.

On six cylinder engines, three injectors that share a common supply indicate a diagnostic code.

**Note:** Injectors 1, 2 and 3 share a common injector driver circuit in the ECM. Injectors 4, 5 and 6 share a common driver circuit in the ECM. If three injectors that share a common supply indicate a diagnostic code then this is probably caused by a faulty ECM.

**Results:**

- OK – Result 1 One or more diagnostic codes are logged. Proceed to Test Step 2.
- OK – Result 2 On four cylinder engines, two injectors that share a common supply indicate a diagnostic code. On six cylinder engines, three injectors that share a common supply indicate a diagnostic code. Proceed to Test Step 3.
- Not OK – No related diagnostic codes are logged. STOP.

## Test Step 2. Check the Faulty Cylinder Numbers

**A.** Use the electronic service tool in order to make a note of the logged diagnostic codes.

**B.** Use the noted diagnostic codes in order to check the cylinders for faulty injectors.

**Expected Result:**

The diagnostic codes indicate the cylinder numbers that have faulty injectors.

**Results:**

- OK – No related diagnostic codes are logged. STOP.
- Not OK – The diagnostic codes indicate the cylinder numbers that have faulty injectors.

  **Repair:** Replace the faulty injectors.

REFERENCE ONLY

Use the electronic service tool in order to program the replacement injector trim files . Refer to Troubleshooting, "Injector Trim File" for further information.

Use the electronic service tool in order to clear the logged codes.

Turn the keyswitch to the ON position.

Start the engine.

Use the electronic service tool in order to perform the "Fuel System Verification Test". If the cylinders indicate "PASS", then the fault has been cleared.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

### Test Step 3. Check the ECM

**A.** Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

**B.** Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

**C.** If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

**D.** Use the electronic service tool in order to perform the "Fuel System Verification Test". Verify that the test eliminates the fault.

**Note:** The "Fuel System Verification Test" will indicate if the cylinder has a "Pass" or "Fail". If the cylinders indicate "Pass" then the fault has been cleared.

**E.** If the fault is resolved with the test ECM, reconnect the suspect ECM.

**F.** Use the electronic service tool in order to perform the "Fuel System Verification Test".

**Expected Result:**

The test ECM clears the fault. Using the electronic service tool in order to perform the "Fuel System Verification Test" with the suspect ECM indicates a "FAIL" condition.

**Results:**

- OK

  **Repair:** The test ECM eliminates the fault and the suspect ECM indicates a "FAIL" condition. Perform the following procedure:

  1. Replace the faulty ECM.
  2. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – The test ECM did not eliminate the fault. Carefully repeat this procedure from Test Step 1.

i03462471

## Injector Solenoid Circuit - Test

**System Operation Description:**

Use this procedure to troubleshoot any suspected faults with the injector solenoids.

Use this procedure for the following diagnostic codes:

- 0001-05 Cylinder #1 Injector current below normal
- 0001-06 Cylinder #1 Injector current above normal
- 0002-05 Cylinder #2 Injector current below normal
- 0002-06 Cylinder #2 Injector current above normal
- 0003-05 Cylinder #3 Injector current below normal
- 0003-06 Cylinder #3 Injector current above normal
- 0004-05 Cylinder #4 Injector current below normal
- 0004-06 Cylinder #4 Injector current above normal
- 0005-05 Cylinder #5 Injector current below normal (1106D engine only)
- 0005-06 Cylinder #5 Injector current above normal (1106D engine only)
- 0006-05 Cylinder #6 Injector current below normal (1106D engine only)
- 0006-06 Cylinder #6 Injector current above normal (1106D engine only)

Perform this procedure under conditions that are identical to the conditions that exist when the fault occurs. Typically, faults with the injector solenoid occur when the engine is warmed up and/or when the engine is under vibration (heavy loads).

REFERENCE ONLY

The engine has Electronic Unit Injectors (EUI) that are mechanically actuated and electronically controlled. The Electronic Control Module (ECM) sends a pulse to each injector solenoid. The pulse is sent at the correct time and for the correct duration for a given engine load and speed. The solenoid is mounted on top of the fuel injector body.

If an open circuit is detected in the solenoid, a diagnostic code is generated. The ECM continues to try to fire the injector. If a short circuit is detected, a diagnostic code is generated. The ECM will disable the solenoid circuit. The ECM will periodically try to fire the injector. If the short circuit remains, this sequence of events will be repeated until the fault is corrected.

**"Injector Solenoid Test"**

Use the "Injector Solenoid Test" on the electronic service tool to aid in diagnosing an open circuit or a short circuit diagnostic code while the engine is not running. The "Injector Solenoid Test" will send a signal to each solenoid. The electronic service tool will indicate the status of the solenoid as "OK", "Open", or "Short".

**Note:** On four cylinder engines, the use of a shared supply will mean that a short circuit in the wire that is used as a supply for the injector solenoid will cause two cylinders to have diagnostic codes.

**Note:** On six cylinder engines, the use of a shared supply will mean that a short circuit in the wire that is used as a supply for the injector solenoid will cause three cylinders to have diagnostic codes.

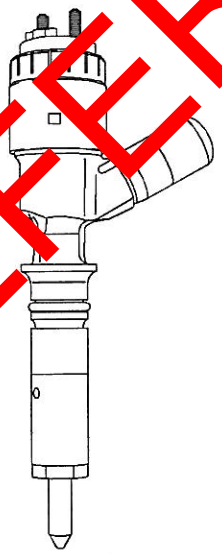


Illustration 77 g01336666
Typical example of the fuel injector

REFERENCE ONLY

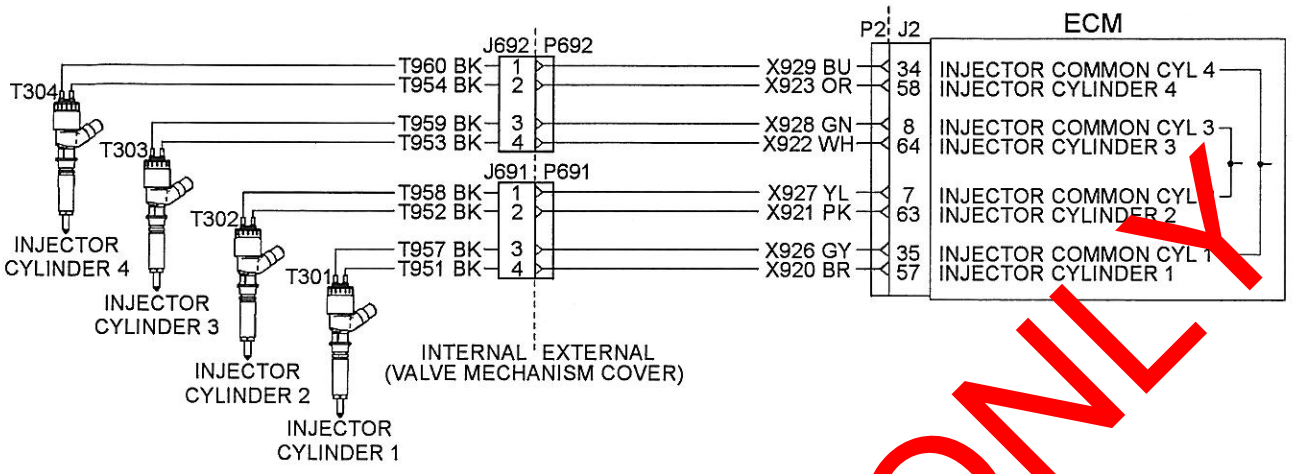



Illustration 78 g01805273

Schematic for the injector solenoid circuit for the 1104D engine

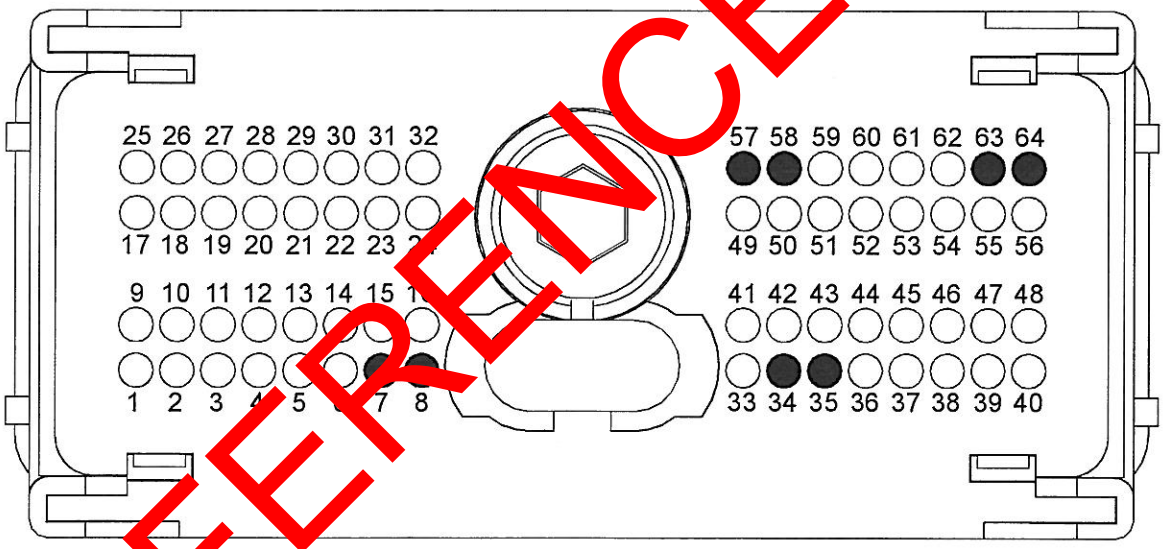
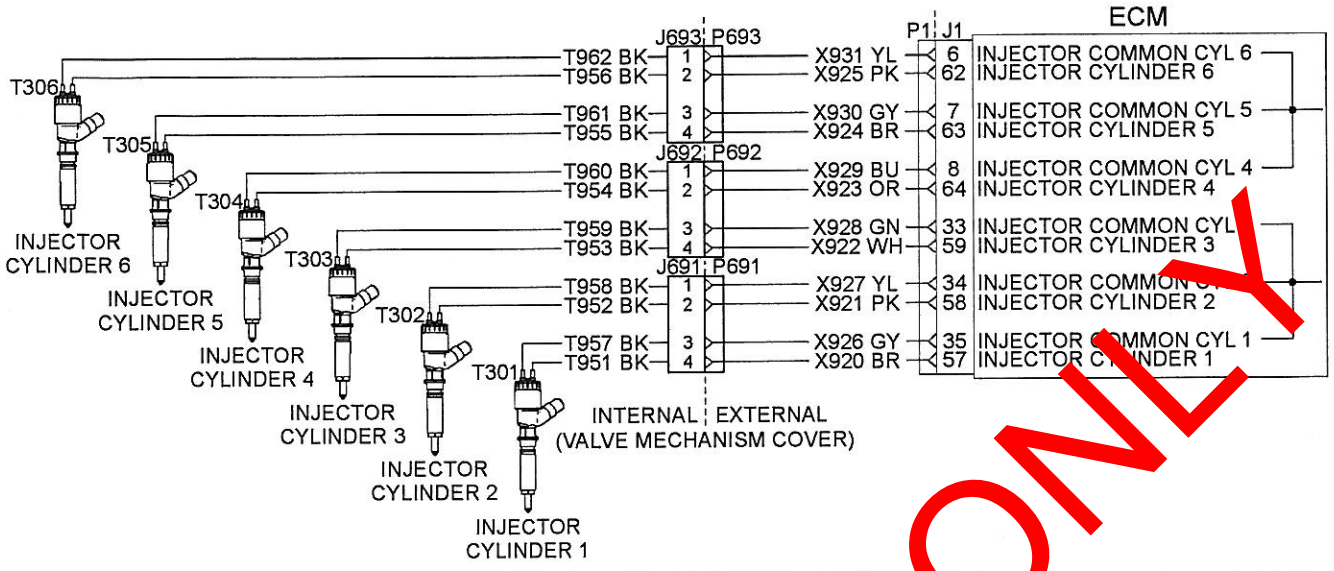



