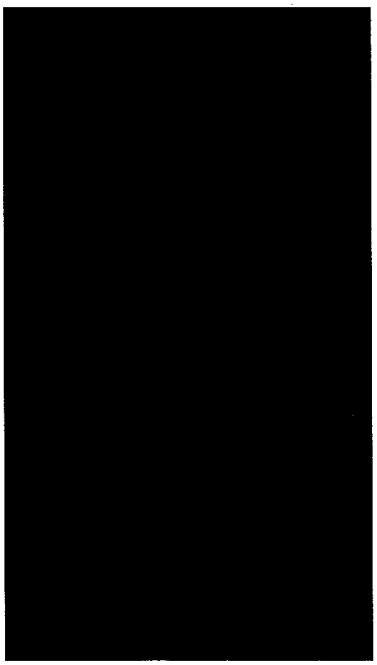
# SERVICE MANUAL



# MITSUBISHI DIESEL ENGINE

# D04FD-TAA

## for HYUNDAI HEAVY INDUSTRIES CO.,LTD.

November 2006

MITSUBISHI HEAVY INDUSTRIES, LTD.

# INTRODUCTION

This service manual describes the specifications, maintenance and service procedures for Mitsubishi diesel engines.

To maintain the performance of the engine for many years and to ensure safe operation, it is important to use the engine correctly and conduct regular inspection and maintenance, and also to take necessary measures which involves the disassembly, inspection, repair and reassembly of the engine and engine parts.

Read this manual carefully and understand the work procedures fully before disassembling, inspecting, repairing or reassembling the engine.

The contents of the manual are based on the engine models that are being produced at the time of publication. Due to improvements made thereafter, the actual engine that you work on may differ partially from the one described in this manual.

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# How to use this manual

This service manual consists of several Groups, which are arranged so as to allow you to make reference quickly to specifications, maintenance standards, adjustment procedures and service procedures including methods for disassembly, inspection, repair and reassembly of the Mitsubishi Diesel Engine (standard model for land use).
A short summary describing the content of each Group is given in the General Contents page, and there is also a detailed table of contents at the beginning of each Group.
Regarding the procedures for operation and periodical maintenance of the engine, refer to the Operation and Maintenance Manual. For information on the engine components and ordering of service parts, refer to the Parts Catalogue. Structure and function of the engine are described in the relevant training manuals.

## Methods of presentation

(1)Index numbers alloted to parts in exploded views are not only a call-out of part names listed in the text but also an indication of the sequence of disassembly.
(2)Inspections to be conducted during disassembly process are indicated in boxes in the relevant exploded views.
(3)Maintenance standards required for inspection and repair works are indicated in the appropriate positions in the text. They are also collectively indicated in Group 2, the General Contents group.
(4)Fasteners to be tightened in "wet" condition, or with engine oil applied, are identified by [Wet] placed after tightening torque values. If no such indication is suffixed, the fastener should be tightened in "dry" condition, or without lubricating with engine oil.
(5)In this manual, important safety or other cautionary instructions are emphasized with the following marks headed.

**⚠ DANGER**

Indicates an immediately hazardous situation which, if not avoided, will result in death or serious injury.

**⚠ WARNING**

Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

**⚠ CAUTION**

Indicates an immediately hazardous situation which, if not avoided, may result in minor or moderate injury.

**CAUTION**

Indicates a potentially hazardous situation which, if not avoided, can result in property damage.

Note:

Indicates important information or information useful for operation or maintenance of the engine.

## Terms used in this manual

Nominal

means the rated (design) size or magnitude of a part to be measured.

Standard

means the quantitative requirement for dimension of a part, clearance between parts and performance. This is given in a form of tolerance. Therfore, the values shown are not in agreement with the design values.

Limit

means that, if this value is reached, the part must be repaired or replaced with a new part.

## Abbreviations

- BTDC: Before Top Dead Center
- ATDC: After Top Dead Center
- BBDC: Before Bottom Dead Center
- ABDC: After Bottom Dead Center
- TIR: Total Indicated Runout
- API: American Petroleum Institute
- ASTM: American Society for Testing and Materials
- JIS: Japanese Industrial Standards
- LLC: Long Life Coolant
- MIL: Military Specifications and Standards (U.S.)
- MSDS: Material Safety Data Sheet
- SAE: Society of Automotive Engineers (U.S.)

## Units of Measurement

Measurements are based on the International System of Units (SI), and their converted metric values are indicated in parentheses { }. For metric conversion, the following rates are used.

- Pressure: 1 MPa = 10.197 kgf/cm$^2$
- Torque: 1 N·m = 0.10197 kgf·m
- Force: 1 N = 0.10197 kgf
- Horsepower: 1 kW = 1.341 HP = 1.3596 PS
- Meter of mercury: 1 kPa = 0.7 cmHg
- Meter of water: 1 kPa = 10.197 cm$H_2O$ (cmAq)
- Rotational speed: 1min$^{-1}$ = 1 rpm

# Safety Cautions

⚠ WARNING

## Fire and explosion

### Keep flames away

Store fuel and engine oil in a well-ventilated designated area.
Make sure that the caps of fuel and engine oil containers are tightly closed.
Do not use flames, do not smoke, or do not work near heater or other fire hazards where fuel or oil is handled or when cleaning solvent is being used for washing parts.
Wipe off spilled fuel, oil and LLC immediately and thoroughly. Spilled fuel, oil and LLC may ignite and cause a fire.

### Keep surrounding area neat and clean

Do not leave combustible or explosive materials, such as fuel, engine oil and LLC, near the engine. Such substances can cause fire or explosion.
Remove dust, dirt and other foreign materials accumulated on the engine and sorrounding parts thoroughly. Such materials can cause fire or the engine to overheat. In particular, clean the top surface of the battery thoroughly. Dust can cause a short-circuit.
Always operate the engine at a position at least 1 m [3.28 ft.] away from buildings and other equipment to prevent possible fire caused by engine heat.

### Care about fuel, oil and exhaust gas leakage

If any fuel, oil or exhaust gas leakage is found, immediately take corrective measures to stop it.
Such leakages, if left uncorrected, can cause fuel or engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable materials, possibly leading to personal injury and/or damage to equipment.

### Use explosion-proof lighting apparatus

When inspecting fuel, engine oil, coolant, battery electrolyte, etc., use a flameproof light. An ordinary light, if it accidentally broken, may ignite and cause an explosion.

### Prevent electrical wires from short-circuiting

Avoid inspecting or servicing the electrical system with the ground cable connected to the battery. Otherwise, a fire could result from short-circuiting. Be sure to disconnect the battery cable from the negative (-) terminal before beginning with the work procedure.
Short-circuits, possibly resulting in fire, may be caused by a loose terminal or damaged cable/wire. Inspect the terminals, cables and wires, and repair or replace the faulty parts before beginning with the service procedure.

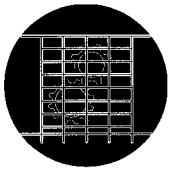
### Keep fire extinguishers and first-aid kit handy

Keep a fire extinguisher handy and be familiarized with their usage.
Keep a first-aid kit at a designated place, and make sure it is easily accessible whenever needed.
Establish emergency procedures to follow in the event of fire or accident, and keep the personnel informed of emergency contact locations and contact methods.

⚠ WARNING

# Stay clear of all rotating and moving parts

### Install protective covers on rotating parts



Make sure the protective covers for engine rotating parts are properly installed as intended. Repair loose or damaged protective covers as necessary.

Never remove the covers guarding personnel from rotating parts, when the engine is operating.

When combining the engine with the engine-driven machine or radiator, always provide a cover on every exposed moving part such as driving belt and coupling. Never remove protective covers.

### Ensure safety of neighboring people before starting engine

Before starting the engine, ensure that there is nobody in the neighborhood and no tools are left on or near the engine. Be sure to give a sign with a shout when starting the engine.

When a tag saying "Do not operate" is attached on or near the starter switch, never start the engine.

### Stay clear of moving parts during engine running

Do not approach rotating or sliding parts of the engine when the engine is in operation.

Keep objects likely to be caught by rotating parts away from such parts.

If any part of the clothing or outfitting is caught by a rotating part, serious bodily injuries could result.

### Lockout and Tagout

Be sure to lockout and tagout before starting inspection and maintenance.

Lockout and tagout are effective methods of cutting off machines and equipment from energy sources.

To accomplish the lockout/tagout, remove the starter switch key, set the battery switch to OFF and attach a "Do Not Run" or similar caution tag to the starter switch. The starter switch key must be kept by the person who performs inspection and maintenance during the work.

In the case of pneumatic starting type, close the main valve of the air tank and post a tag saying "Do Not Open the Valve" or the like.

### Keep engine stopped during servicing

Be sure to stop the engine before proceeding to inspection and service procedure. Never attempt to make adjustments on the engine parts while the engine is running. Rotating parts such as belt can entangle your body and cause serious injuries.

### Always restore engine turning tools after use

Do not forget to remove the tools which have been used for turning the engine during inspection or servicing, after the procedure is finished. Remember also that the turning gear must be returned to the operating condition before starting the engine.

Starting the engine with the turning tools inserted or with the turning gear in engagement can lead to not only engine damage but also personal injuries.

⚠ WARNING

## Be careful of burns

### Do not touch engine during or immediately after operation

Do not touch the engine during or immediately after operation to avoid risk of burns.

To conduct maintenance and inspection work, wait until the engine has cooled sufficiently, checking the temperature gauge.

### Slowly and carefully open radiator cap

Never attempt to open the radiator cap while the engine is running or immediately after the engine stops. Give a sufficient cooling time to the engine coolant before opening the cap.

When opening the radiator cap, slowly turn the cap to release internal pressure. To prevent scalds with steam gushing out, wear thick rubber gloves or cover the cap with a cloth.

Close the radiator cap tightly without fail.

The coolant is very hot and under pressure during engine running or just after the engine stops. If the radiator cap is not closed tightly, steam and hot coolant may gush out and can cause scalds.

### Add coolant only after coolant temperature dropped

Do not add coolant immediately after the engine stops. Wait until the coolant temperature lowers sufficiently to avoid a risk of burns.

⚠ WARNING

## Protect ears from noises

### Wear ear plugs

Always wear ear plugs when entering the machine room (engine room). Combustion sound and mechanical noise generated by the engine can cause hearing problems.

⚠ WARNING

## Be careful of falling down

### Lift engine correctly

For lifting the engine, always use a correct wire rope capable of withstanding the engine weight.
Also, attach the wire rope to the correct lifting hangers originally fitted on the engine using a correct sling.
During lifting process, keep the engine in a well-balanced position by taking the center of gravity of the engine into consideration.
During lifting process, keep the engine in a well-balanced position by taking the center of gravity of the engine into consideration.
If the wire rope contacts the engine directly, place a cloth or other soft padding between them to prevent damage to the engine and wire rope.

### Do not get on engine

Do not get on top of the engine, nor step on any engine parts located on the lateral sides.
To work on parts located on the upper section of engine, use a ladder, stool, etc., firmly secured not to fall down.
Falling down of such footholds could result in not only to damage of the engine parts but also personal injuries.

⚠ CAUTION

## Be careful of handling fuel, engine oil and LLC

### Use only specified fuel, engine oil and coolant (LLC)

Use fuel, oil and LLC specified in this manual, and handle them carefully.
Use of any other fuel, oil or LLC, and improper handling may cause various engine problems and malfunctions.
Obtain the MSDSs issued by the fuel, oil and LLC suppliers, and follow the directions in the MSDSs for proper handling.

### Handle LLC (long life coolant) carefully

When handling LLC, always wear rubber gloves and protective face mask. If LLC or cooling water containing LLC comes into contact with your skin or eyes, or if it is swallowed, you would suffer from inflammation, irritation or poisoning.
Should LLC be accidentally swallowed, induce vomiting immediately and seek medical attention. Should LLC enter your eyes, flush them immediately with plenty of water and seek medical attention. If LLC splashes onto your skin or clothing, wash it away immediately with plenty of water.
Keep flames away from LLC. The LLC can catch flames, causing a fire.
Drained coolant (containing LLC) is harmful. Do not dispose of it in unauthorized manner. Abide by the applicable law and regulations when discarding drained coolant.

### Proper disposal of waste oil and coolant (LLC)

Do not discharge waste engine oil or coolant into sewerage, river, lake or other similar places. Such a way of disposal is strictly prohibited by laws and regulations.
Dispose of waste oil, coolant and other environmentally hazardous waste in accordance with the applicable law and regulations, or consult a Mitsubishi dealer.

⚠ CAUTION

## Service battery

### Handle battery correctly

- Never use flames or allow sparks to generate near the battery. The battery releases flammable hydrogen gas and oxygen gas. Any flames or sparks in the vicinity could cause an explosion.
- Do not use the battery the fluid level of which is lowered below the lower limit line. Sustained use of the battery could result in an explosion.
- Do not short the battery terminals with a tool or other metal object.
- When disconnecting battery cables, always remove the cable from the negative (-) terminal first. When reconnecting the cables, attach the cable to the positive (+) terminal first.
- Charge the battery in a well-ventilated area, with all filling hole plugs removed.
- Make sure the cable clamps are securely installed on the battery terminals. A loose cable clamp can cause sparks that may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or disconnect the cable from the negative (-) battery terminal to cut off the electrical current.
- Electrolyte (battery fluid) contains dilute sulfuric acid. Careless handling of the battery can lead to the loss of sight and/or skin burns. Also, keep the battery fluid off the mouth.
- Wear protective goggles and rubber gloves when working with the battery (when adding water, charging, etc.).
- If electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to thoroughly clean.
- The battery fluid can cause blindness if splashing into eyes. If it gets into eyes, immediately flush it away with plenty of clean fresh water, and seek immediate medical attention.
- If the battery fluid is accidentally swallowed, gargle with plenty of water, then drink lots of water, and seek immediate medical attention.

⚠ CAUTION

## When abnormality occurs

### Stop overheated engine after cooling run

Even if the engine comes to overheat, do not stop the engine immediately. Abrupt stopping of an overheated engine can cause the coolant temperature to rise, resulting in seized engine parts. If the engine comes to overheat, run the engine at low idling speed (cooling operation), and stop the engine after the coolant temperature lowers sufficiently.