Illustration 79 g01805296

P2 pin connections for the 1104D engine

(57) Injector Cylinder (Number 1)
(35) Injector Cylinder (Number 1 Return)
(63) Injector Cylinder (Number 2)
(7) Injector Cylinder (Number 2 Return)
(64) Injector Cylinder (Number 3)
(8) Injector Cylinder (Number 3 Return)
(58) Injector Cylinder (Number 4)
(34) Injector Cylinder (Number 4 Return)

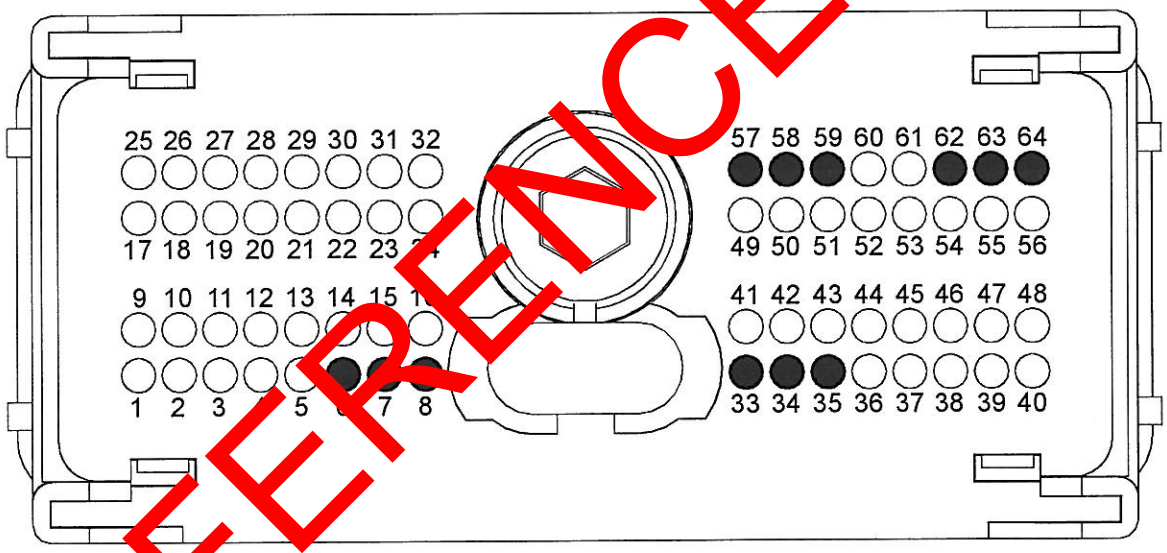
REFERENCE ONLY




g01805313

Illustration 80

Schematic for the injector solenoid circuit for the 1106D engine




g01805334

Illustration 81

P2 pin connections for the 1106D engine

(57) Injector Cylinder (Number 1)
(35) Injector Cylinder (Number 1 Return)
(59) Injector Cylinder (Number 2)
(34) Injector Cylinder (Number 2 Return)
(59) Injector Cylinder (Number 3)
(33) Injector Cylinder (Number 3 Return)
(64) Injector Cylinder (Number 4)
(8) Injector Cylinder (Number 4 Return)
(63) Injector Cylinder (Number 5)
(7) Injector Cylinder (Number 5 Return)
(62) Injector Cylinder (Number 6)
(6) Injector Cylinder (Number 6 Return)

REFERENCE ONLY

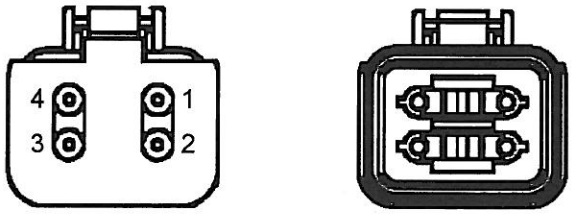



Illustration 82 g01245543

Typical example of the fuel injector harness connector

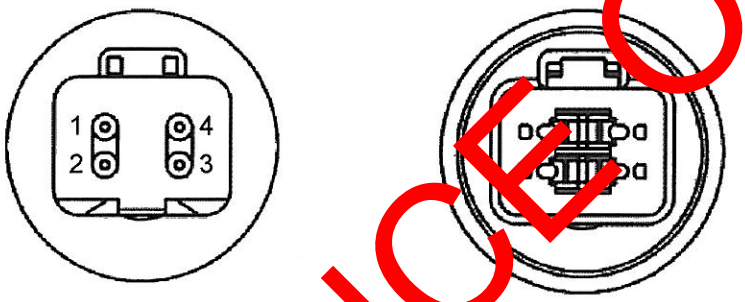



Illustration 83 g01245544

Typical example of the connector on the valve mechanism cover

REFERENCE ONLY

## Test Step 1. Inspect Electrical Connectors and Wiring

**WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-93 volts.**

**A.** Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

**B.** Thoroughly inspect connector P2. Thoroughly inspect the connectors at the valve cover base. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connector that are associated with injector solenoids.

**D.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**E.** Check the harness and wiring for abrasion and for pinch points from the injectors to the ECM.

**Expected Result:**

All connectors, pins, and sockets are completely coupled and/or inserted and the harness is free of corrosion, of abrasion and of pinch points.

**Results:**

- OK – The harness is OK. Proceed to Test Step 2.
- Not OK – There is a fault in the connectors and/or the harness.

  **Repair:** Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly installed and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

### Test Step 2. Check for Logged Diagnostic Codes that are Related to the Injector Solenoids

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Check for logged diagnostic codes that are related to the injector solenoids on the electronic service tool.

**Expected Result:**

One or more diagnostic codes that are related to the injector solenoids have been logged:

- 1-5 Cylinder #1 Injector current below normal
- 1-6 Cylinder #1 Injector current above normal
- 2-5 Cylinder #2 Injector current below normal
- 2-6 Cylinder #2 Injector current above normal
- 3-5 Cylinder #3 Injector current below normal
- 3-6 Cylinder #3 Injector current above normal
- 4-5 Cylinder #4 Injector current below normal
- 4-6 Cylinder #4 Injector current above normal
- 5-5 Cylinder #5 Injector current below normal (1106D engine only)
- 5-6 Cylinder #5 Injector current above normal (1106D engine only)
- 6-5 Cylinder #6 Injector current below normal (1106D engine only)
- 6-6 Cylinder #6 Injector current above normal (1106D engine only)

**Results:**

- OK – One or more diagnostic codes have been logged. Proceed to Test Step 3.
- Not OK – No diagnostic codes have been logged. Proceed to Test Step 4.

### Test Step 3. Use the "Injector Solenoid Test"

**A.** Start the engine.

**B.** Allow the engine to warm up to the normal operating temperature.

**C.** Stop the engine.

**D.** Turn the keyswitch to the ON position.

**E.** Access the "Injector Solenoid Test" by accessing the following display screens in order:

- "Diagnostics"
- "Diagnostic Tests"
- "Injector Solenoid Test"

**F.** Activate the test.

**Note:** Do not confuse the "Injector Solenoid Test" with the "Cylinder Cutout Test". The "Cylinder Cutout Test" is used to shut off fuel to a specific cylinder while the engine is running. The "Injector Solenoid Test" is used to actuate the injector solenoids while the engine is not running. This allows the click of the injector solenoid to be heard while the engine is off in order to determine that the circuit is functioning correctly.

**G.** As each solenoid is energized by the ECM, an audible click can be heard at the valve cover.

**Expected Result:**

All cylinders indicate "OK".

**Results:**

- OK – There is not an electronic fault with the injectors at this time.

  **Repair:** If the "Injector Solenoid Test" returned a "Not OK" for any injector, refer to Troubleshooting, "Engine Misfires, Runs Rough or Is Unstable".

  STOP.

- Open – Note the cylinders that indicate "Open". Proceed to Test Step 5.
- Short – Note the cylinders that indicate "Short". Proceed to Test Step 4.

### Test Step 4. Check the Variation of the Injectors between Cylinders

**A.** Start the engine.

**B.** Allow the engine to warm up to normal operating temperature.

**C.** After the engine is warmed to operating temperature, access the "Cylinder Cutout Test" by accessing the following display screens in order:

- "Diagnostics"
- "Diagnostic Tests"

REFERENCE ONLY

- "Cylinder Cutout Test"

**D.** Select the start button at the bottom of the screen for the cylinder cutout test on the electronic service tool.

**E.** Select the "Cylinder Cutout Test".

**F.** Follow the instructions that are provided in the cylinder cutout test. The cylinder cutout tests are interactive so the procedure is guided to the finish.

**Note:** The "Manual Cylinder Cutout Test" is also available. Access the manual test by selecting the "Change" button on the screen for the cylinder cutout test. The "Cylinder Cutout Test" is the recommended starting procedure. The automated tests run twice collecting data. The two sets of data are analyzed and an "OK" or "Not OK" result is displayed.

**G.** Check for active diagnostic codes and for logged diagnostic codes that are related to the injector solenoids.

**Expected Result:**

All cylinders indicate "OK" on the electronic service tool.

**Results:**

- OK – All cylinders indicate "OK".

  **Repair:** If the engine is misfiring or if the engine has low power, refer to Troubleshooting, "Engine Misfires, Runs Rough or Is Unstable" and Troubleshooting, "Low Power/Poor or No Response to Throttle".

  If a diagnostic code results from running the cylinder cutout test, proceed to Test Step 5.

- Not OK – One or more cylinders displayed "Not OK" during the test. Proceed to Test Step 5.

## Test Step 5. Check the Harness between the ECM and the Valve Cover Base for an Open Circuit

**WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

**A.** Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

**B.** Disconnect the connectors from the valve cover base.

**C.** Turn the keyswitch to the ON position.

**D.** Fabricate a jumper wire 100 mm (4 inch) long with terminals on both ends of the wire.

**E.** Insert one end of the jumper wire into the terminal for the suspect injector's supply. Insert the other end of the jumper wire into the terminal for the suspect injector's return circuit.

**F.** Perform the "Injector Solenoid Test" at least two times.

**G.** Repeat this test for each suspect injector. Stop the "Injector Solenoid Test" before handling the jumper wires.

**Expected Result:**

The electronic service tool displays "Current Above Normal" for the cylinder with the jumper wire.

**Results:**

- OK – The harness between the ECM and the valve cover base is OK. Proceed to Test Step 6.

- Not OK – There is a fault between the ECM and the valve cover base. Proceed to Test Step 7.

## Test Step 6. Check the Injector Harness and the Valve Cover

**WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

**A.** Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

**B.** Remove the valve cover.

**C.** On four cylinder engines, disconnect the harness from the suspect injector. Disconnect the harness from the injector that shares the same supply circuit as the suspect injector.

**Note:** On four cylinder engines, injectors 1 and 4 share a common injector driver circuit in the ECM. Injectors 2 and 3 share a common injector driver circuit in the ECM. If the two injectors that share a common supply indicate "Open Circuit" fault codes, the open circuit is probably caused by a faulty ECM.

**D.** On six cylinder engines, disconnect the harness from the suspect injector. Disconnect the harness from the injectors that share the same supply circuit as the suspect injector.