Do not add coolant immediately after stopping the engine. Adding coolant to a hot engine can cause the cylinder heads to crack due to sudden change in temperature. Add coolant little by little after the engine cools down to room temperature.

### Avoid immediate restart after abnormal stop

If the engine stops abnormally, do not restart the engine immediately. If the engine stops with an alarm, check and remedy the cause of the problem before restarting. Sustained use of the engine without any remedy could result in serious engine problems.

### Avoid continued engine operation with too low oil pressure

If an abnormal engine oil pressure drop is indicated, stop the engine as immediately as possible, and inspect the lubrication system to locate the cause. Continuing to operate the engine with low oil pressure may cause seizure of the bearings and other parts.

### Stop the engine immediately if fan belt is broken

If the fan belt is broken, stop the engine immediately. Continued operation of the engine with the fan belt broken could cause the engine to overheat and thereby the coolant to boil into steam, which may gush out from the reserve tank or radiator, and cause personal injuries.

⚠ CAUTION

## Other cautions

### Modification of engine prohibited

Unauthorized modification of the engine will void the manufacturer's warranty.
Modification of the engine may not only cause engine damage but also produce personal injuries.

### Pre-operational check and periodic inspection/maintenance

Be sure to perform the pre-operational checks and periodic inspection/maintenance as described in this manual.
Neglecting the pre-operational check or periodic inspection/maintenance can arouse various engine troubles such as damage to parts, eventually leading to serious accidents.

### Break-in operation

A new engine needs to be broken in for the first 50 hours of operation. During this period, do not subject the engine to heavy loads.
Operating a new engine under high loads or severe conditions during the break-in period can shorten the service life of the engine.

### Warming-up operation

After starting the engine, run the engine at low idling speeds for 5 to 10 minutes for warming-up. Start the work after this operation is completed.
Warm-up operation circulates the lubricant through the engine. Therefore, individual engine parts are well lubricated before they are subjected to heavy loads. This is very important for longer service life, high-performance and economical operation.
Do not conduct warm-up operation for a longer time than necessary. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion.

### Avoid engine operations under overload condition

If the engine is considered to be in an overloaded condition which is identified by too much black smoke, etc., immediately reduce the load on the engine such that the correct output and load condtions may be achieved.
Overloading the engine causes not only high fuel consumption but also excessive carbon deposits inside the engine. Excessive carbon deposits can cause various engine problems and shorten the service life of the engine remarkably.

### Cooling operation before stopping engine

Always conduct the cooling operation (low speed idling) for 5 to 6 minutes before stopping the engine.
Abruptly stopping the engine immediately after high-load operation can cause partial overheating and shorten the service life of the engine.
During cooling operation, check the engine for abnormalities.

### Protection of engine against water entry

Do not allow rainwater, etc. to enter the engine through the air inlet or exhaust openings.
Do not wash the engine while it is operating. Cleaning fluid (water) can be sucked into the engine.
Starting the engine with water inside the combustion chambers can cause the water hammer action which may result in internal engine damage and serious accidents.

### Maintenance of air cleaner or pre-cleaner

The major cause of abnormal wear on engine parts is dust entering with intake air. Worn parts produce many problems such as an increase of oil consumption, decrease of output, and starting difficulties. For effective removal of dust from intake air, conduct maintenance of the air cleaner according to the following instructions.

- Do not conduct maintenance of the air cleaner/pre-cleaner while the engine is operating. Engine operation without the air cleaner/precleaner in place allows foreign matters to enter the turbocharger, causing it to damage seriously.
- Remove the air cleaner/pre-cleaner slowly to prevent dust accumulated on the element from falling off. After removing the air cleaner or pre-cleaner, immediately cover the opening (inlet port in case of air cleaner; port in body in case of pre-cleaner) with plastic sheet or similar means to prevent dust from entering the engine.
- Air cleaners equipped with a dust indicator will issue an alarm if the element gets clogged. Service the cleaner as soon as possible if an alarm is issued.

### Safety rules at work site

When operating or servicing the engine, always observe the applicable safety rules established at each work site.

If you are feeling ill, do not operate the machine, but inform the supervisor of your condition.

Unsatisfactory physical condition reduces the concentration. Operation of the machine with reduced concentration may cause operation errors that may result in accidents.

When working in a group, use specified hand signals to communicate among the workers.

### Work clothing and protective gear

Wear a hardhat, face shield, safety shoes, dust mask, gloves and other protective gear as needed.

When handling compressed air, wear safety goggles, hardhat, gloves and other necessary protective gear. Works without wearing proper protective gear could result in serious injuries.

### Use of tools optimum for each work

Always keep in mind to select most appropriate tools for the work to be performed and use them correctly. If tools are damaged, replace with new tools.

### Avoidance of prolonged time of starter operation

Do not operate the starter for more than 10 seconds at a time even if the engine does not start. Wait for at least 30 seconds before next engine cranking.

Continuous operation of the starter will drain the battery power and cause seizing of the starter.

### Do not turn off battery switch during operation

If the battery switch is turned OFF when the engine is running, not only various meters will stop working but also the alternator may have its diode and transistor deteriorated.

### Cautionary instructions for transporting engine

When transporting the engine on a truck, consider the engine weight, width and height to ensure safety. Abide by road traffic law, road vehicles act, vehicle restriction ordinance and other pertinent laws.

### Avoid continuous engine operation under low load conditions

Do not operate the engine continuously for more than 10 minutes with a load of less than 30%. Engine operation under low load conditions increases the emission of unburned fuel. Therefore, a prolonged time of engine operation under low load conditions increases the quantity of unburned fuel adhering to engine parts, provoking the possibility of engine malfunctioning and shortening the service life of the engine.

### Ventilation of engine room

Always keep the engine room well-ventilated. Insufficient amount of intake air causes the operating temperature to rise, resulting in poor output and lowered performance.

It is highly recommended to calculate the required amount of air supply to the engine and install an adequate ventilation system before putting the engine to use.

### Avoid contact with high-pressured fuel

Should fuel leak from a fuel injection pipe, do not touch the spouting fuel directly.

Fuel in the fuel injection pipes is under high pressure. If high-pressured fuel contacts you skin, it penetrates through the skin and may result in gangrene.

⚠ CAUTION

# About warning labels

## Maintenance of warning labels

Make sure all warning/caution labels are legible.

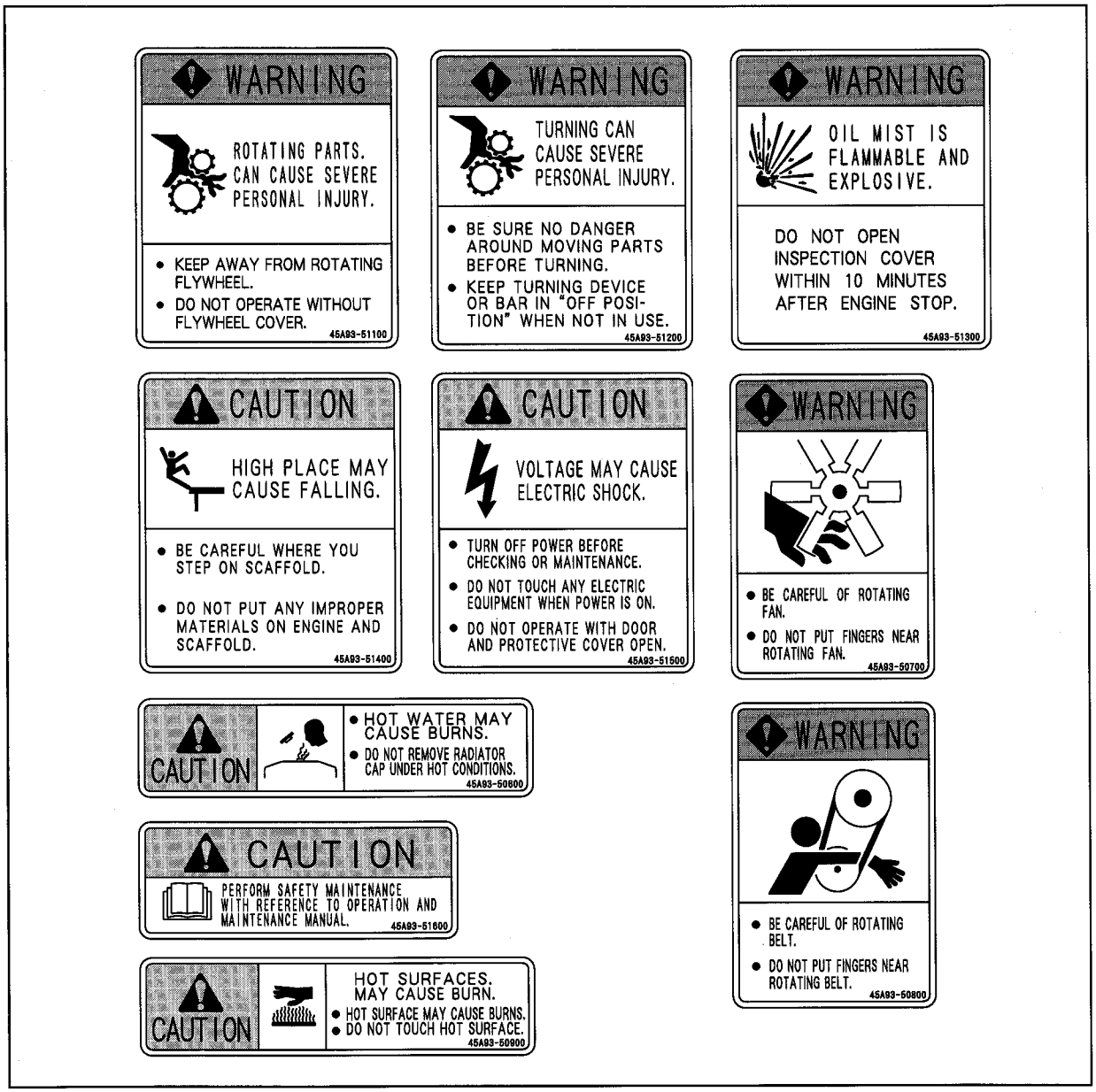
Clean or replace the warning/caution labels the description and/or illustration of which cannot be seen clearly.

For cleaning the warning/caution labels, use a cloth, water and soap. Do not use cleaning solvents, gasoline or other chemicals to prevent the letters from getting blurred or the adhesion from being weakened.

Replace damaged or fractured labels with new ones.

If any engine part on which a warning label is attached is replaced with a new one, attach a new identical warning label to the new part.

To obtain replacement warning labels, contact a Mitsubishi dealer.



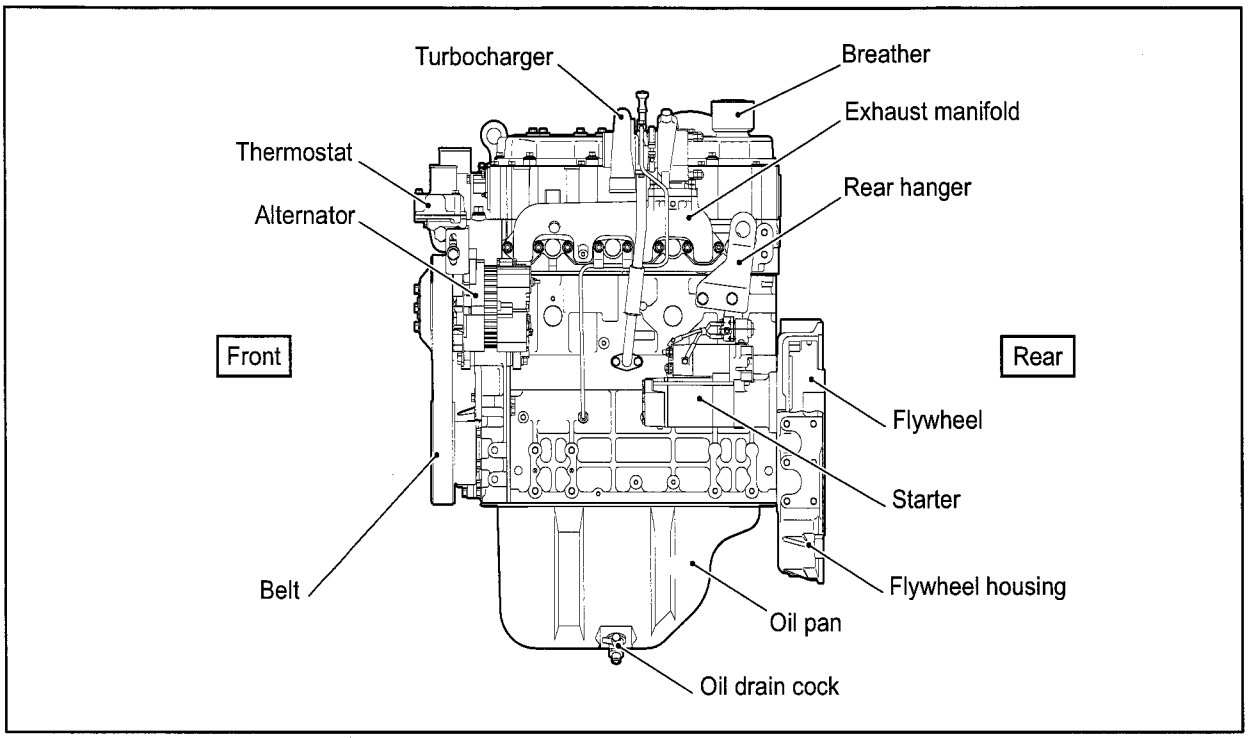

Warning labeles

# GENERAL CONTENTS

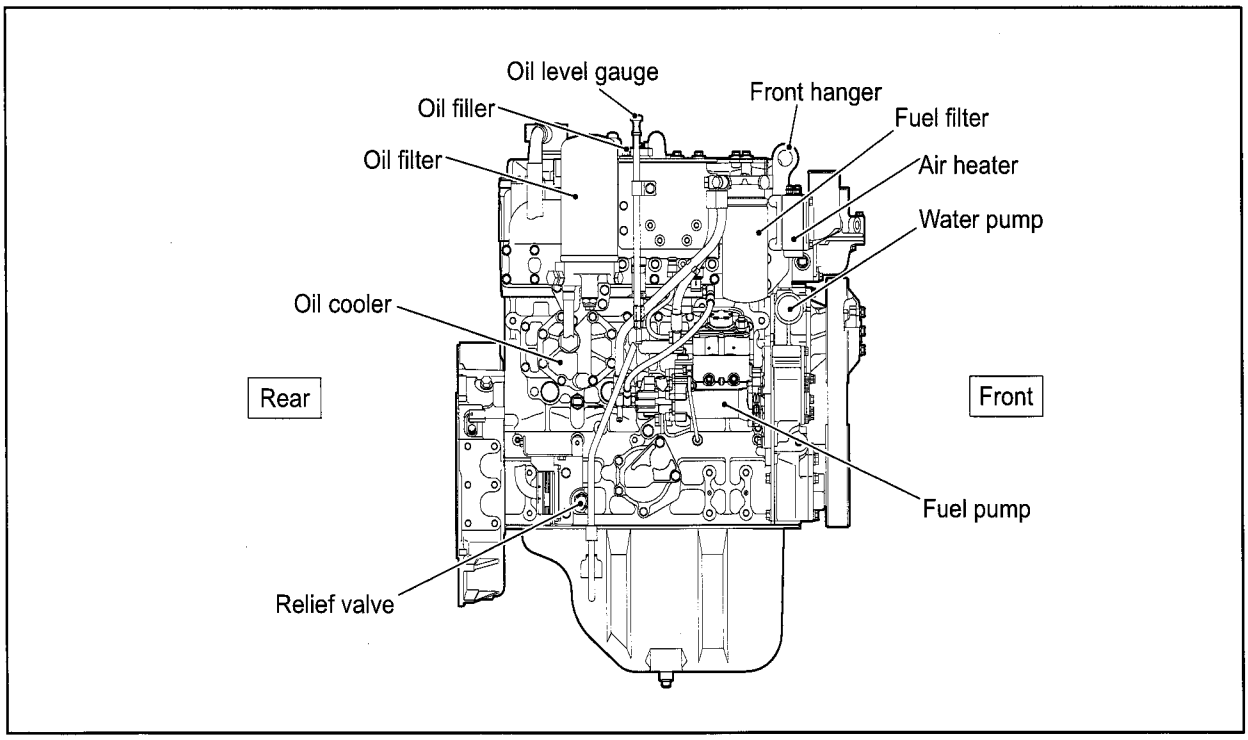
# GENERAL

# 1. Outline drawings

## 1.1 D04FD-TAA Outline drawings



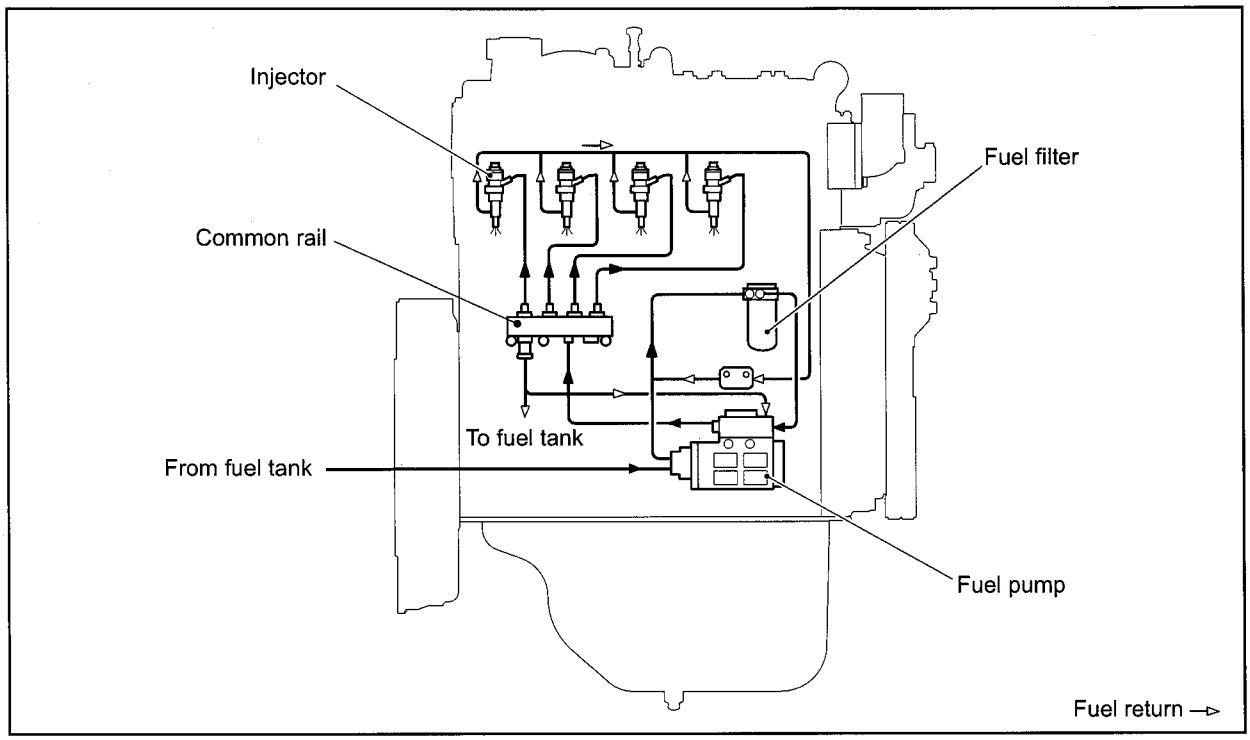

Engine left view




Engine right view

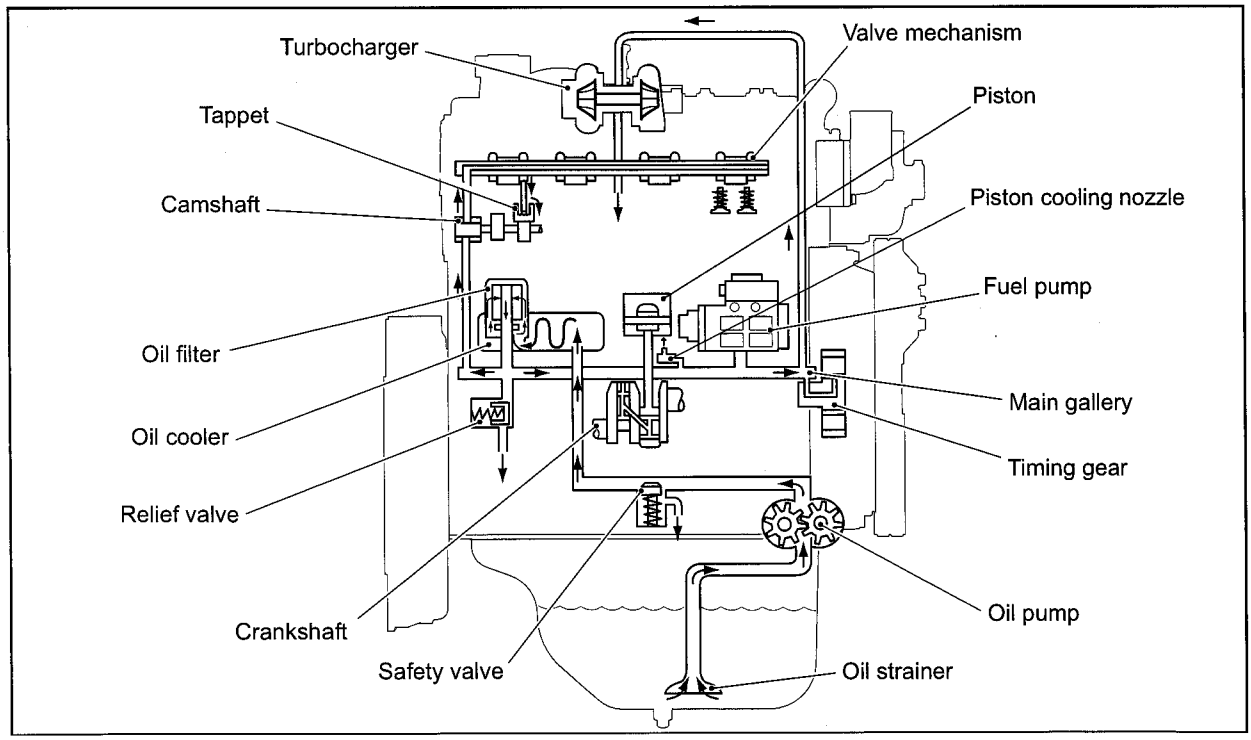
## 2. System flow

### 2.1 Fuel flow



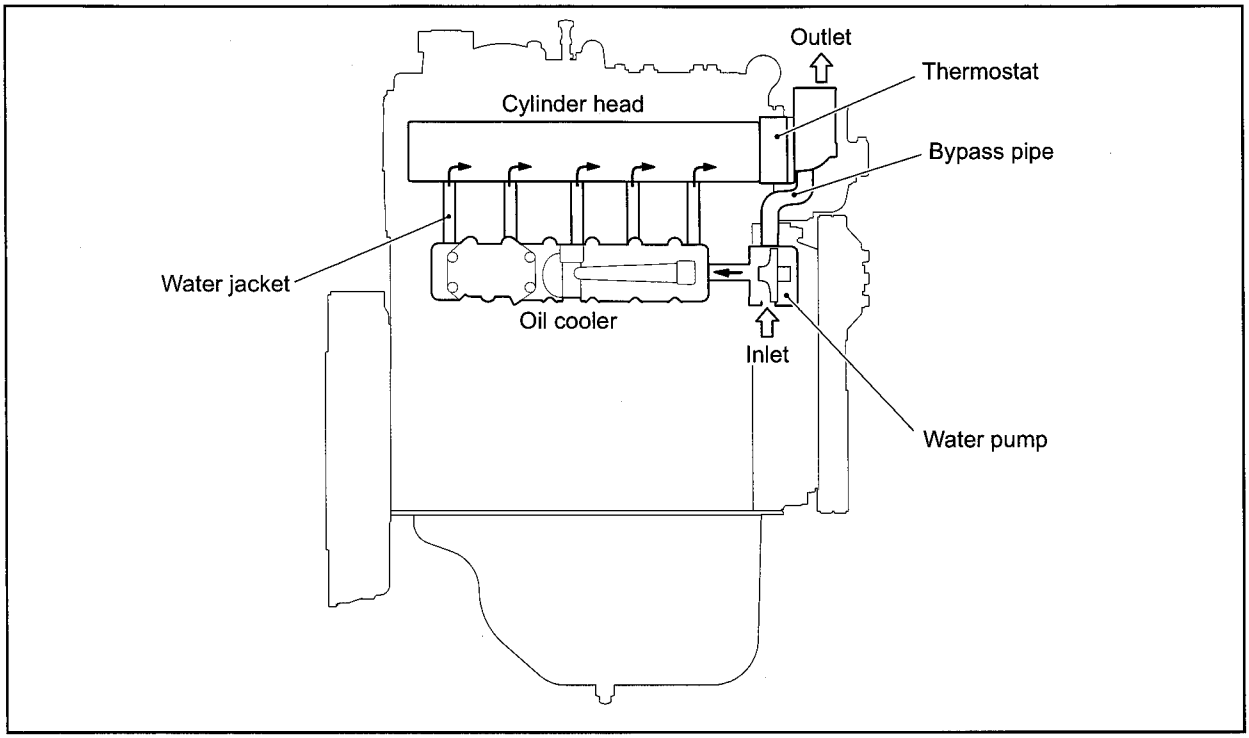

Fuel flow

### 2.2 Oil flow



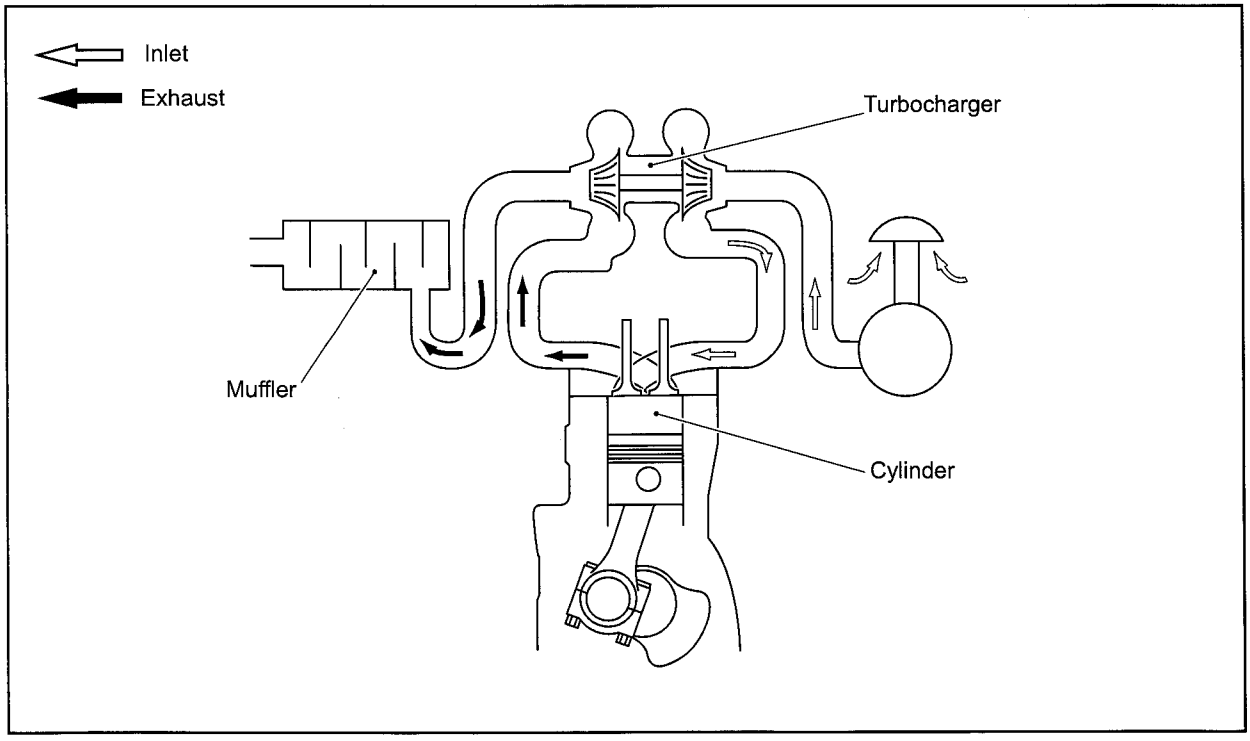

Oil flow

### 2.3 Cooling water flow



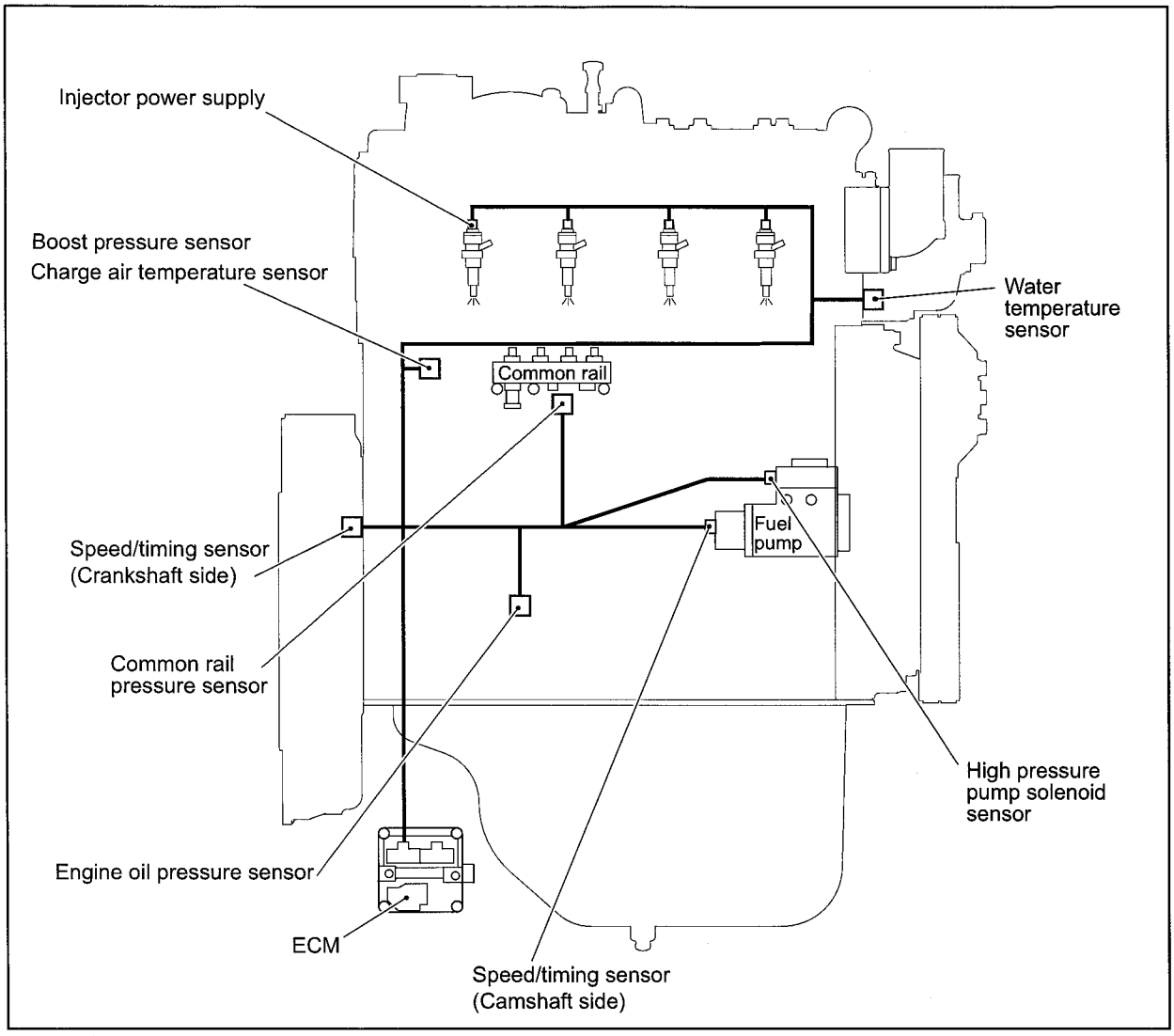

Cooling water flow

### 2.4 Inlet and exhaust flow




Inlet and exhaust flow

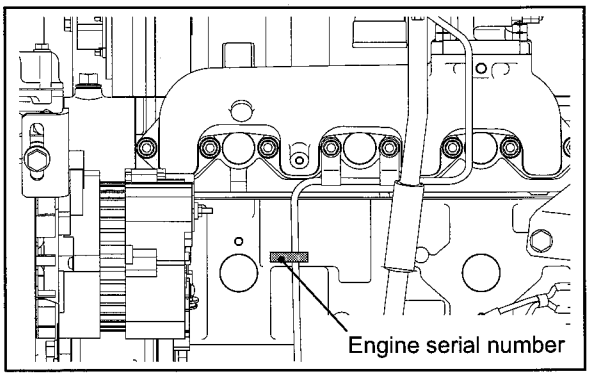
## 2.5 Electrical wiring diagram




Electrical wiring diagram

## 3. Engine serial number location

The engine serial number is stamped on the side of the crankcase.




Stamp location of engine serial number

## 4. Main specifications

Table 1-1 Main specifications (1 / 3)

| Engine model | | | | D04FD-TAA |
|---|---|---|---|---|
| Main specification | Type | | | Water cooled, 4 cycle diesel engine, turbocharged |
| | No. of cylinders - arrangement | | | 4 cylinder in-line |
| | Combustion system | | | Direct injection |
| | Valve mechanism | | | Overhead (2 intake valves, 2 exhaust valves) |
| | Cylinder bore × stroke | | | 102 × 130 mm [4.02 × 5.12 in.] |
| | Displacement | | | 4.249 L [259 cu. in.] |
| | Compression ratio | | | 16.5 : 1 |
| | Fuel | | | Diesel fuel |
| | Firing order | | | 1-3-4-2 |
| | Direction of rotation | | | Counterclockwise when viewed from flywheel side |
| | Dimensions (varies depending on the specifications) | Length | | 881 mm [34.68 in.] |
| | | Width | | 703 mm [27.68 in.] |
| | | Height | | 989 mm [38.94 in.] |
| | Dry weight | | | Approx. 420 kg [926 lbs] |
| Engine main parts | Cylinder sleeve type | | | Dry |
| | Number of piston ring | Compression ring | | 2 |
| | | Oil ring | | 1 (with expander) |
| | Valve timing (when engine is hot) | Inlet valve | Open | BTDC 15° |
| | | | Close | ABDC 45° |
| | | Exhaust valve | Open | BBDC 49° |
| | | | Close | ATDC 15° |
| | Starting system | | | Starter |
| | Starting aid system | | | Air heater |
| Fuel System | Type | | | Common rail fuel injection system |
| | Model number | | | CAT-CR200 |
| | Manufacturer | | | Caterpillar Inc. |
| | Fuel filter type | | | Cartridge type paper element |
| Oil system | Lubricating type | | | Forced circulation type (oil pump pressure feed type) |
| | Engine oil | Classification | | API classification CF-4 or above class |
| | | Total capacity (including oil filter) | | 18.5 L [4.89 US gallons] |
| | Oil pump | Type | | Gear type oil pump |
| | | Delivery capacity | | 66 L [17.4 US gallons]/1800 $min^{-1}$ |
| | Relief valve | Type | | Piston valve type |
| | | Valve opening pressure | | 0.35 ± 0.05 MPa {3.5 ± 0.5 kgf/$cm^2$} [50 ± 7 psi] |
| | Oil cooler type | | | Water-cooled, multi-plate type |
| | Oil filter type | | | Cartridge type paper element |
| | Safety valve opening pressure | | | 1.1 MPa {11 kgf/$cm^2$} [157 psi] |

Table 1-1 Main specifications (2 / 3)

| Engine model | | | D04FD-TAA |
|---|---|---|---|
| Cooling system | Cooling type | | Water-cooled, forced circulation |
| | Coolant capacity (Engine water jacket) | | 6 L [1.59 US gallons] approx. |
| | Water pump | Type | Centrifugal |
| | | Discharge capacity | 174 L [46 US gallons] /1800 $min^{-1}$ |
| | Water pump pulley speed ratio | | Varies depending on the specifications |
| | Fan belt type | | Ribbed belt |
| | Thermostat | Type | Wax type |
| | | Valve opening temperature | 71 ± 2°C [160 ± 3.6°F] |
| Inlet and exhaust system | Turbocharger | Model number | TD04HL |
| | | Qty | 1 |
| Control system | ECM (Electronic Control Module) | Model number | ADEM A4E2 |
| | | Manufacturer | Caterpillar Inc. |

Table 1-1 Main specifications (3 / 3)

| Engine model | | | | D04FD-TAA |
|---|---|---|---|---|
| Electrical system | Starter | Manufacturer | | Mitsubishi Electronic Corporation |
| | | Type | | M008T60471 |
| | | Pinion meshing type | | Pinion shift |
| | | Output | | 24V - 5 kW |
| | | Qty | | 1 |