REFERENCE ONLY

**Note:** On six cylinder engines, injectors 1, 2, and 3 share a common injector driver circuit in the ECM. Injectors 4, 5, and 6 share a common injector driver circuit in the ECM. If the three injectors that share a common supply indicate "Open Circuit" fault codes, the open circuit is probably caused by a faulty ECM.

**E.** Thoroughly clean the terminals on the injectors and on the harness connectors.

**F.** Exchange the harness between two of the injectors that share the common driver.

**G.** Turn the keyswitch to the ON position.

**H.** Perform the "Injector Solenoid Test" at least two times.

**Expected Result:**

Exchanging the harness between the two injectors caused the fault to move to the other injector.

**Results:**

- OK – There is a fault with the injector harness under the valve cover.

  **Repair:** Repair the injector harness or replace the injector harness under the valve cover.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – The injector may be faulty.

  **Repair:** Replace the faulty injector. Refer to Disassembly and Assembly, "Electronic Unit Injectors - Remove" and "Disassembly and Assembly, "Electronic Unit Injectors - Install".

  Restore the wiring to the correct injectors.

  Perform the "Injector Solenoid Test".

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 7. Check the ECM for an Open Circuit

**⚠ WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

**A.** Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

**B.** Disconnect connector P2 from the ECM.

**C.** Remove the supply wire and the return wire for the suspect injector from connector P2. Install a jumper wire into connector P2 in order to provide a short between the supply and the return of the suspect injector.

**D.** Reinstall connector P2 to the ECM.

**E.** Turn the keyswitch to the ON position.

**F.** Perform the "Injector Solenoid Test" at least two times.

**Expected Result:**

The electronic service tool displays "Current Above Normal" for the cylinder with the jumper wire.

**Note:** On four cylinder engines, shorting a shared supply will affect the status of two injectors. Ignore the status of the other injector that is on the shared supply.

**Note:** On six cylinder engines, shorting a shared supply will affect the status of three injectors. Ignore the status of the other injectors that are on the shared supply.

**Results:**

- OK – The ECM is OK.

  **Repair:** On four cylinder engines, if the two injectors that share a supply indicate "Open Circuit" fault codes, the open circuit is probably caused by a faulty ECM.

  On six cylinder engines, if the three injectors that share a supply indicate "Open Circuit" fault codes, the open circuit is probably caused by a faulty ECM.

  Repair the engine harness or replace the engine harness, as required.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – There may be a fault with the ECM.

  **Repair:** Perform the following procedure:

REFERENCE ONLY

1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
2. Remove the jumper wire from connector P2 and reinstall the injector wires.
3. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

4. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
5. Perform the "Injector Solenoid Test".
6. If the fault is resolved with the test ECM, reconnect the suspect ECM.
7. If the fault returns with the suspect ECM, replace the ECM.
8. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 8. Check the Harness between the ECM and the Valve Cover Base for a Short Circuit

**⚠ WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

A. Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

B. Disconnect the connectors from the valve cover base.

C. Turn the keyswitch to the ON position.

D. Perform the "Injector Solenoid Test" at least two times.

**Expected Result:**

All cylinders indicate "Current Below Normal".

**Results:**

- OK – All cylinders indicate "Current Below Normal". Proceed to Test Step 10.
- Not OK – One or more cylinders indicate "Current Above Normal". Note the cylinders that indicate "Current Above Normal". Proceed to Test Step 9.

## Test Step 9. Check the ECM for a Short Circuit

**⚠ WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

A. Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

B. Disconnect connector P1 from the ECM and check for evidence of moisture entry.

C. Turn the keyswitch to the ON position.

D. Perform the "Injector Solenoid Test" at least two times.

**Expected Result:**

All cylinders indicate "Current Below Normal" when connector P2 is disconnected from the ECM.

**Note:** When the engine harness is disconnected, all of the diagnostic codes for supply voltage to the sensors will be active. This is normal. Clear all of the logged diagnostic codes after completing this test step.

**Results:**

- OK – The short circuit is in the engine harness.

  **Repair:** The fault is most likely in one of the wires to the injector. Inspect the connectors for moisture and for corrosion. Also, check the wire insulation for damage and for strands that are exposed.

  Repair the engine harness or replace the engine harness, as required. Clear all diagnostic codes after completing this test step.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – There may be a fault with the ECM.

  **Repair:** Perform the following procedure:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

REFERENCE ONLY

2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
4. Perform the "Injector Solenoid Test".
5. If the fault is resolved with the test ECM, reconnect the suspect ECM.
6. If the fault returns with the suspect ECM, replace the ECM.
7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 10. Check the Engine Harness Under the Valve Cover for a Short Circuit

**⚠ WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

**A.** Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

**B.** Remove the valve cover.

**C.** Disconnect each of the injectors that indicate a "Short" from the wiring harness. Ensure that each of the connectors from the disconnected injector harness does not touch any other components.

**D.** Turn the keyswitch to the ON position.

**E.** Perform the "Injector Solenoid Test" at least two times.

**Expected Result:**

All of the injectors that were disconnected indicate "Current Below Normal".

**Results:**

- OK – All of the injectors that were disconnected indicate "Current Below Normal".

  **Repair:** Leave the injector wires disconnected. The supply wire is not shorted to the engine.

  Proceed to Test Step 11.

- Not OK – One or more of the injectors that were disconnected indicate "Current Above Normal".

  **Repair:** The fault is most likely in the supply to the injector. Inspect the connectors for moisture and for corrosion. Also, check the supply wire's insulation for damage and for strands that are exposed.

  Repair the injector harness or replace the injector harness under the valve cover.

  Use the electronic service tool to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

## Test Step 11. Check for a Short Circuit in the Return Wire

**⚠ WARNING**

**Electrical shock hazard. The electronic unit injector system uses 67-73 volts.**

**A.** Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

**B.** Disconnect the connector P2 from the ECM.

**C.** Locate the terminal for the supply of the faulty injector in the connector P2. Measure the resistance from the terminal to the engine ground stud.

**Expected Result:**

The resistance is greater than 10 Ohms.

**Results:**

- OK – The resistance is greater than 10 Ohms.

  **Repair:** Reconnect connector P2.

  Replace the faulty injector.

  Perform the "Injector Solenoid Test".

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – There is a short in the return line.

  **Repair:** Disconnect the connectors from the valve cover base.

REFERENCE ONLY

Measure the resistance of the return wire between connector P2 and the engine ground stud.

If the resistance is less than 10 Ohms, the fault is in the return wire between the ECM and the valve cover base.

If the resistance is greater than 10 Ohms, the fault is in the return wire under the valve cover.

Repair the injector harness or replace the injector harness.

Use the electronic service tool to clear all logged diagnostic codes and then perform the "Injector Solenoid Test" in order to verify that the repair eliminates the fault.

STOP.

i03462542

# Mode Selection Circuit - Test

**System Operation Description:**

Use this procedure under the following circumstances:

- Diagnostic code 1743-02 has been generated.
- Check if the mode switch operates correctly.

The mode switch inputs provide the operator with the ability to select a maximum of four different modes of operation. Different modes of operation can be used in a particular situation by giving the operator a means to select the most efficient method of completing the required work.

Each mode has a single fuel limit map, a rated speed, and a matched fuel delivery. Each mode also has a specific droop value for throttle 1 and throttle 2.

For 1104D engines, refer to table 58 for a list of examples of different modes of operation.

For 1106D engines, refer to table 59 for a list of examples of different modes of operation. Refer to table 60 for a list of mode switch connections.

REFERENCE ONLY

Table 58

| Switch 2 | Switch 1 | Mode Number | 1104D Engine Rating | Droop (%)(1) | | |
|---|---|---|---|---|---|---|
| | | | | Throttle 1 | Throttle 2 | Torque Speed Control |
| Open | Open | 1 | 80 KW @ 2200 RPM | 10 | 10 | 10 |
| Open | Closed | 2 | 80 KW @ 2200 RPM | 5 | 2 | 0 |
| Closed | Open | 3 | 100 KW @2200 RPM | 10 | 10 | 10 |
| Closed | Closed | 4 | 100 KW @ 2200 RPM | 5 | 5 | |

(1) Throttle droop can be configured in 1% increments.

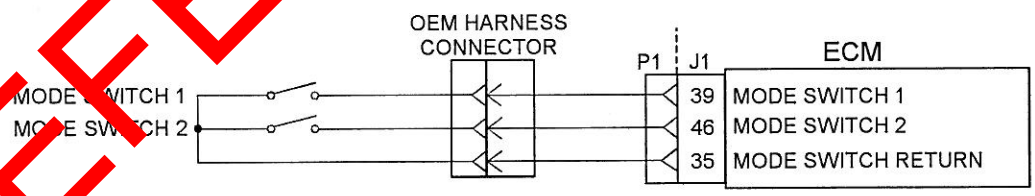
Table 59

| Switch 2 | Switch 1 | Mode Number | 1106D Engine Rating | Droop (%)(1) | | |
|---|---|---|---|---|---|---|
| | | | | Throttle 1 | Throttle 2 | Torque Speed Control |
| Open | Open | 1 | 100 KW @ 2200 RPM | 10 | 10 | 10 |
| Open | Closed | 2 | 100 KW @ 2200 RPM | | 2 | 0 |
| Closed | Open | 3 | 120 KW @2200 RPM | 10 | 10 | 10 |
| Closed | Closed | 4 | 120 KW @ 2200 RPM | 5 | 5 | 0 |

(1) Throttle droop can be configured in 1% increments.

Table 60

| Function | P1 Connector Pin Assignment |
|---|---|
| Mode Switch 1 | 39 |
| Mode Switch 2 | 46 |
| Switch return (Ground) | |




g01805358

Illustration 84

Typical schematic for the mode switches

REFERENCE ONLY

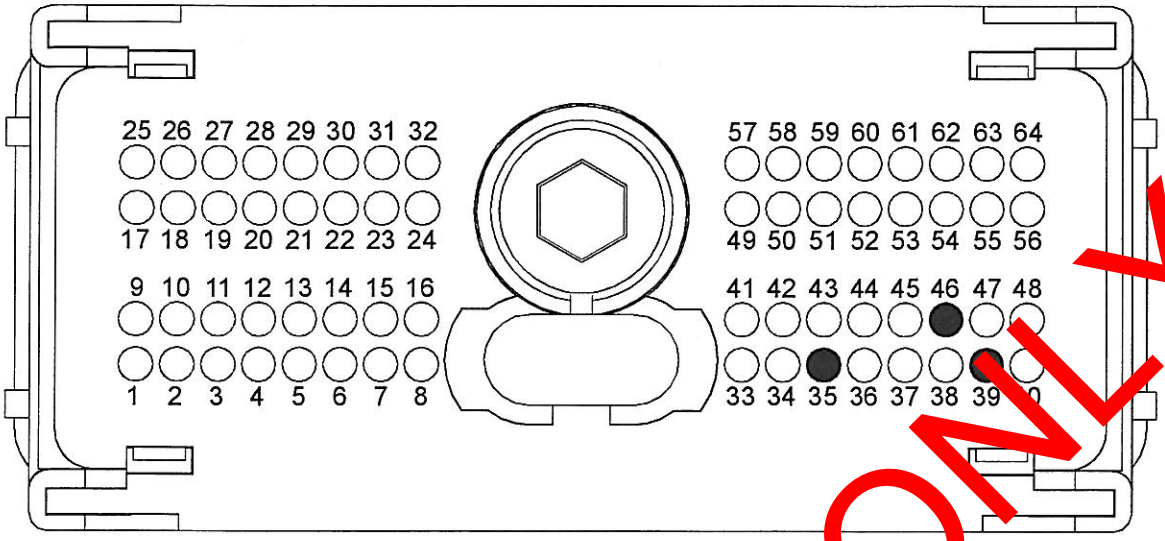



Illustration 85 g01805359

Typical view of the pin locations for the P1 connector

(35) Mode switch return (GND) (39) Mode switch 1 (46) Mode switch 2

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Turn the keyswitch OFF.