| | | Ring gear and pinion ratio | | 10/127 |
| | | No-load characteristics | Voltage | 23V |
| | | | Current | 85A or below |
| | | | Speed | 3300 $min^{-1}$ or above |
| | | Load characteristics | Voltage | 9V |
| | | | Current | 1400A or below |
| | | | Torque | 88 N·m {9.0 kgf·m} [65 lbf·ft] or above |
| | | Switching voltage | ON | 16V or below |
| | | | OFF | When circuit is opened, plunger returns |
| | Alternator | Type | | 3-phase alternating current, with rectifier |
| | | Manufacturer | | Mitsubishi Electronic Corporation |
| | | Model number | | A004TU3599 |
| | | Output | | 24V-50A |
| | | Rated voltage generating speed | | 1000 $min^{-1}$ |
| | | Rated output generating speed | | 5000 $min^{-1}$ |
| | | Permissible speed | | 8000 $min^{-1}$ |
| | | Regulated voltage | | 28.5 V ± 0.5V |
| | | Speed ratio (to crank pulley speed) | | Varies depending on specifications. |
| | Air heater | Type | | Electric heater |
| | | Capacity | | 2.1 kW |

## 5. Tips on disassembling and reassembling

This service manual specifies the recommended procedures to be followed when servicing Mitsubishi engines. The manual also specifies the special tools that are required for the work, and the basic safety precautions to follow when working.

Note that this manual does not exhaustively cover potential hazards that could occur during maintenance, inspection and service work of engine.

When working on an engine, follow the relevant directions given in this manual and observe the following instructions:

### 5.1 Disassembling

(1) Use correct tools and instruments. Serious injury or damage to the engine will result from using the wrong tools and instruments.

(2) Use an overhaul stand or work bench if necessary, and follow the disassembling procedures described in this manual.

(3) Keep the engine parts in order of removal to prevent losing them.

(4) Pay attention to assembling marks. Put your marks on the parts , if necessary, to ensure correct reassembling.

(5) Carefully check each part for defects during disassembling or cleaning. Do not miss symptoms which can not be detected after disassembling or cleaning.

(6) When lifting or carrying heavy parts, excercise utmost caution to ensure safety. Pay attention to blance of heavy parts when handling. (Get help, and use jacks, chain blocks and guide bolts as necessary.)

### 5.2 Reassembling

(1) Wash all engine parts, except such parts as oil seals, O-rings and rubber sheets, in cleaning oil and dry them with compressed air.

(2) Use correct tools and instruments.

(3) Use only high-quality lubricating oils and greases of appropriate types. Be sure to apply oil, grease or adhesive to the part wherever specified.

(4) Use a torque wrench to tighten parts correctly when their tightening torques are specified.
Refer to "List of Tightening Torque."

(5) Replace all gaskets and packings with new ones unless specified otherwise. Apply adhesive if necessary. Use only the proper amount of adhesive.

# SERVICE DATA

# 1. Maintenance service data

## 1.1 Engine general

Table 2-1 Maintenance service data table - Engine general Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Maximum revolution speed | | | Varies depending on specifications of destination | | | |
| Minimum revolution speed | | | | | | |
| Compression pressure (at 300 $min^{-1}$) | | | 2.9 MPa {30 kgf/cm²} [427 psi] | | 2.6 MPa {27 kgf/cm²} {[384 psi] | When oil and water temperatures at 20 to 30°C [68 to 86 °F] |
| Lubricating oil pressure | Rated speed | | 0.2 to 0.4 MPa {2 to 4 kgf/cm²} [28.4 to 56.9 psi] | | 0.15 MPa {1.5 kgf/cm²} [21.3 psi] | Oil temperature at 70 to 90 °C [158 to 194 °F] |
| | Low idling | | 0.1 MPa {1 kgf/cm²} [14.2 psi] | | 0.05 MPa {0.5 kgf/cm²} [7.1 psi] | |
| Valve timing | Inlet | Open | BTDC 15° | | | ±3° (crank angle) |
| | | Close | ABDC 45° | | | |
| | Exhaust | Open | BBDC 49° | | | |
| | | Close | ATDC 15° | | | |
| Valve clearance (when cold) | Inlet | | | 0.25 [0.0098] | | |
| | Exhaust | | | 0.40 [0.0157] | | |
| Fan belt deflection | | | | 8 to 10 [0.315 to 0.394] | | Deflection when the belt forcefully pressed with a thumb |