**B.** Thoroughly inspect the P1 connector. Thoroughly inspect the connectors for the mode switch, plugs and interconnections on the harness. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the P1 connector that are associated with the mode switch.

**D.** Check the screw for the Electronic Control Module (ECM) connector for the correct torque of 5.0 N·m (44 lb in).

**E.** Check the harness for abrasions and for pinch points from the battery to the ECM.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

**Repair:** Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are completely coupled.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

- – If the fault has not been eliminated proceed to Test Step 2.

## Test Step 2. Check the Status of the Mode Switch

**A.** Turn the keyswitch to the OFF position.

**B.** Connect the electronic service tool to the diagnostic connector.

**C.** Turn the keyswitch to the ON position.

**D.** Monitor the status screen on the electronic service tool. Cycle the mode switches to the ON position and to the OFF position.

**Expected Result:**

The switch status should change as you cycle the mode switches. When the switch is in the OFF position the switch has an open condition. When the switch is in the ON position the switch has a closed condition.

**Results:**

- OK

REFERENCE ONLY

**Repair:** Verify that the status of the switch changes as the switch is cycled.

STOP.

- Not OK – There is a fault with the circuit for the mode switch. Proceed to Test Step 3.

## Test Step 3. Insert a Jumper at the Suspect Mode Switch

**A.** Turn the keyswitch to the OFF position.

**B.** Perform the following procedure to test the circuit of mode switch No. 1. Place a jumper wire across the contacts of switch No. 1.

**C.** Perform the following procedure to test the circuit of mode switch No. 2. Place a jumper wire across the contacts of switch No. 2.

**D.** Turn the keyswitch to the ON position. Monitor the status screen on the electronic service tool. Connect the jumper wire. Monitor the electronic service tool status screen. Disconnect the jumper wire. Monitor the electronic service tool status screen.

**Expected Result:**

When the jumper wire is connected the switch should be in the CLOSED position.

**Results:**

- OK

  **Repair:** Verify that the jumper wire has been removed. The suspect mode switch is faulty. Replace the switch. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

- Not OK – Proceed to Test Step 4.

## Test Step 4. Measure the Resistance of the Wiring Harness at the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P1 connector.

**C.** Measure the resistance between P1:35 switch return and the following ECM pins:

- P1:46 Mode Switch No. 2
- P1:39 Mode Switch No. 1

**D.** Cycle each mode switch to the OFF position and to the ON position.

**Expected Result:**

The resistance is less than 10 Ohms in the mode switch ON position.

The resistance is more than 4000 Ohms in the mode switch OFF position.

**Results:**

- OK – There is no faults in the harness. Proceed to Test Step 5.
- Not OK – The fault is in the harness between the sensor connector and the P1 connector.

  **Repair:** Repair the connector or replace the connector. Use the electronic service tool to clear all diagnostic codes and then verify that the repair has eliminated the fault.

  Proceed to Test Step 5 if the fault has not been eliminated.

## Test Step 5. Test the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Temporarily disconnect the P1 connector from the ECM. Remove the pins 35, 39 and 46 from the P1 connector.

**C.** Reconnect the P1 connector.

**D.** Turn the keyswitch to the ON position. Monitor the status screen of the electronic service tool.

**E.** Disconnect the P1 connector from J1.

**F.** Insert a jumper wire between the suspect switch socket and P1:35.

**G.** Turn the keyswitch to the ON position. Monitor the status screen of the electronic service tool.

**Expected Result:**

When the connections are removed from the P1 connector, the indication for the mode switch on the electronic service tool will be in the OFF position. The switch will indicate an open condition.

When the jumper is connected to the P1 connector, the indication for the mode switch on the electronic service tool will be in the ON position. The switch will indicate a closed condition.

**Results:**

- OK – The ECM is operating correctly. STOP.
- Not OK – The ECM is not operating correctly.

REFERENCE ONLY

**Repair:** Perform the following procedure:

1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
2. Remove all jumpers and replace all connectors.
3. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

4. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
5. Use the electronic service tool to recheck the system for active diagnostic codes.
6. If the fault is resolved with the test ECM, reconnect the suspect ECM.
7. If the fault returns with the suspect ECM, replace the ECM.
8. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

i03460580

## PTO Switch Circuit - Test

**System Operation Description:**

Use this procedure under the following circumstances:

- Verify that the PTO switches receive the correct supply voltage.
- Check that the PTO switches operate correctly.

**Note:** Some applications may only have one PTO switch.

Also, use this procedure if another procedure has directed you here.

The PTO switches provide the operator with the ability to select the desired engine speed. Engine speed will decrease with increasing load. The PTO switches can be used to control the engine speed.

The engine has the following options of set speed control:

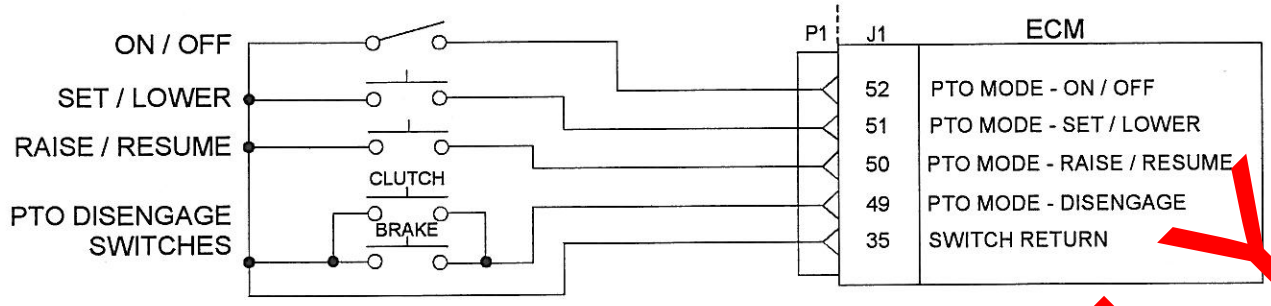
- Single speed
- No speed (no PTO control)

The PTO switches are listed below:

- P1:52 PTO Control ON or P1
- P1:50 PTO Raise/Resume
- P1:51 PTO Set or Lower
- P1:49 (Clutch or Brake) PTO Disengage Switches

An indicator lamp is used to indicate the status of the PTO.

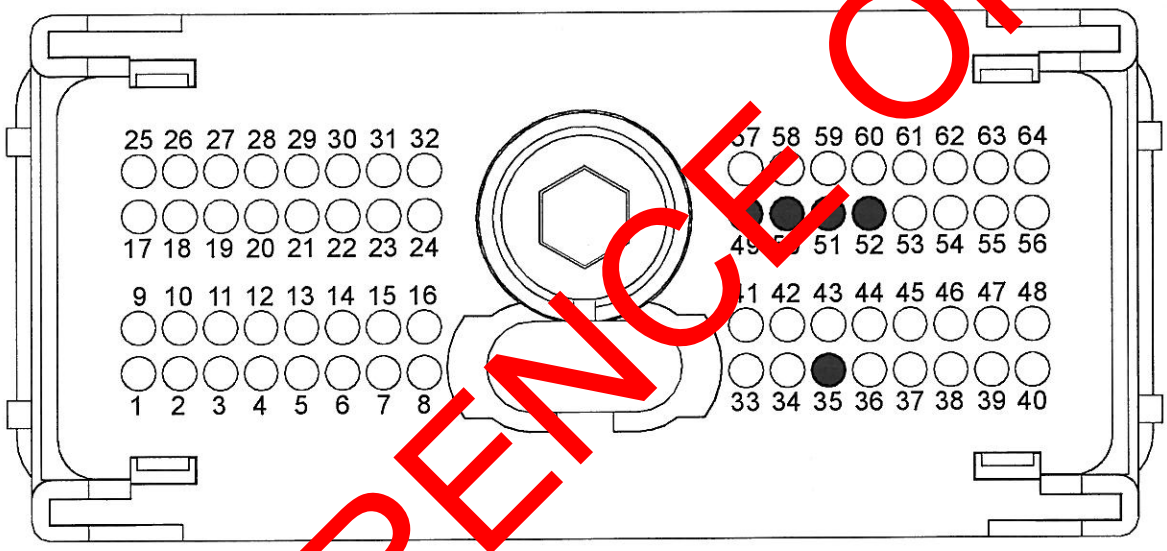
REFERENCE ONLY




g01805393

Illustration 86

Schematic for the PTO switches




g01805477

Illustration 87

Typical view of the pin locations on the P1 connector for the PTO switch

(35) Switch Ground (GND)
(49) PTO mode - disengage
(50) PTO mode - raise/resume
(51) PTO mode - set/lower
(52) PTO mode - ON/OFF

REFERENCE ONLY

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Turn the key switch to the OFF position.

**B.** Thoroughly inspect the J1/P1 connector on the Electronic Control Module (ECM), the switch connections and battery connections. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the sensor connector and the ECM connector that are associated with the active diagnostic code. Refer to illustration 87.

**D.** Verify that the latch tab of the connector is correctly latched. Also verify that the latch tab of the connector has returned to the fully latching position.

**E.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**F.** Check the harness for corrosion, abrasion, and pinch points from the throttle switch to the ECM.

**Expected Result:**

All connectors, pins and sockets should be completely inserted and coupled. The harness should be free of corrosion, abrasion and pinch points.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

  **Repair:** Repair the circuit.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 2. Check the "PTO Mode Switches" on the Electronic Service Tool

**A.** Turn the keyswitch to the OFF position.

**B.** Connect the electronic service tool to the diagnostic connector.

**C.** Turn the keyswitch to the ON position.

**D.** Observe the status of the PTO mode switch on the electronic service tool while you operate the "PTO ON/OFF switch" from the ON position to the OFF position.

**E.** Use the electronic service tool in order to observe the status of the PTO mode switch while you operate the "PTO Set/Lower switch" from the OFF position to the ON position.

**F.** Use the electronic service tool in order to observe the status of the PTO mode switch while you operate the "PTO Raise/Resume switch" from the OFF position to the ON position.

**Expected Result:**

**Result 1** The electronic service tool shows that the "PTO mode ON/OFF switch" is in the OPEN condition when the control switch is OFF.

The electronic service tool shows that the "PTO mode ON/OFF switch" is in the CLOSED condition when the control switch is ON.

**Note:** The PTO mode lamp is OFF when the switch is in the OFF position. The lamp is flashing when the switch is in the ON position.

**Result 2** When the "PTO mode Set/Lower switch" is in the OFF position, the switch is in the OPEN position.

When the "PTO mode Set/Lower switch" is in the ON position, the "PTO mode Set/Lower switch" is in the CLOSED position.

**Result 3** When the "PTO mode Raise/Resume switch" is in the OFF position, the display screen shows an OPEN condition.

When the "PTO mode Raise/Resume switch" is in the ON position, the display screen shows a CLOSED condition.

**Note:** The "PTO mode lamp" flashes when the "PTO mode" is switched ON. The PTO mode lamp changes from flashing to ON when the PTO mode Set/Lower switch is CLOSED. The PTO mode lamp changes from flashing to ON when the PTO mode Raise/Resume switch is CLOSED.

**Results:**

- OK – The PTO mode switches operate correctly. STOP.
- Not OK – Proceed to Test Step 3.

## Test Step 3. Check the Status of the PTO Mode Disengage Switches

**A.** Use the electronic service tool in order to observe the switch status while the PTO mode disengage switches are operated OFF and ON.

**Note:** The PTO mode disengage switches usually function by the operation of the brake, clutch or the operator switch. These switches must be operated separately for this test.

**Expected Result:**

When the PTO mode is switched ON, the electronic service tool shows that the "PTO mode disengage switches" are in the "ENGAGED" position. If the "PTO mode disengage switches" are activated, the electronic service tool shows the status of the "PTO mode disengage switches". If the "PTO mode disengage switches" are activated, the electronic service tool shows that the "PTO mode disengage switches" are in the "DISENGAGED" position.

**Results:**

- OK – The "PTO mode disengage switches" operate correctly. STOP.
- Not OK – Proceed to Test Step 4.

## Test Step 4. Check the Suspect PTO Switch

**A.** Turn the keyswitch to the OFF position.

**B.** Remove the two wires from the suspect switch. Use a suitable jumper in order to join the two wires together.

**C.** Turn the keyswitch to the ON position.

**D.** Monitor the status screen on the electronic service tool while the jumper wire is being disconnected and reconnected.

REFERENCE ONLY

**Expected Result:**

When the jumper wire is connected, the status of the PTO mode switches is "CLOSED".

When the jumper wire is disconnected, the status of the PTO mode switches is "OPEN".

**Results:**

- OK – The switch is faulty.

  **Repair:** Replace the switch. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

- Not OK – There is a fault with the harness between the PTO mode switches and the engine ECM. Proceed to Test Step 5.

## Test Step 5. Measure the Resistance of the Cables at the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Connect the cables to the suspect switch.

**C.** Disconnect the P1 connector from the ECM.

**D.** Measure the resistance between P1:35 and the appropriate pin on the P1 connector for the suspect switch. Refer to illustration 87.

**E.** Repeat the procedure for each of the PTO mode switches.

**Expected Result:**

The measured resistance should be less than 10 Ohms with the switch ON.

The measured resistance should be more than 20,000 Ohms with the switch OFF.

**Results:**

- OK – Proceed to Test Step 6.

- Not OK – There is a fault with the wires between the suspect switch and the P1 connector.

  **Repair:** Repair the wires or replace the wires.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

## Test Step 6. Test the Engine ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P1 connector from the ECM.

**C.** Use a suitable pin removal tool to temporarily remove the wires from the suspect switch socket. Use a suitable pin removal tool to temporarily remove the wire from P1:35.

**D.** Insert a jumper wire between the suspect switch socket and P1:35.

**E.** Turn the keyswitch to the ON position.

**F.** Monitor the status screen of the electronic service tool while the jumper wire is being disconnected and reconnected.

**Expected Result:**

The status screen displays an OPEN condition with the switch in the OFF position.

The status screen displays a CLOSED condition with the switch in the ON position.

**Results:**

- OK – The ECM is working correctly. STOP.

- Not OK – The ECM is not working correctly.

  **Repair:** Perform the following procedure:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

  2. Contact the Technical Help Desk.

  **Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

  4. Use the electronic service tool to recheck the system for active diagnostic codes.

  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

  6. If the fault returns with the suspect ECM, replace the ECM.

  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

REFERENCE ONLY

i03463054

# Starting Aid (Glow Plug) Relay Circuit - Test

**System Operation Description:**

Use this procedure if another test procedure has directed you here.

Use this procedure for the following diagnostic codes:

- 2246-06 Glow Plug Start Aid Relay Current above normal

**The following background information is related to this procedure:**

The starting aid is used to improve the engine starting when the engine is cold. With the keyswitch in the ON position, the engine Electronic Control Module (ECM) will monitor the coolant temperature and the intake manifold air temperature in order to determine if the glow plugs are required to be switched ON. If the glow plugs are required, then the ECM activates the starting aid relay for a controlled period of time. While the glow plug start aid relay is energized the glow plug start aid relay will switch power to the glow plugs. If a "Wait To Start" lamp is installed, the la will be illuminated in order to indicate the "Wait To Start" period.

**"Wait to Start/Start Aid Active Lamp"**

This feature may be included as a optio.

On a cold start, when the EC dete ines that it is necessary for the glo plugs to be ctivated prior to starting, a lamp ou ut will indicate that the operator needs to "W t to St t". It is possible that starting aids may b used durin the cranking of the engine. Starting aids may be used if the engine has previously bee started. The "Wait to Start" lamp will not be activ in th se co itions.

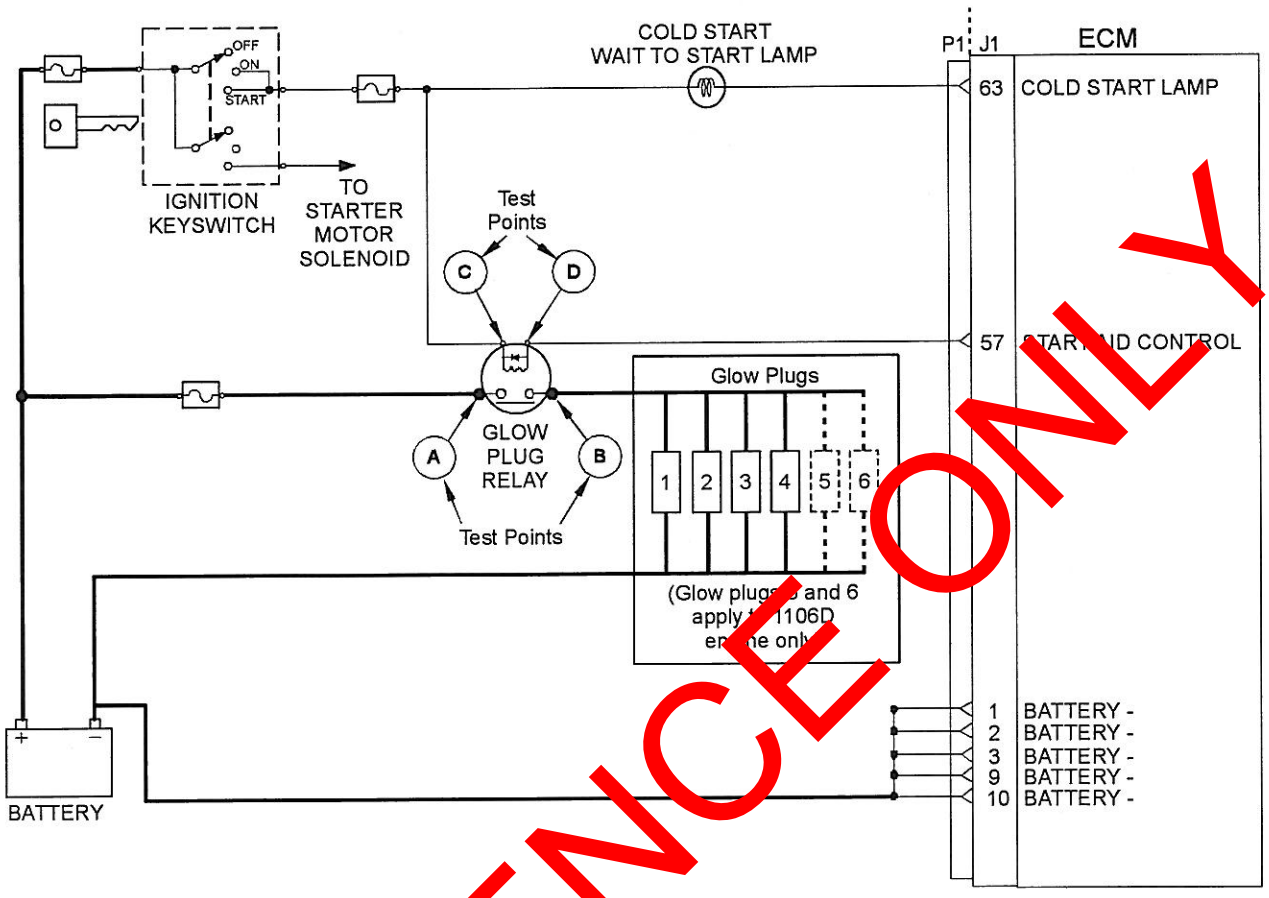
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Th elec service tool includes the test "Glow Plug art Aid Override Test". The "Glow Plug Start Aid Ove ide Test" will assist the analysis of the cold starting aid.

**Overview of the Glow Plug Start Aid Override Test**

This glow plug start aid override test switches on the cold starting aid when the engine is not running. The glow plug start aid override test aids the analysis of the circuit for the glow plug start aid relay.

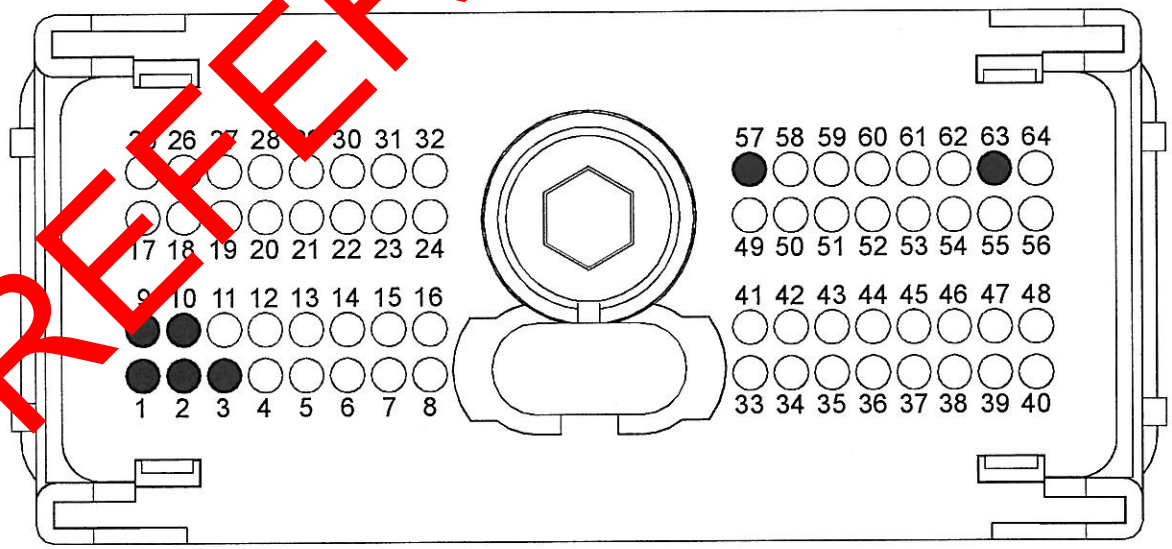
REFERENCE ONLY




g01805814

Illustration 88

Typical schematic for the starting aid switch




g01805855

Illustration 89

Typical view of the pin locations on the P1 connector

(1) Ground (GND)
(2) Ground (GND)
(3) Ground (GND)
(9) Ground (GND)
(10) Ground (GND)
(57) Start aid control
(63) Cold start lamp

REFERENCE ONLY

### Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Inspect the following connectors:

- P1 connector
- P2 connector

**B.** Inspect the terminal connections on the glow plug start aid relay. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the ECM connector that are associated with the glow plug starting aid.

**D.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**E.** Check the harness for abrasion and pinch points from the glow plugs back to the ECM.

**F.** Check that the fuses are not blown.

**Expected Result:**

All connectors, pins and sockets are correctly coupled and/or inserted. The harness is free of corrosion, abrasion and pinch points. The fuses are not blown.