## 1.2 Engine main part

Table 2-2 Maintenance service data table - Engine main part (1 / 4) Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Crankcase | Flatness of top surface | | | 0.05 [0.0020] or less | 0.2 [0.008] | Reface minimum as possible. Total grinding thickness of crankcase top and cylinder head bottom is 0.2 [0.008] max. |
| Cylinder sleeve | Inside diameter | | ø 102 [4.02] | 102.010 to 102.045 [4.0161 to 4.0175] | 102.700 [4.0433] | If limit is exceeded, use oversize sleeve, and hone to +0.010 to +0.045 [0.0004 to 0.0018]. Use oversize piston and piston ring. |
| | Circularity | | | 0.01 [0.0004] or less | | |
| | Cylindricality | | | 0.015 [0.0006] or less | | |
| Main bearing | Clearance between main bearing and crank journal | | | 0.050 to 0.118 [0.0020 to 0.0046] | 0.200 [0.0079] | If the measured value exceeds the standard and is less than the limit, replace bearing. If the limit is exceeded, grind the crank journal, and use undersize bearing. |
| | Width of thrust journals (Thrust clearance) | | | 0.100 to 0.264 [0.0039 to 0.0104] | (0.300) [0.0118] | Replace thrust plate. The limit value means a play in the direction of thrust. |
| Tappet hole | Inside diameter | | ø 22 [0.87] | 22.000 to 22.021 [0.8661 to 0.8670] | 22.100 [0.8701] | Repair limit: 102.200 [4.0236] |
| | Clearance between tappet and tappet hole | | | 0.035 to 0.086 [0.0014 to 0.0034] | 0.120 [0.0047] | Replace tappet if diameter of tappet hole is +0.10 [0.0039] or less. |
| Camshaft bushing | Clearance between bushing and camshaft journal | Front Middle | | 0.04 to 0.09 [0.0016 to 0.0035] | 0.15 [0.0059] | Replace bushing. (Ream if necessary.) |
| | | Rear | | 0.04 to 0.119 [0.0016 to 0.0047] | 0.15 [0.0059] | |
| Cylinder head | Distortion of bottom surface | | | 0.05 [0.0020] or less | 0.2 [0.008] | Reface minimum as possible. Total grinding thickness of crankcase top and cylinder head bottom is 0.2 [0.008] max. |
| | Compressed thickness of gasket | | 1.7 [0.07] | ±0.05 [0.0020] | | |
| Valve and valve guide | Valve stem diameter | Inlet | ø 6.6 [0.260] | 6.565 to 6.580 [0.2585 to 0.2591] | 6.500 [0.2559] | |
| | | Exhaust | | 6.530 to 6.550 [0.2571 to 0.2579] | 6.500 [0.2559] | |
| | Clearance between guide and stem | Inlet | | 0.020 to 0.050 [0.0008 to 0.0020] | 0.100 [0.0039] | |
| | | Exhaust | | 0.050 to 0.085 [0.0020 to 0.0034] | 0.100 [0.0039] | |
| | Height to top of valve guide | | 16 [0.63] | | | |

Table 2-2 Maintenance service data table - Engine main part (2 / 4) Unit: mm [in.]

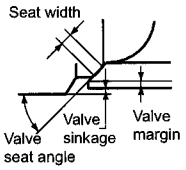
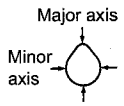
| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Valve seat and valve | Valve seat angle | Inlet | 30° | | |   |
| | | Exhaust | 45° | | | |
| | Valve sinkage | Inlet | 0.3 [0.012] | 0.2 to 0.4 [0.008 to 0.016] | 1.1 [0.0433] | |
| | | Exhaust | 0.3 [0.012] | 0.2 to 0.4 [0.008 to 0.016] | 1.1 [0.0433] | |
| | Seat width | Inlet | 1.0 [0.039] | | 1.4 [0.055] | |
| | | Exhaust | 1.2 [0.047] | | 1.6 [0.063] | |
| | Valve margin | | 1.7 [0.067] | 1.55 to 1.85 [0.0610 to 0.0728] | Refacing permissible up to 1.2 [0.047] | |
| Valve springs | Free length | | | 48.7 [1.917] | 47.3 [1.862] | |
| | Perpendicularity | | | $\theta$ = 2.0° or less<br>$\Delta$ = 1.8 [0.071] or less<br>Lf = 48.7 [1.917] | $\Delta$ = 1.8 [0.071] over entire length |   |
| | Set length/load | | | 42.5 [1.673]/112.1 to 125.9 N {11.3 to 12.7 kgf} [24.9 to 27.9 lbf] | 42.5 [1.673]/103 N {10.5 kgf} [23.1 lbf] | |
| Rocker arm | Rocker bushing inside diameter | | ø 25 [0.98] | 24.949 to 24.975 [0.9822 to 0.9833] | | |
| | Rocker shaft diameter | | ø 25 [0.98] | 24.915 to 24.928 [0.9809 to 0.9814] | | |
| | Clearance between rocker bushing and rocker shaft | | | 0.021 to 0.060 [0.0008 to 0.0024] | 0.078 [0.0031] | |
| Pushrod | Runout | | | 0.4 [0.016] or less | 0.4 [0.016] | TIR |
| Crank shaft | Runout | | | 0.04 [0.0016] or less | 0.10 [0.0039] | TIR |
| | Crank journal diameter | | ø 90 [3.54] | 89.95 to 89.97 [3.5413 to 3.5421] | 89.85 [3.5374] | If the diameter is the limit or above, replace bearing. If the diameter is less than the limit, grind the journal and use undersize bearing. Service limit: 89.10 [3.5079] |
| | Crankpin diameter | | ø 65 [2.56] | 64.945 to 64.965 [2.5569 to 2.5577] | 64.800 [2.5512] | |
| | Distance between centers of journal and crankpin | | 65 [2.56] | ± 0.05 [± 0.002] | | |
| | Parallelism between journal and crankpin | | | Pin maximum defection: 0.01 [0.0004] or less | | |
| | Roundness of journals and crankpins (diameter difference) | | | 0.01 [0.0004] or less | 0.03 [0.0012] | |
| | Cylindricity of journals and crankpins (diameter difference) | | | 0.01 [0.0004] or less | 0.03 [0.0012] | |
| | Fillet radius of journals | | R3 [0.12] | ± 0.2 [± 0.008] | | |
| | Fillet radius of pins | | R4 [0.16] | ± 0.2 [± 0.008] | | |
| | End play | | | 0.100 to 0.264 [0.0039 to 0.0104] | 0.300 [0.0118] | If end play is less than the limit, replace thrust plates. If end play exceeds the limit, replace with oversize thrust plates. |

Table 2-2 Maintenance service data table - Engine main part (3 / 4) Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Pistons | Outside diameter (at piston skirt) | STD | ø 102 [4.02] | 101.915 to 101.945 [4.0124 to 4.0136] | 101.73 [4.0051] | |
| | | 0.25/OS | | 102.165 to 102.195 [4.0222 to 4.0234] | 101.98 [4.0150] | |
| | | 0.25/OS | | 102.415 to 102.445 [4.0321 to 4.0333] | 102.23 [4.0248] | |
| | Protrusion from crankcase | | 0.8 [0.031] | | | Bearing clearance check. Gasket compressed (installed) thickness: 1.7 ± 0.05 [0.067 ± 0.0020] |
| | Clearance between piston pin hole and piston pin | | | 0.005 to 0.021 [0.0002 to 0.0008] | 0.050 [0.0020] | |
| | Weight difference in one engine | | | 5.0 g [0.2 oz.] or less | | |
| | Clearance between piston ring and ring groove | No. 1 compression ring | | 0.08 to 0.12 [0.0031 to 0.0047] | 0.200 [0.0079] | |
| | | No. 2 compression ring | | 0.08 to 0.12 [0.0031 to 0.0047] | 0.150 [0.0059] | |
| | | Oil ring | | 0.025 to 0.065 [0.0010 to 0.0026] | 0.150 [0.0059] | |
| Piston ring | End gap | Compression rings | | 0.30 to 0.45 [0.0118 to 0.0177] | 1.50 [0.0591] | |
| | | Oil ring | | 0.30 to 0.50 [0.0118 to 0.0197] | | |
| Piston pin | Outside diameter | | ø 34 [1.34] | 33.991 to 33.997 [1.3382 to 1.3385] | | |
| | Clearance between pin and connecting rod bushing | | | 0.023 to 0.054 [0.0009 to 0.0021] | 0.080 [0.0031] | |
| | Inside diameter of bushing | | ø 34 [1.34] | 34.020 to 34.045 [1.3394 to 1.3404] | | |
| Connecting rod | Bend and twist | | | 0.05/100 [0.0020/3.94] or less | 0.150 [0.0059] | |
| | Clearance between crankpin and connecting rod bearing | | | 0.035 to 0.100 [0.0014 to 0.0039] | 0.200 [0.0079] | |
| | End play | | | 0.15 to 0.35 [0.0059 to 0.0138] | 0.50 [0.0197] | Replace connecting rod bearings. |
| | Weight difference in one engine | | | 10 g [0.4 oz.]or less | | |
| Flywheel | Flatness | | | 0.15 [0.0059] or less | 0.5 [0.0197] | |
| | Runout | | | 0.15 [0.0059] or less | 0.5 [0.0197] | |

Table 2-2 Maintenance service data table - Engine main part (4 / 4) Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Camshaft | Runout | | | 0.04 [0.0016] or less | 0.10 [0.0039] | TIR<br>Repair using a press, or replace. |
| | Cam lift | Inlet | Major axis $46.446\ ^{+0.1}_{-0.3}$ [$1.8286\ ^{+0.004}_{-0.012}$] | Major axis - minor axis = 6.154 [0.2423] | Major axis - minor axis = 5.654 [0.2226] |  |
| | | Exhaust | Major axis $46.137\ ^{+0.1}_{-0.3}$ [$1.8164\ ^{+0.004}_{-0.012}$] | Major axis - minor axis = 7.463 [0.2938] | Major axis - minor axis = 6.963 [0.2741] | |
| | Journal diameter | Front, middle | ø 54 [2.13] | 53.94 to 53.96 [2.1236 to 2.1244] | 53.90 [2.1220] | |
| | | Rear | ø 53 [2.09] | 52.94 to 52.96 [2.0842 to 2.0850] | 52.90 [2.0827] | |
| | End play | | | 0.10 to 0.25 [0.0039 to 0.0098] | 0.30 [0.0118] | Replace thrust plate. |
| Idler | Clearance between idler bushing and shaft | | | 0.009 to 0.050 [0.0004 to 0.0020] | 0.100 [0.0039] | Replace bushing. |
| | Idler gear end play | | | 0.05 to 0.20 [0.0020 to 0.0079] | 0.35 [0.0138] | Replace thrust plate. |
| | Interference between shaft and crankcase hole | | 35 [1.38] | -0.016 to -0.035 [-0.0006 to -0.0138] | | |
| Timing gear backlash | Between crankshaft gear and idler gear | | | 0.051 to 0.157 [0.0020 to 0.0062] | 0.25 [0.0098] | Replace gear. |
| | Between camshaft gear and idler gear | | | 0.052 to 0.158 [0.0021 to 0.0062] | 0.25 [0.0098] | |
| | Between injection pump gear and idler gear | | | 0.056 to 0.205 [0.0022 to 0.0081] | 0.25 [0.0098] | |

## 1.3 Lubrication system

Table 2-3 Maintenance service data table - Lubrication system Unit: mm [in.]

| | Inspection point | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|
| Oil pump | Backlash between the oil pump idler gear and the idler gear | | 0.096 to 0.228 [0.0038 to 0.0090] | 0.35 [0.0138] | Replace gear. |
| | Backlash between the oil pump idler gear and the oil pump drive gear | | 0.057 to 0.172 [0.0022 to 0.0068] | 0.35 [0.0138] | |
| | End clearance of gears in case | | -0.01 to 0.054 [-0.0004 to 0.0021] | 0.150 [0.0059] | |
| | Radial clearance of gear in case | | 0.05 to 0.098 [0.0020 to 0.0039] | 0.100 [0.0039] | |
| | Clearance between gear shaft and pump body, and clearance between gear shaft and pump cover. | | 0.04 to 0.07 [0.0016 to 0.0028] | 0.15 [0.0059] | |
| | Spindle outside diameter | ø 25 [0.98] | 24.939 to 24.960 [0.9818 to 0.9827] | | |
| | Oil pump idler gear bushing inside diameter | ø 25 [0.98] | 25.000 to 25.021 [0.9843 to 0.9851] | | |
| | Oil pump idler gear end play | | 0.10 to 0.27 [0.0039 to 0.0106] | | |
| Relief valve | Valve opening pressure | | 0.35 ± 0.05 MPa {3.5 ± 0.5 kgf/cm²} [49.8 ± 7.1 psi] | | |
| Safety valve | Valve opening pressure | | 1.1 MPa {11 kgf/cm²} [157 psi] | | |

## 1.4 Cooling system

Table 2-4 List of maintenance standards - Cooling system

Unit: mm [in.]

| Item | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Water pump | Interference between pump shaft and flange | | | 0.035 to 0.065 [0.0014 to 0.0026] | | Reassembling is limited to twice. |
| | Interference between pump shaft and impeller | | | 0.022 to 0.062 [0.0009 to 0.0025] | | Reassembling is limited to twice. |
| | Clearance between impeller and case | | | 0.46 to 1.62 [0.0181 to 0.0638] | | |
| | Unit seal | Carbon protrusion | | 1.5 [0.059] | 0 | |
| | | Free height | | 20.8 to 22.8 [0.819 to 0.898] | | |
| | Inside diameter of pump case bearing fitting portion | | ø52 [2.05] | 51.988 to 52.018 [2.0468 to 2.0479] | | |
| | | | ø62 [2.44] | 61.988 to 62.018 [2.4405 to 2.4416] | | |
| | Bearing | Inside diameter | ø25 [0.98] | 24.880 to 25.000 [0.9795 to 0.9843] | | |
| | | Outside diameter | ø52[2.05] | 51.987 to 52.000 [2.0467 to 2.0472] | | |
| | | | ø62[2.44] | 61.987 to 62.000 [2.4404 to 2.4409] | | |
| | Inside diameter of shaft bearing fitting portion | | ø25 [0.98] | 25.002 to 25.011 [0.9843 to 0.9847] | | |
| Thermostat | Valve opening temperature | | | 71 ± 2°C [160 ± 3.6°F] | | |
| | Temperature at which valve lift becomes 10mm [0.039 in.] or above | | | 85°C [185°F] | | |

## 1.5 Inlet and exhaust system

Table 2-5 List of maintenance standards - Inlet and exhaust system

Unit: mm [in.]

| Item | Nominal | Standard | Limit | Remarks |
|---|---|---|---|---|
| Distortion of exhaust manifold | | 0.2 [0.008] or less | | |