**Results:**

- OK – The harness and the connectors appear to be OK. Proceed to Test Step 2.
- Not OK – There is a fault with the harness and/or connectors.

  **Repair:** Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly installed and ensure that the connectors are completely coupled. Replace blown fuses.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

  STOP.

### Test Step 2. Check for Active Diagnostic Codes

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position. Do not start the engine.

**C.** Use the electronic service tool to select the "Glow Plug Override Test" in order to turn on the power for the glow plugs.

**D.** Check for active diagnostic codes or recently logged diagnostic codes.

**Expected Result:**

The following diagnostic code is active or recently logged:

- 2246-06 Glow Plug Start Aid Relay Current above normal

**Results:**

- OK – The expected diagnostic code is active or recently logged. Proceed to Test Step 3.
- Not OK – An active diagnostic code or a recently logged diagnostic code was not displayed.

  **Repair:** Perform one of the following procedures:

  - If an intermittent fault is suspected, use the electronic service tool to perform a "Wiggle Test" in order to locate intermittent connections.

    If there is a fault on the glow plug or a fault on the starting aid and a diagnostic code is not displayed, there may be a fault with the glow plug switched power circuit or there may be an open circuit in the relay coil circuit. The ECM does not monitor the status of these items. Refer to Testing and Adjusting, "Glow Plugs - Test".

  STOP.

### Test Step 3. Check the Wiring for a Short Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Remove the P1 connector from the ECM.

**C.** Check the connector, pins and the sockets for corrosion or damage.

**D.** Check the resistance between P1:57 and each of the pins on the P1 connector.

**Expected Result:**

The resistance between P1:57 and each of the pins on the P1 connector is more than 10,000 Ohms.

**Results:**

- OK – The harness connects the ECM to the glow plug start aid relay and there are no shorts to other circuits. The ECM or the glow plug start aid relay is suspect. Proceed to Test Step 4.
- Not OK – The harness is faulty.

REFERENCE ONLY

**Repair:** If the resistance between P1:57 and each of the other pins on the P1 connector is less than 10,000 Ohms then there is a short circuit or high resistance in the connection to another wire. Locate the open circuit, the short circuit or high resistance in the connection in the harness. Repair the connectors or the harness and/or replace the connectors or the harness. Ensure that all of the seals are correctly in place and ensure that the connectors are correctly coupled. Replace any fuses that may be open circuit.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair has eliminated the fault.

If the fault still exists, proceed to Test Step 4.

### Test Step 4. Bypass the ECM In Order to Check the Operation of the Glow Plug Start Aid Relay

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the connection from test point "D" on the glow plug start aid relay.

**C.** Connect a jumper wire between the battery ground and terminal "D" on the glow plug start aid relay.

**D.** Measure the voltage from the battery ground and terminal "B" on the glow plug start aid relay.

**E.** Connect a multimeter between terminal "B" on the glow plug start aid relay and the battery ground.

**F.** Turn the keyswitch to the ON position.

**Note:** The engine has not been started at this Test Step.

**G.** Use the electronic service tool in order to operate the glow plugs.

**H.** Measure the voltage from the battery ground and terminal "B" on the glow plug start aid relay.

**Expected Result:**

The keyswitch is in the OFF position. The voltage should be 0 Volts DC.

The keyswitch is in the ON position. The measured voltage for the 12 Volt systems is a constant 10.5 to 13.5 Volts DC. The measured voltage for the 24 Volt systems is a constant 21.0 to 27.0 Volts DC.

**Results:**

- OK – The glow plug start aid relay is operating correctly. Reconnect the connection to test point "D" on the glow plug start aid relay. Proceed to Test Step 5.
- Not OK – The glow plug start aid relay is faulty.

  **Repair:** Replace the glow plug start aid relay. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  If the fault still exists, proceed to Test step 5.

### Test Step 5. Check the ECM

**A.** Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

**B.** Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

**C.** If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

**D.** Use the electronic service tool in order to perform the "Glow Plug Override Test".

**E.** If the fault is resolved with the test ECM, reconnect the suspect ECM.

**Expected Result:**

The replacement ECM functions correctly. Performing the "Glow Plug Override Test" energizes the glow plugs. The fault returns with the suspect ECM.

**Results:**

- OK – The replacement ECM functions correctly.

  **Repair:** Install the replacement ECM. Refer to Troubleshooting, "Replacing the ECM".

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03464364

## Throttle Switch Circuit - Test

**System Operation Description:**

Use this procedure to troubleshoot the system under the following conditions:

- Use this procedure if another procedure has directed you here.

REFERENCE ONLY

- There is an active diagnostic code or a recently logged diagnostic code that is related to the following:
- 0091-02 Throttle Position Sensor erratic, intermittent, or incorrect
- 0774-02 Secondary Throttle Position Sensor erratic, intermittent, or incorrect

Check that the software configuration on the Electronic Control Module (ECM) is correct for a multi-position throttle.

If the engine has an analog throttle with an Idle Validation Switch (IVS), then refer to Troubleshooting, "Idle Validation Switch Circuit - Test".

The throttle switch provides the operator with the ability to select the desired engine speed. The throttle switch configuration may be selected between 0 to 4 switches. A multi-position rotary switch may be used.

The throttle switch is typically connected to the four throttle inputs of the ECM. Each position generates a specific ON/OFF pattern on the throttle inputs. A diagnostic code is generated if a pattern that does not correspond with any of the switch positions is detected.

Once a diagnostic code is generated, the ECM ignores the throttle input signals. The desired engine speed is set to low idle if no alternative throttle is detected.

Voltage at the throttle inputs to the ECM should be 13.8 ± 0.5 Volts DC when the throttle inputs are open. The voltage should be less than 0.5 Volts DC when the throttle inputs are closed.

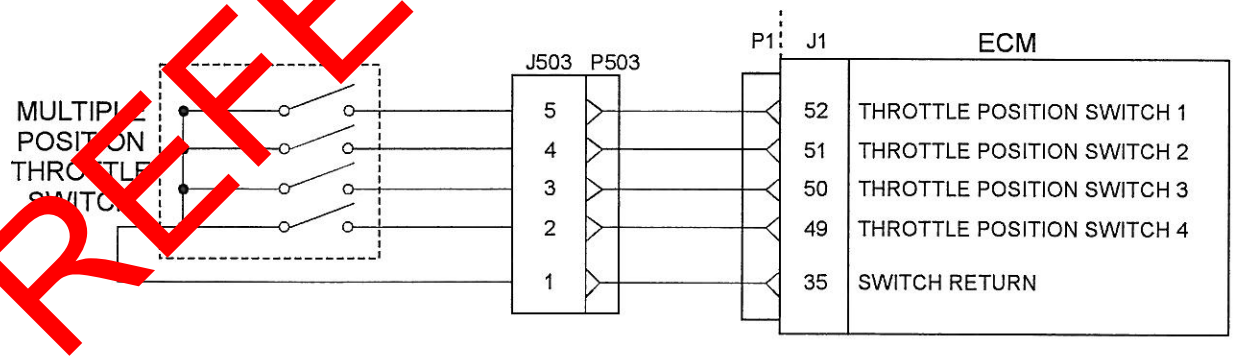
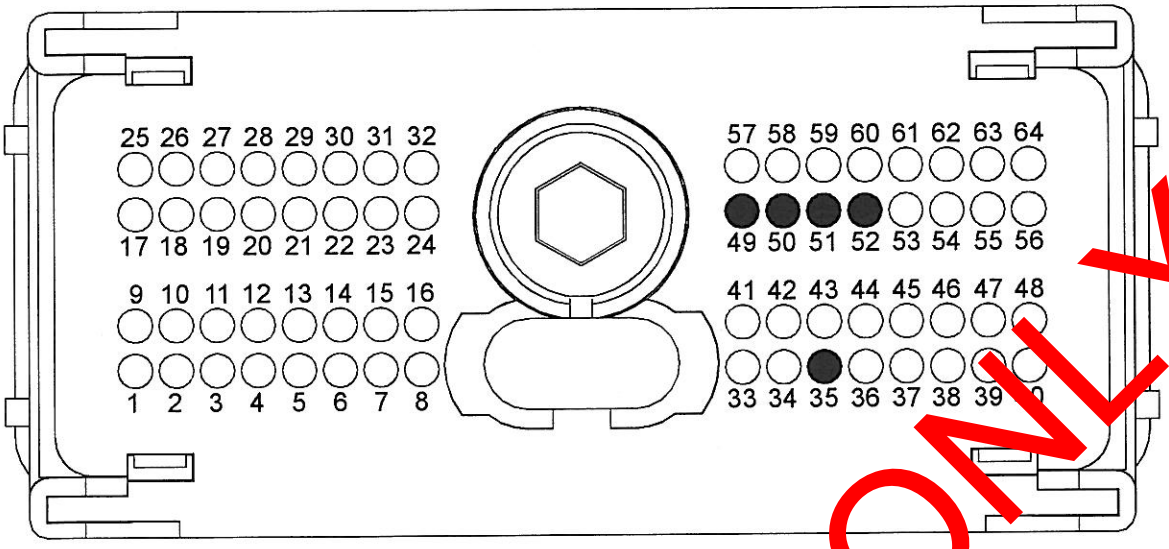



Illustration 90 g01806833

Schematic for the circuit for the throttle switch

REFERENCE ONLY




g01806834

Illustration 91

Typical view of the pin locations for the throttle switch on the P1 connector

(35) Switch return
(52) Throttle position switch 1
(51) Throttle position switch 2
(50) Throttle position switch 3
(49) Throttle position switch 4

REFERENCE ONLY

## Test Step 1. Inspect Electrical Connectors and Wiring

**A.** Turn the keyswitch to the OFF position.

**B.** Thoroughly inspect the P1/J1 connector and any other connectors that are included in the machine for this throttle switch. Refer to Troubleshooting, "Electrical Connectors - Inspect" for details.

**C.** Perform a 45 N (10 lb) pull test on each of the wires in the sensor connector and the ECM connector that are associated with the active diagnostic code. Refer to illustration 91.

**D.** Verify that the latch tab of the connector is correctly latched. Also verify that the latch tab of the connector has returned to the fully latching position.

**E.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**F.** Check the harness for corrosion, abrasion, and pinch points from the throttle switch to the ECM.

**Expected Result:**

All connectors, pins, and sockets should be completely inserted and coupled. The harness should be free of corrosion, abrasion and pinch points.

**Results:**

- OK – Proceed to Test Step 2.
- Not OK

**Repair:** Repair the circuit.

Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

## Test Step 2. Check "Throttle Cab Switch Position" on the Electronic Service Tool

**A.** Connect the electronic service tool to the diagnostic connector.

**B.** Turn the keyswitch to the ON position.

**C.** Observe the status of the throttle switch and the throttle inputs on the electronic service tool while the throttle switch is moved to each position.

**Results:**

- OK – The throttle switch is functioning correctly at this time.

  **Repair:** Refer to Troubleshooting, "Electrical Connectors - Inspect" if the fault is intermittent.

  STOP.

- Not OK – Record the suspect input. Proceed to Test Step 3.

### Test Step 3. Jumper the Switch Input at the Throttle Switch Connector

**A.** Disconnect connector P503 for the throttle switch.

**B.** Observe the status of the suspect throttle input on the electronic service tool.

**C.** Use a suitable jumper wire to short P503:1 to the terminal for the suspect throttle input at connector P503.

**D.** Observe the status of the suspect throttle input on the electronic service tool.

**E.** Remove the jumper wire.

**Expected Result:**

The status of the suspect throttle input should be OFF when connector J503/P503 is disconnected. The status should be ON when the jumper wire is installed.