## 1.6 Electrical system

Table 2-6 List of maintenance standards - Electrical system

Unit: mm [in.]

| Item | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Starter | Commutator diameter | | | 32.0 [1.259] | 31.4 [1.236] | |
| | Commutator runout | | | 0.03 or below [0.0012 or below] | 0.10 [0.0039] | |
| | Undercut depth | | | | 0.2 [0.008] | |
| | Brush | Height | | 18 [0.71] | 11 [0.43] | |
| | | Spring tension | 34 N {3.5 kgf} [25 lbf] | 29 to 39 N {3.0 to 4.0 kgf} [6.6 to 8.8 lbf] | 13.7 N {1.4 kgf} [3.0 lbf] | |
| | Pinion gap | | 0.5 to 2.0 [0.02 to 0.08] | | | |

# 2. List of tightening torque

## 2.1 Major bolts and nuts tightening torque

### 2.1.1 Basic engine

Table 2-7 Major bolts and nuts tightening torque - Basic engine

| Item | Threads Dia x Pitch (mm) | Tightening torque | | | Remark |
|---|---|---|---|---|---|
| | | N·m | kgf·m | lbf·ft | |
| Cylinder head bolt | 12 × 1.75 | 137 ± 5 | 14 ± 0.5 | 101 ± 3.6 | [Wet] |
| Rocker cover bolt | 8 × 1.25 | 18 ± 2 | 1.8 ± 0.2 | 13 ± 1.4 | |
| Rocker shaft bracket bolt | 8 × 1.25 | 18 ± 2 | 1.8 ± 0.2 | 13 ± 1.4 | |
| Main bearing cap bolt | 14 × 2 | 137 ± 5 | 14 ± 0.5 | 101 ± 3.6 | [Wet] |
| Connecting rod cap nut | 12 × 1.25 | 103 ± 5 | 10.5 ± 0.5 | 76 ± 3.6 | [Wet] |
| Flywheel bolt | 12 × 1.25 | 83 ± 5 | 8.5 ± 0.5 | 62 ± 3.6 | |
| Camshaft thrust plate bolt | 8 × 1.25 | 12 ± 2 | 1.2 ± 0.2 | 9 ± 1.4 | |
| Front plate bolt | 10 × 1.5 | 35 ± 5 | 3.6 ± 0.5 | 26 ± 3.6 | |
| Timing gear case bolt | 10 × 1.5 | 35 ± 5 | 3.6 ± 0.5 | 26 ± 3.6 | |
| Crankshaft pulley nut | 30 × 1.5 | 706 ± 59 | 72 ± 6 | 521 ± 43 | |
| Idler thrust plate bolt | 10 × 1.25 | 34 ± 5 | 3.5 ± 0.5 | 25 ± 3.6 | |
| Piston cooling nozzle | 12 × 1.25 | 34 ± 5 | 3.5 ± 0.5 | 25 ± 3.6 | |
| Oil pan bolt | 8 × 1.25 | 18 ± 2 | 1.8 ± 0.2 | 13 ± 1.4 | |
| Oil pan drain cock | 24 × 1.5 | 49 ± 5 | 5 ± 0.5 | 36 ± 3.6 | |
| Oil pan drain plug | 24 × 1.5 | 83 ± 10 | 8.5 ± 1 | 62 ± 7.2 | |
| Lifting bolt | 12 × 1.75 | 108 ± 5 | 11 ± 0.5 | 80 ± 3.6 | |

### 2.1.2 Fuel system

Table 2-8 Major bolts and nuts tightening torque -Fuel system

| Item | Threads Dia x Pitch (mm) | Tightening torque | | | Remark |
|---|---|---|---|---|---|
| | | N·m | kgf·m | lbf·ft | |
| Nozzle gland | 8 × 1.25 | 29.4 ± 2.9 | 3 ± 0.3 | 22 ± 2.2 | |
| Fuel relief pipe mounting eye bolt | 12 × 1.25 | $25^{+2.5}_{0}$ | $2.5^{+0.25}_{0}$ | $18^{+1.8}_{0}$ | |
| Fuel pump gear nut | 14 × 1.5 | 90 ± 6 | 9.2 ± 0.6 | 66.5 ± 4.3 | |
| Fuel pipe nut | 14 × 1.5 | 41 ± 5 | 4.2 ± 0.5 | 30.4 ± 3.6 | |
| Fuel pump oil feed pipe | 12 × 1.0 | 19.5 ± 3.5 | 2.0 ± 0.4 | 14.5 ± 2.9 | |
| Fuel hose mounting eye bolt | 14 × 1.5 | 34 ± 4 | 3.4 ± 0.4 | 24.6 ± 2.9 | |
| Fuel injector leak off pipe eye bolt | 10 × 1.25 | 15 ± 2 | 1.5 ± 0.2 | 10.8 ± 1.4 | |
| Fuel hose connector | 12 × 1.5 | $25^{+2.5}_{0}$ | $2.5^{+0.25}_{0}$ | $18^{+1.8}_{0}$ | |
| Fuel hose | 11/16 × 16UN | 26 ± 3 | 2.5 ± 0.3 | 18 ± 2.2 | |
| Fuel filter air bleed plug | 8 × 1.25 | 8.8 ± 1.0 | 0.9 ± 0.1 | 6.5 ± 0.7 | |
| Fuel pump oil feed pipe connector (pump side) | 12 × 10 | $15^{+1.5}_{0}$ | $1.5^{+0.15}_{0}$ | $11^{+1.1}_{0}$ | |
| Fuel pump oil feed pipe connector (crankcase side) | 12 × 10 | 18 ± 3.5 | 1.8 ± 0.35 | 13 ± 2.5 | |

### 2.1.3 Lubrication system

Table 2-9 Major bolts and nuts tightening torque - Lubrication system

| Item | Threads Dia × Pitch (mm) | Tightening torque | | | Remark |
|---|---|---|---|---|---|
| | | N·m | kgf·m | lbf·ft | |
| Relief valve | 22 × 1.5 | 49 ± 4.9 | 5 ± 0.5 | 36.2 ± 3.6 | |
| Relief valve plug | 18 × 1.5 | 44 ± 4.9 | 4.5 ± 0.5 | 32.5 ± 3.6 | |
| Safety valve | 18 × 1.5 | 69 ± 4.9 | 7 ± 0.5 | 50.6 ± 3.6 | |
| Oil pump cover bolt | 10 × 1.5 | 33 ± 3.3 | 3.4 ± 0.34 | 24.6 ± 2.5 | |
| Turbocharger oil feed eye bolt | 10 × 1.25 | 17 ± 2 | 1.7 ± 0.2 | 12.3 ± 1.4 | |

### 2.1.4 Inlet and exhaust system

Table 2-10 Major bolts and nuts tightening torque - Inlet and exhaust system

| Item | | Threads Dia × Pitch (mm) | Tightening torque | | | Remark |
|---|---|---|---|---|---|---|
| | | | N·m | kgf·m | lbf·ft | |
| Air heater terminal nut | Terminal side | 6 × 1 | 12.75 ± 1 | 1.3 ± 0.1 | 9.4 ± 0.7 | |
| | Short bar side | 6 × 1 | 7.35 ± 1.5 | 0.75 ± 0.15 | 5.4 ± 1.1 | |
| Air heater terminal flange nut | | 6 × 1 | 8.8 ± 1 | 0.9 ± 0.1 | 6.5 ± 0.7 | |
| Inlet manifold bolt | | 8 × 1.25 | 18 ± 2 | 1.8 ± 0.2 | 13 ± 1.4 | |
| Exhaust manifold nut | | 8 × 1.25 | 18 ± 2 | 1.8 ± 0.2 | 13 ± 1.4 | |

### 2.1.5 Electrical system

Table 2-11 Major bolts and nuts tightening torque - Electrical system

| Item | Threads Dia x Pitch (mm) | Tightening torque | | | Remark |
|---|---|---|---|---|---|
| | | N·m | kgf·m | lbf·ft | |
| Starter B terminal | 8 × 1.25 | 9.9 ± 1 | 1 ± 0.1 | 7.2 ± 0.7 | |
| Alternator E terminal | 6 × 1 | 5 ± 1 | 0.5 ± 0.1 | 3.6 ± 0.7 | |
| Alternator B terminal | 5 × 0.8 | 2.75 ± 0.35 | 0.27 ± 0.03 | 2.0 ± 0.2 | |
| Alternator pulley nut | 20 × 1.5 | 147 ± 15 | 15 ± 1.5 | 108 ± 11 | |
| Alternator through bolt | 6 × 1 | 5.4 ± 1.5 | 0.54 ± 0.15 | 3.9 ± 1.1 | |

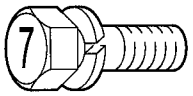
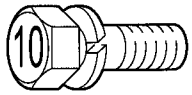
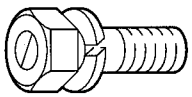
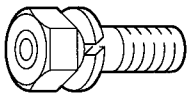
### 2.1.6 Sensors and ECM

Table 2-12 Major bolts and nuts tightening torque - Sensors and ECM

| Item | Threads Dia x Pitch (mm) | Tightening torque | | | Remark |
|---|---|---|---|---|---|
| | | N·m | kgf·m | lbf·ft | |
| Water temperature sensor<br>Charge air temperature sensor | M12 ± 1.5 | 15 ± 3 | 1.5 ± 0.3 | 10.8 ± 2.2 | |
| Boost pressure sensor | M14 ± 1.5 | 10 ± 2 | 1 ± 0.2 | 7.2 ± 1.4 | |
| Engine oil pressure sensor | M12 ± 1.5 | 10 ± 2 | 1 ± 0.2 | 7.2 ± 1.4 | |
| Common rail pressure sensor | M12 ± 1.5 | 34 ± 6 | 3.4 ± 0.6 | 24.6 ± 4.3 | |
| Speed/timing sensor (crankshaft side) | M8 ± 1.25 | 17 ± 1.7 | 1.65 ± 0.15 | 11.9 ± 1.1 | |
| ECM connector mounting hexagon bolt | - | 5 ± 1 | 0.50 ± 0.10 | 3.7 ± 0.7 | |
| Relay connector mounting hexagon bolt | - | 2.8 ± 0.3 | 0.29 ± 0.03 | 2.07 ± 0.22 | |

## 2.2 Standard bolt and nut tightening torque

Table 2-13 Standard bolt and nut tightening torque

| Description | Thread Dia × Pitch (mm) | Width across flats (mm) [in.] | Strength classification | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7T | | | 10.9 | | |
| | | |  | | |  | | |
| | | | N·m | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft |
| Metric automobile screw thread | M8 × 1.25 | 12 [0.47] | 17 | 1.7 | 12 | 30 | 3.1 | 22 |
| | M10 × 1.25 | 14 [0.55] | 33 | 3.4 | 25 | 60 | 6.1 | 44 |
| | M12 × 1.25 | 17 [0.67] | 60 | 6.1 | 44 | 108 | 11.0 | 80 |
| | M14 × 1.5 | 22 [0.87] | 97 | 9.9 | 72 | 176 | 17.9 | 129 |
| | M16 × 1.5 | 24 [0.94] | 145 | 14.8 | 107 | 262 | 26.7 | 193 |
| | M18 × 1.5 | 27 [1.06] | 210 | 21.4 | 155 | 378 | 38.5 | 278 |
| | M20 × 1.5 | 30 [1.18] | 291 | 29.7 | 215 | 524 | 53.4 | 386 |
| | M22 × 1.5 | 32 [1.26] | 385 | 39.3 | 284 | 694 | 70.8 | 512 |
| | M24 × 1.5 | 36 [1.42] | 487 | 49.7 | 359 | 878 | 89.5 | 647 |
| | M27 × 1.5 | 41 [1.61] | 738 | 75.3 | 544 | 1328 | 135.5 | 980 |
| | | |  | | |  | | |
| | | | N·m | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft |
| Metric course screw thread | M10 × 1.5 | 14 [0.55] | 32 | 3.3 | 24 | 58 | 5.9 | 43 |
| | M12 × 1.75 | 17 [0.67] | 57 | 5.8 | 42 | 102 | 10.4 | 75 |
| | M14 × 2 | 22 [0.87] | 93 | 9.5 | 69 | 167 | 17.0 | 123 |
| | M16 × 2 | 24 [0.94] | 139 | 14.2 | 103 | 251 | 25.6 | 185 |
| | M18 × 2.5 | 27 [1.06] | 194 | 19.8 | 143 | 350 | 35.7 | 258 |
| | M20 × 2.5 | 30 [1.18] | 272 | 27.7 | 200 | 489 | 49.9 | 361 |
| | M22 × 2.5 | 32 [1.26] | 363 | 37.0 | 268 | 653 | 66.6 | 482 |
| | M24 × 3 | 36 [1.42] | 468 | 47.7 | 345 | 843 | 86.0 | 622 |
| | M27 × 3 | 41 [1.61] | 686 | 70.0 | 506 | 1236 | 126.0 | 911 |

Note: (a) This table lists the tightening torque for standard bolts and nuts.

(b) The numerical values in the table are for fasteners with spring washers.

(c) The table shows the standard values with a maximum tolerance value of ±10%.

(d) Use the tightening torque in this table unless otherwise specified.

(e) Do not apply oil to threaded sections. (Dry)

## 2.3 Standard eyebolt tightening torque

Table 2-14 Standard eyebolt tightening torque

| Threads Dia × Pitch (mm) | Width across flats (mm) [in.] | Strength classification | | |
|---|---|---|---|---|
| | | 4T | | |
| | | N·m | kgf·m | lbf·ft |
| M8 × 1.25 | 12 [0.47] | 8 ± 1 | 0.8 ± 0.1 | 5.8 ± 0.7 |
| M10 × 1.25 | 14 [0.55] | 15 ± 2 | 1.5 ± 0.2 | 11 ± 1.5 |
| M12 × 1.25 | 17 [0.67] | 25 ± 3 | 2.5 ± 0.3 | 18 ± 2.2 |
| M14 × 1.5 | 19 [0.75] | 34 ± 4 | 3.5 ± 0.4 | 25 ± 2.9 |
| M16 × 1.5 | 22 [0.87] | 44 ± 5 | 4.5 ± 0.5 | 33 ± 3.6 |
| M18 × 1.5 | 24 [0.94] | 74 ± 5 | 7.5 ± 0.5 | 54 ± 3.6 |
| M20 × 1.5 | 27 [1.06] | 98 ± 10 | 10.0 ± 1.0 | 72 ± 7.2 |
| M24 × 1.5 | 32 [1.26] | 147 ± 15 | 15.0 ± 1.5 | 109 ± 11 |
| M27 × 1.5 | 41 [1.61] | 226 ± 20 | 23.0 ± 2.0 | 166 ± 15 |

(Dry)

## 2.4 Standard union nut tightening torque

Table 2-15 Standard union nut tightening torque

| Nominal diameter | Cap nut size M (mm) | Width across flats (mm) [in.] | N·m | kgf·m | lbf·ft |
|---|---|---|---|---|---|
| 63 | M14 × 1.5 | 19 [0.75] | 39 | 4 | 29 |
| 80 | M16 × 1.5 | 22 [0.87] | 49 | 5 | 36 |
| 100 | M20 × 1.5 | 27 [1.06] | 78 | 8 | 58 |
| 120 | M22 × 1.5 | 30 [1.18] | 98 | 10 | 72 |
| 150 | M27 × 1.5 | 32 [1.26] | 157 | 16 | 116 |
| 180 | M30 × 1.5 | 36 [1.42] | 196 | 20 | 145 |
| 200 | M30 × 1.5 | 36 [1.42] | 196 | 20 | 145 |
| 220 | M33 × 1.5 | 41 [1.61] | 245 | 25 | 181 |
| 254 | M36 × 1.5 | 41 [1.61] | 294 | 30 | 217 |

(Maximum tolerance value: ±10%, dry)

# BASIC AND SPECIAL TOOLS

## 1. Special tools

Table 3-1 List of Special Tools (1 / 4)

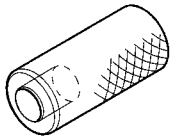
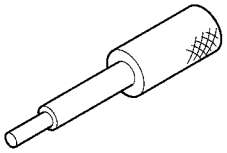
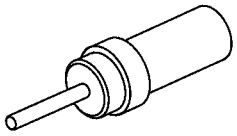
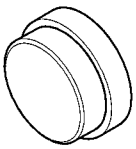
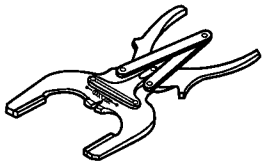
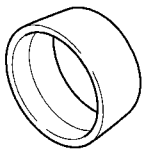
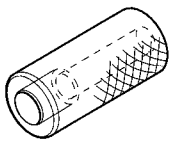
| Tool name | Part number | Illustration | Use |
|---|---|---|---|
| Valve guide installer | 32F91-00400 |  | Valve guide installation |
| Valve guide remover | 32F91-00300 |  | Valve guide removal |
| Insert caulking tool | 32F91-00100 (Inlet) 32F91-00200 (Exhaust) |  | Valve seat installation |
| Sleeve installer | 34291-00200 |  | Cylinder sleeve installation |
| Piston ring pliers | 30091-07100 |  | Piston ring removal/ installation |
| Piston guide | 34291-00100 |  | Piston installation |
| Stem seal installer | 32F91-00500 |  | Steam seal installation |

Table 3-1 List of Special Tools (2 / 4)

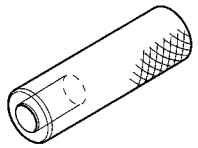
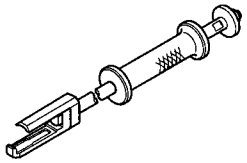
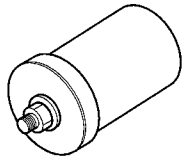
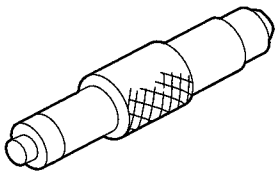
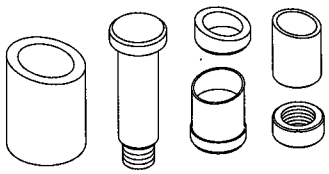
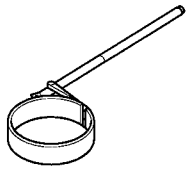
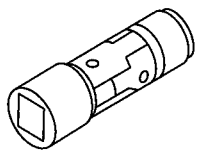
| Tool name | Part number | Illustration | Use |
|---|---|---|---|
| Bridge guide installer | 32F91-00600 |  | Bridge guide installation |
| Injector remover | 32F91-03030 |  | Injector removal |
| Idler shaft puller | MH061077 |  | Idler shaft removal |
| Idler bushing puller | 30091-07300 |  | Idler bushing removal/ installation |
| Connecting rod bushing installer | 32F91-03050 |  | Connecting rod bushing removal/installation |
| Oil filter wrench | 34591-00100 |  | Oil and fuel filters removal/ installation |
| Universal extension | 30091-01101 |  | Fuel injection pump removal/installation |

Table 3-1 List of Special Tools (3 / 4)

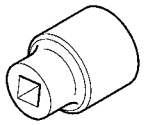
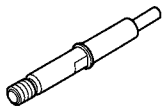
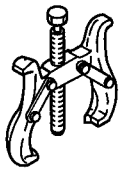
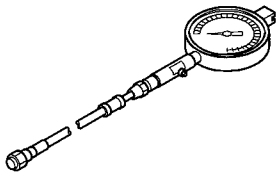
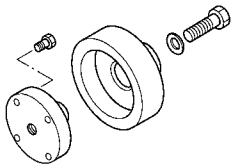
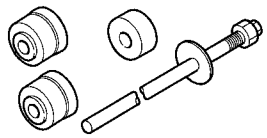
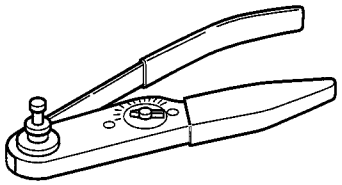
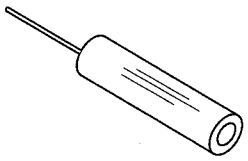
| Tool name | Part number | Illustration | Use |
|---|---|---|---|
| Socket | 58309-73100 |  | Engine turning |
| Gauge adapter | 32F91-00700 |  | Engine compression pressure measurement |
| Puller assembly | 64309-12900 |  | Removal for crankshaft gear,<br>Camshaft gear, and<br>Crankshaft pulley |
| Compression gauge | 33391-02100 |  | Compression pressure measurement |
| Rear oil seal installer | 34291-00020 |  | Oil seal sleeve installation on the crankshaft rear side |
| Camshaft bushing installer set | 30691-00010 |  | Camshaft bushing removal/ installation |
| Crimp tool | 32E91-03100 |  | Terminals replacement |

Table 3-1 List of Special Tools (4 / 4)

| Tool name | Part number | Illustration | Use |
|---|---|---|---|
| Extract tool | 32E91-03300 |  | Harness connector terminal removal |

# OVERHAUL INSTRUCTIONS

## 1. Determining overhaul timing

In most cases, the engine should be overhauled when the compression pressure of the engine becomes low. An increase in engine oil consumption and blow-by gas are also considered to evaluate the engine condition. Besides, such symptoms as a decrease in output, increase in fuel consumption, decrease in oil pressure, difficulty of engine starting and increase in noise are also considered for judging the overhaul timing, althrough those symptoms are often affected by other causes, and are not always effective to judge the overhaul timing. Decreased compression pressure shows a variety of symptoms and engine conditions, thus making it difficult to accurately determine when the engine needs an overhaul. The following shows typical problems caused by reduced compression pressure.

(1) Decreased output power
(2) Increased fuel consumption
(3) Increased engine oil consumption
(4) Increased blow-by gas through the breather due to worn cylinder liners and piston rings (Visually check the blow-by amount)
(5) Increased gas leakage due to poor seating of inlet and exhaust valves
(6) Difficulty in starting
(7) Increased noise from engine parts
(8) Abnormal exhaust color after warm-up operation

The engine can exhibit these conditions in various combinations. Some of these problems are directly caused by worn engine parts, while others are not. Phenomena described in items (2) and (6) will result from improper fuel injection volume, fuel injection timing, worn plunger, faulty nozzles and also faulty conditions of electrical devices such as battery and starter. The most valid reason to overhaul an engine is a decrease in compression pressure due to worn cylinder liners and pistons, as described in item (4). In addition to this item, it is reasonable to take other problems into consideration for making the total judgment.

## 2. Testing compression pressure

**CAUTION**

(a) Measure all cylinders for compression pressure. Do not measure only one cylinder and make assumption about the other cylinders as it will lead to a wrong conclusion.

(b) Compression pressure varies depending on the engine speed. When measuring the compression pressure, be sure to measure the engine speed as well.

(c) It is important to regularly check the compression pressure so that you can tell the change with time.

(1) Disconnect the main harness from the relay connector.

(2) Disconnect the high pressure pump solenoid connector from the high pressure pump solenoid sensor.

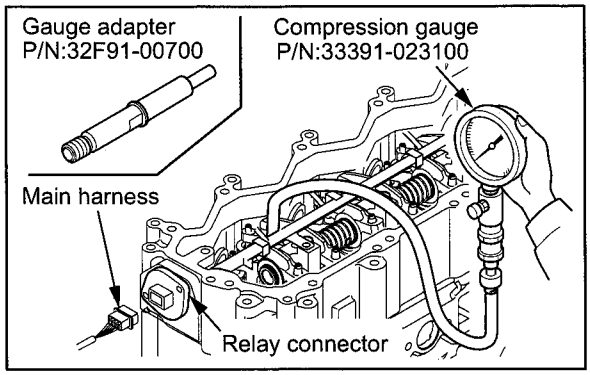
(3) Select a cylinder, and remove the injector in the cylinder. (Each cylinder is tested one at a time.)

(4) Install a gauge adapter in the same location that the injector was mounted, and install a compression gauge to the gauge adapter.

(5) Start the engine using starter. With the engine running at specified speed, read the compression gauge.

(6) If the measured value is at the limit or below, overhaul the engine.

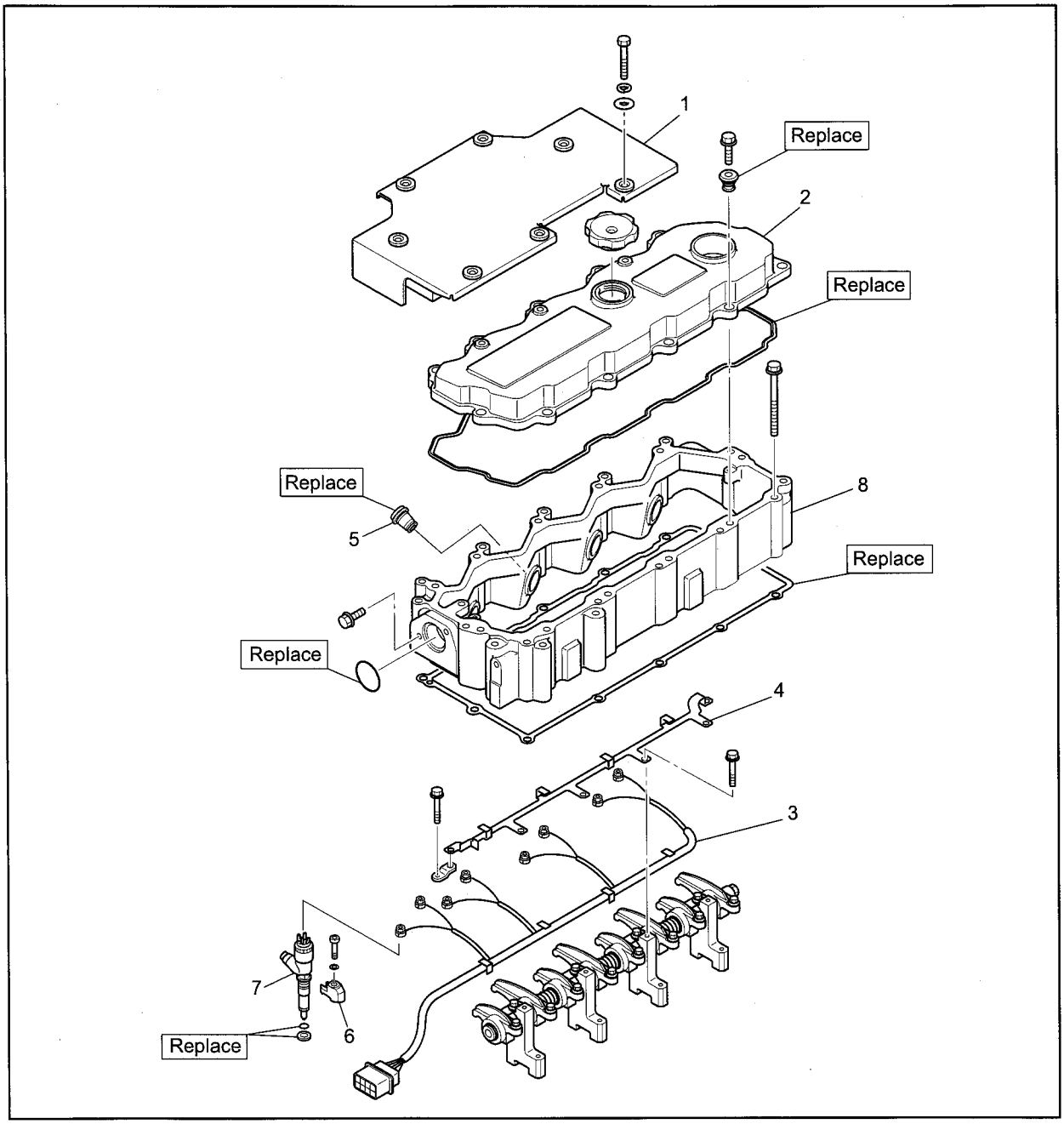
| Item | Standard | Limit |
|---|---|---|
| Engine speed | 300 $min^{-1}$ | - |
| Compression pressure | 2.9 MPa {30kgf/$cm^2$} [427 psi] | 2.6 MPa {27 kgf/$cm^2$} [384 psi] or above |