**Results:**

- OK – The harness and the ECM are OK.

  **Repair:** Replace the throttle switch.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

- Not OK – Proceed to Test Step 4.

### Test Step 4. Check for Short in the Harness

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P1 connector and connector P503/J503.

**C.** Measure the resistance between engine ground and the terminal for the suspect throttle input on connector P503.

**D.** Measure the resistance between the terminal for the suspect throttle input on connector P503 and the remaining terminals at the connector.

**Expected Result:**

Resistance should be greater than 20,000 Ohms for each reading.

**Results:**

- OK – Proceed to Test Step 5.

- Not OK – There is a short in the harness between the ECM and the throttle switch.

  **Repair:** Repair the circuit.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

### Test Step 5. Check Resistance through the Harness

**A.** Use a jumper wire to short P503:1 to the terminal of the suspect throttle input on connector J503.

**B.** Measure the resistance between P1:35 and the terminal for the suspect throttle input on the P1 connector.

**Expected Result:**

Resistance should be less than 10 Ohms.

**Results:**

- OK – Proceed to Test Step 6.

- Not OK – There is an open circuit or excessive resistance in the harness.

  **Repair:** Repair the circuit.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

### Test Step 6. Check the Harness and the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P1 connector and remove the wire for the suspect throttle input from the P1 connector.

**C.** Reconnect all connectors.

**D.** Turn the keyswitch to the ON position.

**E.** Observe the status of the suspect throttle input on the electronic service tool.

**F.** Turn the keyswitch to the OFF position.

**G.** Disconnect the P1 connector and remove the wire from P1:35.

REFERENCE ONLY

**H.** Fabricate a jumper wire with pins at both ends. Insert the jumper wire at P1:35 and the suspect throttle input on the P1 connector.

**I.** Reconnect all connectors.

**J.** Turn the keyswitch to the ON position.

**Note:** Additional diagnostic codes will be generated because P1:35 will no longer be connected to other sensors and switches. Ignore the codes and clear the codes when you complete this test.

**K.** Observe the status of the suspect throttle input on the electronic service tool.

**L.** Turn the keyswitch to the OFF position.

**M.** Remove the jumper wire from the P1 connector and reconnect all wires and connectors.

**Expected Result:**

The status of the suspect throttle input should be OFF when the throttle input is open. The status should be ON when the jumper wire is installed.

**Results:**

- OK – There is a fault in the harness between the ECM and the throttle switch.

  **Repair:** Repair the circuit.

  Verify that the repair eliminates the fault.

  STOP.

- Not OK – The switch signal appears at the ECM. The ECM is not reading the switch correctly.

  **Repair:** Perform the following repair:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".
  2. Contact the Technical Help Desk.

  **Note:** The consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".
  4. Use the electronic service tool to recheck the system for active diagnostic codes.
  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.
  6. If the fault returns with the suspect ECM, replace the ECM.
  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

i03464381

# Wastegate Solenoid - Test

**System Operation Description:**

This procedure is only applicable to engines that have a wastegate regulator.

**Use this procedure under the following conditions:**

Use this procedure if another procedure has directed you here. Use this procedure if any of the following diagnostic codes are active:

- 0526-05 Turbo Wastegate Drive current below normal
- 0526-06 Turbo Wastegate Drive current above normal
- 0526-07 Turbo Wastegate Drive not responding properly

Some engine models will have a turbocharger with an electronically controlled wastegate. Typically, the wastegate is a mechanical valve that is used in the turbocharger in order to regulate the intake manifold pressure to a set value.

The control system for the electronically controlled wastegate precisely regulates the intake manifold pressure by using a wastegate regulator to control the wastegate.

The required intake manifold pressure is calculated by the software that is contained in the Electronic Control Module (ECM). The ECM uses the wastegate regulator to control the wastegate in order to provide the precise value of intake manifold pressure. The wastegate regulator is controlled by a PWM signal from the ECM.

REFERENCE ONLY

Table 61

| Pin Connections | | |
|---|---|---|
| **Sensor Pin** | **Function** | **P2 Pin Connection** |
| 1 | Ground | 44 |
| 2 | Signal | 17 |

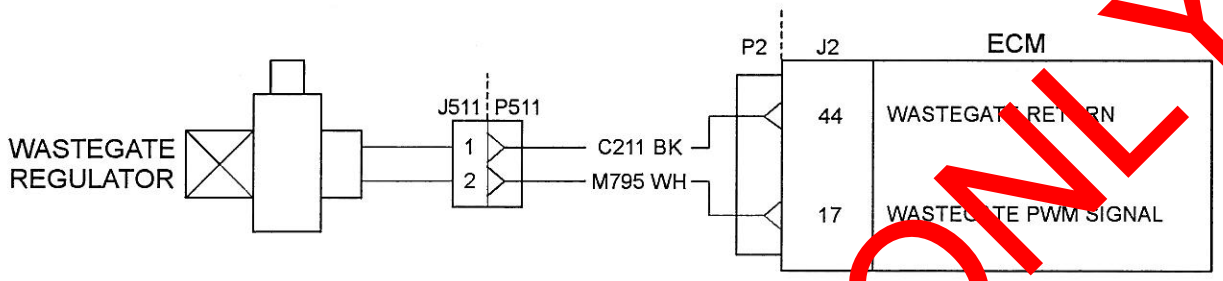



Illustration 92 g01806857

Schematic for the wastegate regulator

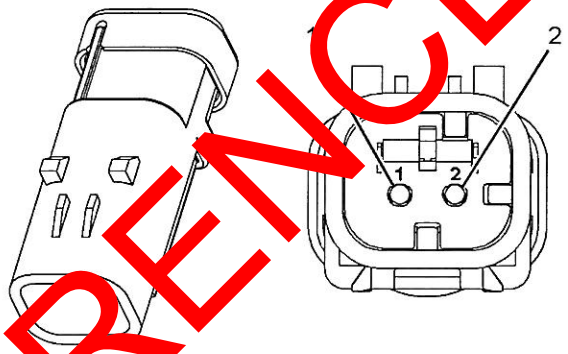
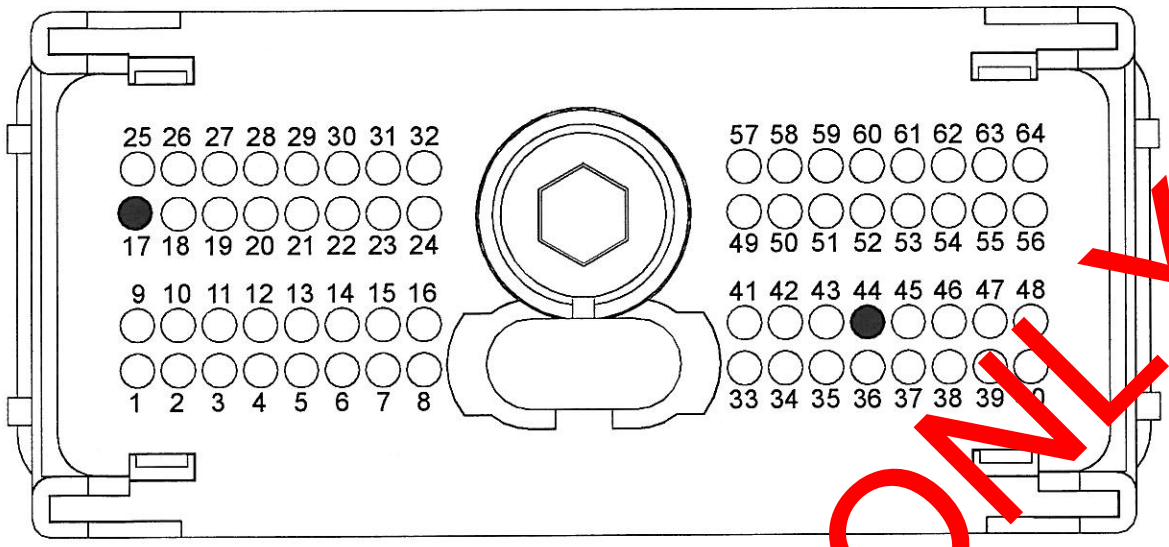



Illustration 93 g01806858

Wastegate regulator connector

(1) Ground (GND) (2) Signal (SIG)

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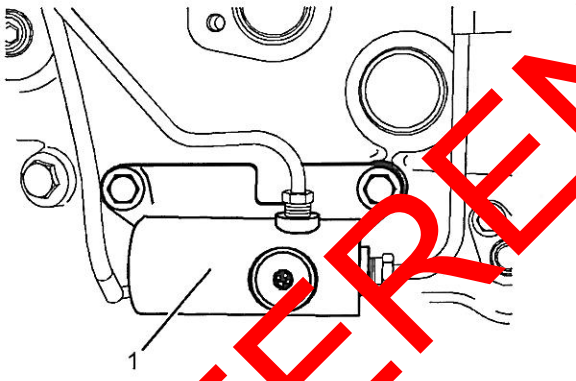



g01806859

Illustration 94

Typical view of the pin locations on the P1 connector

(17) Wastegate pulse width modulation (PWM) signal
(44) Wastegate return




g01806873

Illustration 95

Wastegate regulator

(1) Wastegate regulator

## Test Step 1. Check for Diagnostic Codes

**A.** Turn the keyswitch to the OFF position.

**B.** Connect the electronic service tool to the diagnostic connector.

**C.** Turn the keyswitch to the ON position. Start the Perkins EST.

**D.** Monitor the electronic service tool for active diagnostic codes and/or logged diagnostic codes.

**Expected Result:**

One or more diagnostic codes are active or logged.

**Results:**

- Diagnostic codes 526-5 and/or 526-6 are active and/or logged – Proceed to Test Step 2.
- No Codes – The fault seems to be resolved.

  **Repair:** For intermittent faults, refer to Troubleshooting, “Electrical Connectors - Inspect”.

  STOP.

## Test Step 2. Inspect Electrical Connectors and Wiring

**A.** Thoroughly inspect the P2/J2 ECM connector and the P511 connector for the wastegate regulator. Refer to Troubleshooting, “Electrical Connectors - Inspect” for details.

**B.** Perform a 45 N (10 lb) pull test on each of the wires that are associated with the wastegate solenoid.

**C.** Check the screw for the ECM connector for the correct torque of 5.0 N·m (44 lb in).

**Expected Result:**

All connectors, pins, and sockets are completely coupled and/or inserted and the harness is free of corrosion, abrasion, and pinch points.

**Results:**

- OK – The harness is OK. Proceed to Test Step 3.

REFERENCE ONLY

- Not OK – There is a fault in the connectors and/or the harness.

  **Repair:** Repair the connectors or the harness or replace the connectors or the harness. Ensure that all of the seals are correctly installed and ensure that the connectors are completely coupled.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 3. Determine the Diagnostic Code that is Active

**A.** Turn the keyswitch to the ON position. Access the "Diagnostics Tests" on the electronic service tool. Activate the "Turbo Wastegate Solenoid Test". Wait at least 30 seconds in order for the result to be displayed.

**B.** Determine if the fault is related to either of the following:

- "Low current" (open circuit)
- "High current" (short circuit)

**Expected Result:**

The electronic service tool displays no diagnostic codes.

**Results:**

- OK – There are no active codes.

  **Repair:** The original codes may have been caused by a loose connector. If this is an intermittent fault, refer to Troubleshooting, "Electrical Connectors - Inspect".

  STOP.

- Not OK – Diagnostic code 526-5 is active at this time. Proceed to Test Step 4.

- Not OK – Diagnostic code 526-6 is active at this time. Proceed to Test Step 6.

- Not OK – Diagnostic code 526-7 is active at this time. Proceed to Test Step 4.

## Test Step 4. Create a Short Circuit in the Harness at the Solenoid

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P511 connector for the wastegate regulator.

**C.** Fabricate a jumper wire between P511:1 and P511:2 in order to create a short circuit.

**D.** Turn the keyswitch to the ON position. Access the "Diagnostics Tests" on the electronic service tool. Activate the "Turbo Wastegate Solenoid Test". Wait at least 30 seconds in order for the result to be displayed.

**E.** Check for active diagnostic codes on the electronic service tool.

**Expected Result:**

Diagnostic code 526-6 is now active.

**Results:**

- OK – Diagnostic code 526-6 is now active. There is a fault in the wastegate regulator.

  **Repair:** Perform the following procedure:

  1. Temporarily connect a replacement wastegate regulator.
  2. Turn the keyswitch to the ON position. Access the "Diagnostics Tests" on the electronic service tool. Activate the "Turbo Wastegate Solenoid Test". Wait at least 30 seconds in order for the result to be displayed.
  3. Diagnostic code 526-6 is no longer active.
  4. If the fault is eliminated, reconnect the suspect wastegate regulator. If the fault returns, permanently install the replacement wastegate regulator.

  STOP.

- Not OK – The low current diagnostic code (open circuit) is still active. Proceed to Test Step 5.

## Test Step 5. Create a Short Circuit at the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Temporarily remove the wires from P2:17 and P2:44.

**C.** Fabricate a jumper wire between P2:17 and P2:44 in order to create a short circuit.

**Note:** The P2/J2 connector must be connected during the next step.

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**D.** Turn the keyswitch to the ON position. Access the "Special Tests" under the "Diagnostics" menu on the electronic service tool. Activate the "Turbo Wastegate Solenoid Output" on the electronic service tool. Wait at least 30 seconds for activation of the diagnostic codes.

**E.** Check for active diagnostic codes on the electronic service tool.

**Expected Result:**

Diagnostic code 526-6 is now active.

**Results:**

- OK – Diagnostic code 526-6 is now active. There is a fault in the harness between the ECM and the wastegate regulator.

  **Repair:** Repair the harness or replace the harness.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminated the fault.

  STOP.

- Not OK – There is still an open circuit diagnostic code.

  **Repair:** Perform the following procedure:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

  2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

  4. Use the electronic service tool to recheck the system for active diagnostic codes.

  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

  6. If the fault returns with the suspect ECM, replace the ECM.

  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

  STOP.

## Test Step 6. Disconnect the Wastegate Regulator in order to Create an Open Circuit

**A.** Turn the keyswitch to the OFF position.

**B.** Disconnect the P511 connector for the wastegate regulator in order to create an open circuit.

**C.** Turn the keyswitch to the ON position. Access the "Diagnostics Tests" on the electronic service tool. Activate the "Turbo Wastegate Solenoid Test". Wait at least 30 seconds in order for the result to be displayed.

**D.** Check for active diagnostic codes on the electronic service tool.

**Expected Result:**

Diagnostic code 526-5 is now active.

**Results:**

- OK – Diagnostic code 526-5 is now active.

  **Repair:** There is a short in the solenoid of the wastegate regulator.

  1. Temporarily connect a replacement wastegate regulator.

  2. If the fault is eliminated, reconnect the suspect wastegate regulator. If the fault returns, permanently install the replacement wastegate regulator.

  STOP.

- Not OK – Diagnostic code 526-6 is still active. Proceed to Test Step 7.

## Test Step 7. Create an Open Circuit at the ECM

**A.** Turn the keyswitch to the OFF position.

**B.** Remove the wires from P2:17 and P2:44 in order to create an open circuit at the ECM.

**C.** Turn the keyswitch to the ON position. Access the "Diagnostics Tests" on the electronic service tool. Activate the "Turbo Wastegate Solenoid Test". Wait at least 30 seconds in order for the result to be displayed.

**D.** Check for active diagnostic codes on the electronic service tool.

**Expected Result:**

Diagnostic code 526-5 is now active.

REFERENCE ONLY

**Results:**

- OK – Diagnostic code 526-5 is now active. There is a short circuit in the harness between the ECM and the wastegate regulator.

  **Repair:** Repair the harness or replace the harness.

  Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminated the fault.

  STOP.

- Not OK – Diagnostic code 526-6 is still present.

  **Repair:** Perform the following procedure:

  1. Make sure that the latest flash file for the application is installed in the ECM. Refer to Troubleshooting, "Flash Programming".

  2. Contact the Technical Help Desk.

**Note:** This consultation can greatly reduce the repair time.

  3. If the Technical Help Desk recommends the use of a test ECM, install a test ECM. Refer to Troubleshooting, "Replacing the ECM".

  4. Use the electronic service tool to recheck the system for active diagnostic codes.

  5. If the fault is resolved with the test ECM, reconnect the suspect ECM.

  6. If the fault returns with the suspect ECM, replace the ECM.

  7. Use the electronic service tool in order to clear all logged diagnostic codes and then verify that the repair eliminates the fault.

STOP.

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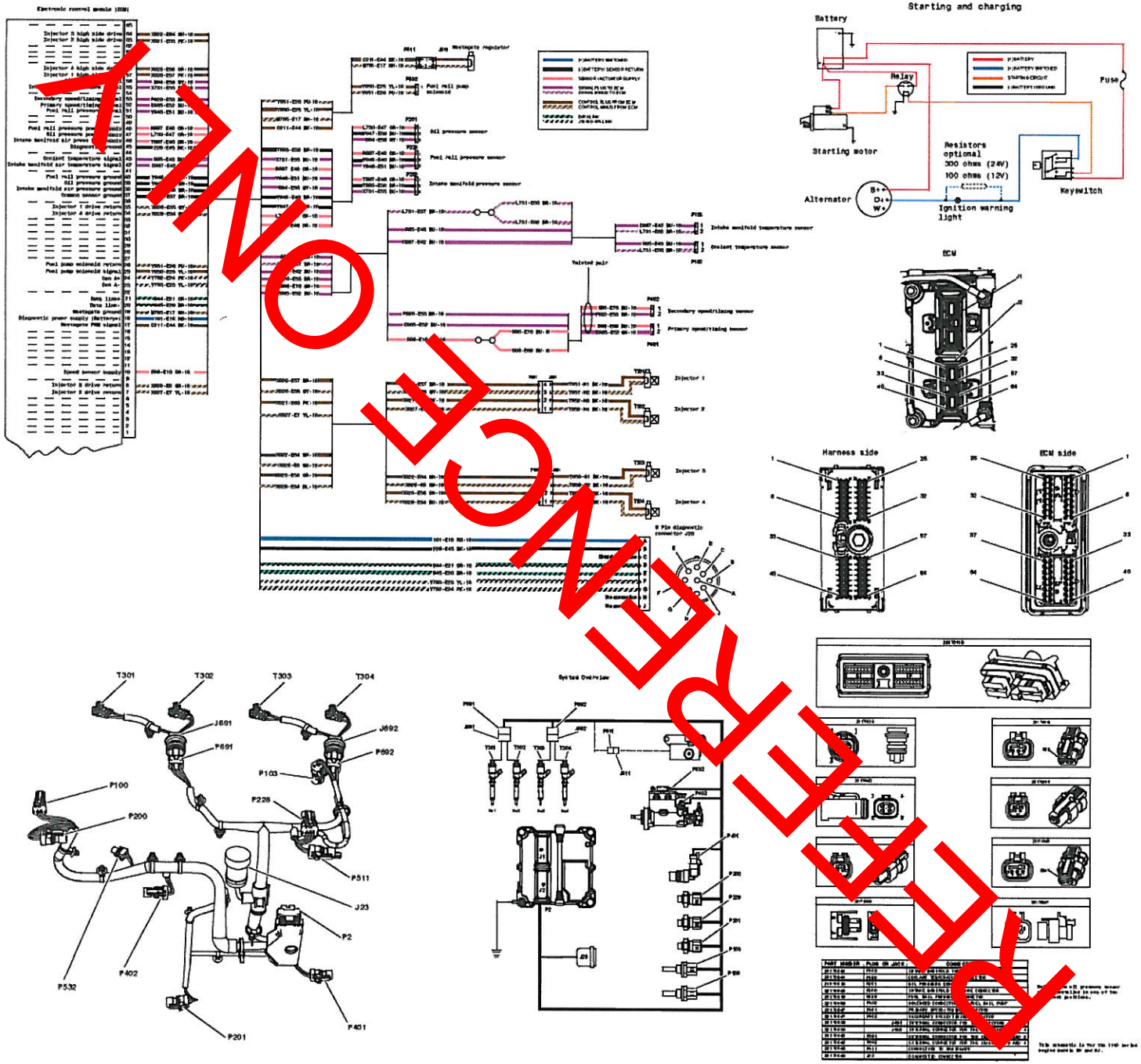
TRIM 12 PG
FOLD
FOLD
TRIM 12 PG

| Component Identifiers (CID*) |
|---|
| Engine Control Module |
| C100 — Camshaft Position Sensor |
| C110 — Crankshaft Position Sensor |
| C175 — Coolant Temperature Sensor |
| C180 — Engine Oil Temperature Sensor |
| C187 — Fuel Temperature Sensor |
| C197 — Fuel Rail Pressure Sensor |
| C198 — Fuel Rail Pressure Sensor |
| C199 — Fuel Rail Pressure Sensor |
| C200 — Intake Manifold Pressure Sensor |
| C208 — Engine Oil Level Sensor |
| C220 — Sensor Supply (ECM) |
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| C253 — Sensor Supply (Sensors) |
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*1 The CID is a diagnostic code that identifies a specific circuit or fault.

| Perkins Diagnostic Trouble Codes (DTC*) |
|---|
| PID No. — Perkins Description |
| 1 — Cylinder #1 Injector Solenoid Circuit Open/Short |
| 2 — Cylinder #2 Injector Solenoid Circuit Open/Short |
| 3 — Cylinder #3 Injector Solenoid Circuit Open/Short |
| 4 — Cylinder #4 Injector Solenoid Circuit Open/Short |
| 5 — Cylinder #5 Injector Solenoid Circuit Open/Short |
| 6 — Cylinder #6 Injector Solenoid Circuit Open/Short |
| 7 — Injector Trim Not Programmed or Incompatible |
| 8 — Engine Speed/Position Sensor Circuit Abnormal |
| 9 — Engine Speed/Position Sensor Circuit Intermittent or Erratic |
| 10 — Engine Speed/Position Sensor Circuit Abnormal or Incorrect Installation |
| 11 — Unspecified Electronic System Failure |
| 12 — Unspecified Electronic System Failure |
| 13 — Sensor Supply #1 Circuit Out of Range |
| 14 — Sensor Supply #2 Circuit Out of Range |
| 15 — Sensor Supply #3 Circuit Out of Range |
| 16 — Engine Coolant Temperature Sensor Circuit Out of Range |
| 17 — Engine Coolant Temperature Sensor Circuit Intermittent or Erratic |
| 18 — Engine Coolant Temperature Sensor Circuit Abnormal Rate of Change |
| 19 — Engine Coolant Temperature Sensor Circuit Voltage Above Expected Range |
| 20 — Engine Coolant Temperature Sensor Circuit Voltage Below Expected Range |
| 21 — Fuel Temperature Sensor Circuit Out of Range |
| 22 — Fuel Temperature Sensor Circuit Intermittent or Erratic |
| 23 — Fuel Temperature S

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