Testing compression pressure

# DISASSEMBLING ENGINE MAIN PARTS

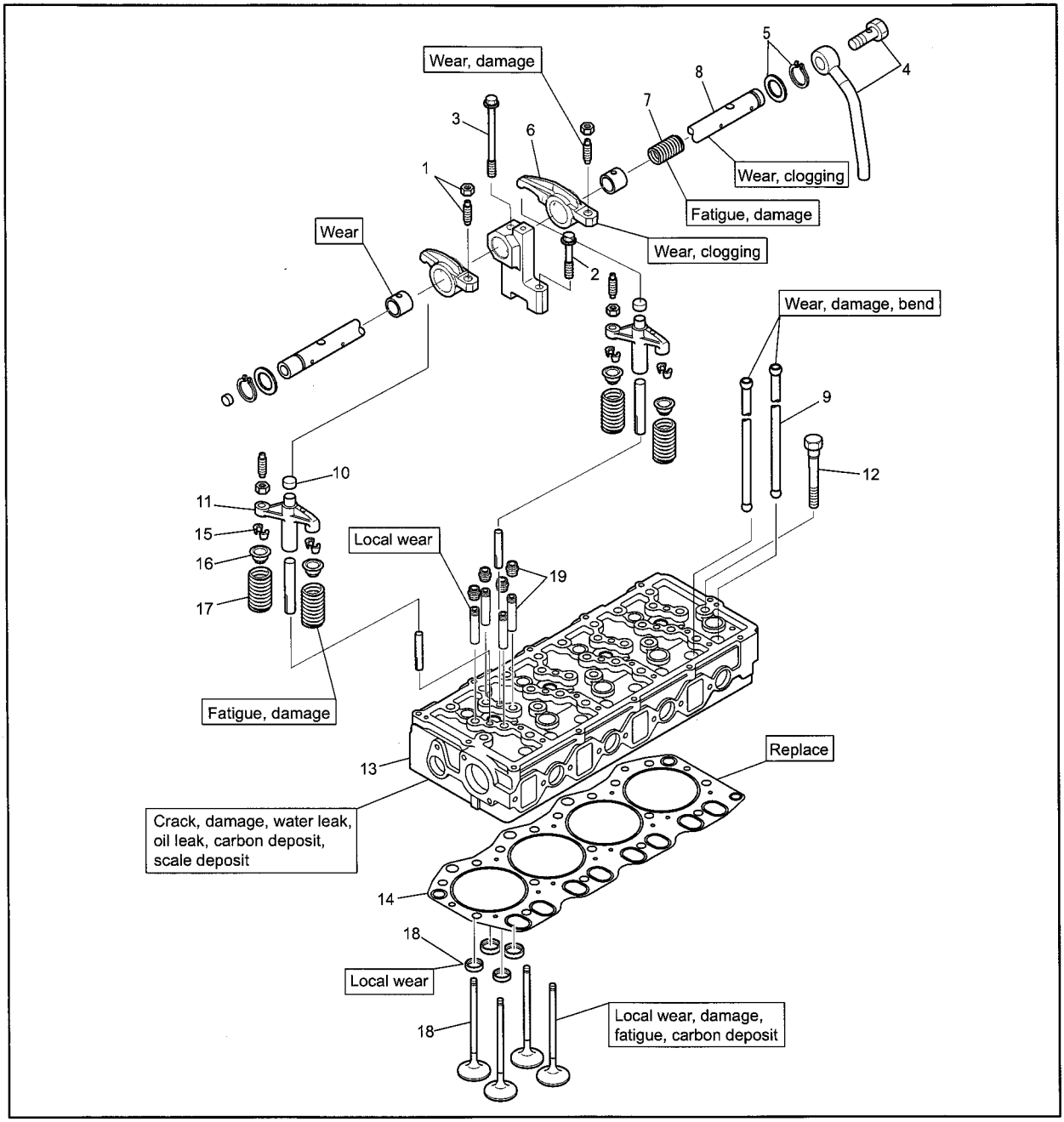
## 1. Disassembling and inspecting cylinder head and valve mechanism




Removing rocker case and injector

Disassembling sequence

1 Pipe cover
2 Rocker cover
3 Harness
4 Harness bracket
5 Injection seal
6 Nozzle gland
7 Injector
8 Rocker case



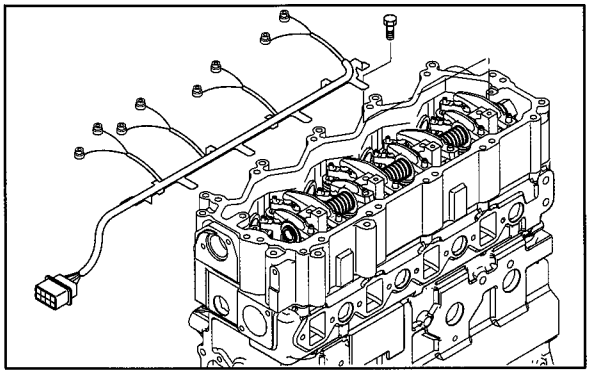

Disassembling and inspecting cylinder head and valve mechanism

Disassembling sequence

1 Adjusting screw
2 Bolt (short)
3 Bolt (long)
4 Eye bolt , oil pipe
5 Snap ring , spacer
6 Rocker arm
7 Rocker shaft spring
8 Rocker shaft
9 Pushrod
10 Bridge cap
11 Valve bridge
12 Cylinder head bolt
13 Cylinder head
14 Gasket
15 Valve cotter
16 Valve retainer
17 Valve spring
18 Valve , valve seat
19 Stem seal , valve guide

### 1.1 Removing harness

(1) Loosen the nuts of harness, and disconnect the harness from the injector.
(2) Remove the harness bracket together with the harness.

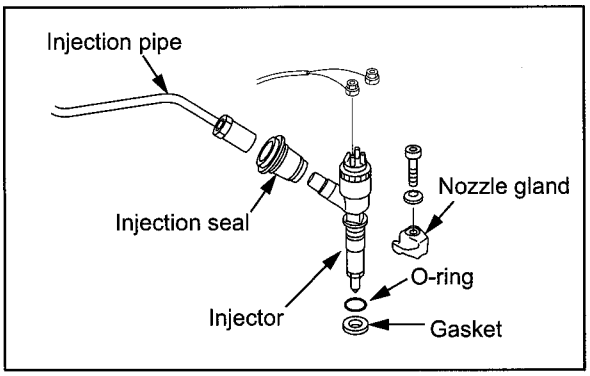


Removing harness

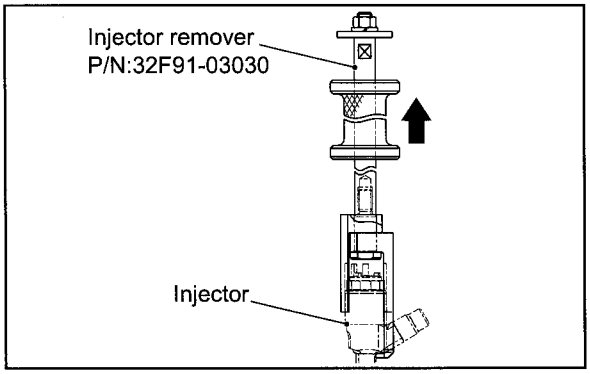
### 1.2 Removing injector

(1) Remove the injection pipe.
(2) Remove the injection seal.
(3) Using an injector remover, remove the injector together with the nozzle gland.
(4) Remove the gasket from cylinder head injector insertion opening.

Note: Make a note of the injector serial number of each cylinder. If reusing the injector, be sure to reinstall the injector to the same cylinder.
When replacing the injector with a new one, refer to "Troubleshooting."



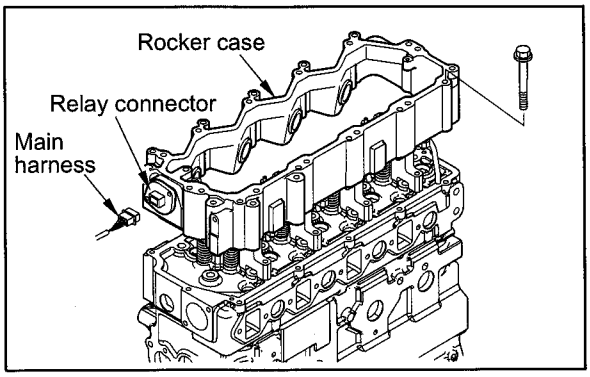

Removing injector




Pulling out injector

### 1.3 Removing rocker case

(1) Disconnect the relay connector from the main harness.
(2) Loosen the rocker case mounting bolts, and remove the rocker case from the cylinder head.



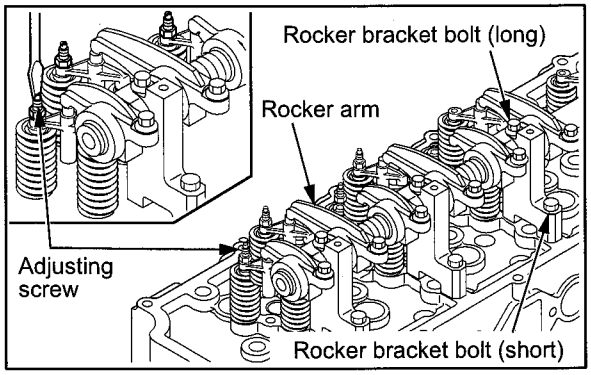

Removing rocker case

### 1.4 Removing rocker shaft assembly

**⚠ CAUTION**

Always loosen shorter bolts first. Failing that may cause the damage to the rocker shaft bracket.

(1) Loosen the rocker arm adjusting screws by rotating about one turn.
(2) Loosen shorter rocker bracket bolts first.
(3) Then, loosen longer rocker bracket bolts.
(4) Remove the rokcer bracket bolts, and remove the rocker shaft assembly from the cylinder head.
(5) Remove push rods.

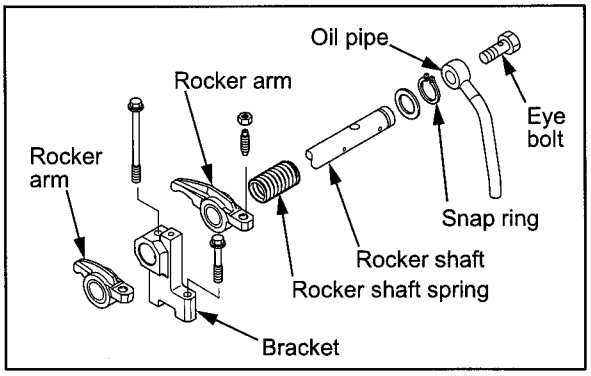



Removing rocker shaft assembly

### 1.5 Disassembling rocker shaft assembly

(1) Remove eye bolt, oil pipe, and snap ring.
(2) Separate the rocker shaft assembly into the rocker arms, brakets, rocker shaft springs and rocker shaft.

Note: Be sure to arrange the disassembled rocker shaft assembly in the order. When reassembling the rocker shaft assembly, reassemble it in the reverse order of disassembling. This is to ensure the correct order of locker arms to restore original clearances between the rocker arms and rocker shaft on reassembly.

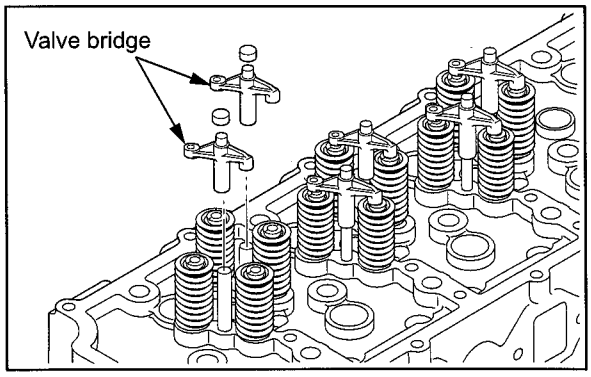



Disassembling rocker shaft assembly

### 1.6 Removing valve bridge

Remove the valve bridge and bridge cap.

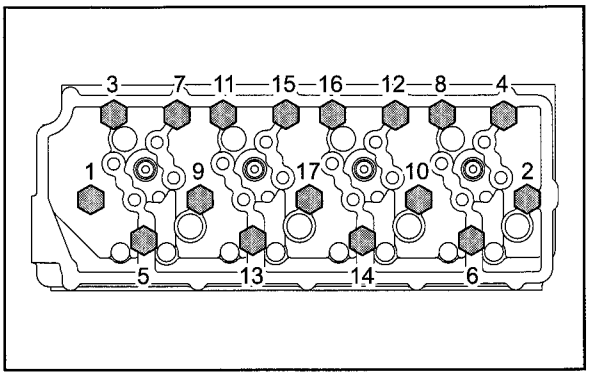
Note: Be careful not to drop bridge caps into the crankcase through the pushrod holes.




Removing valve bridge

### 1.7 Removing cylinder head bolt

Loosen cylinder head bolts in the numerical order as shown in the illustration.




Removing cylinder head bolt

### 1.8 Removing cylinder head assembly

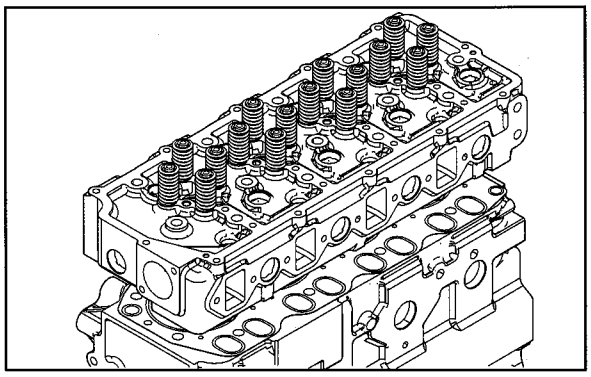
(1) Lift up the cylinder head assembly to remove.

Note: If the cylinder head assembly cannot be removed due to crimping of the cylinder head gasket, tap the thick area on the side of the cylinder head to give a shock.

(2) Remove the gasket from the cylinder head.

Note: (a) Be careful not to damage the fitting surfaces of the gasket when removing the gasket from the cylinder head.

(b) Before removing the cylinder head bolts, check the cylinder head components for any defects or faults. If any of them is faulty or defective, check the bolts for tightness with a torque wrench.



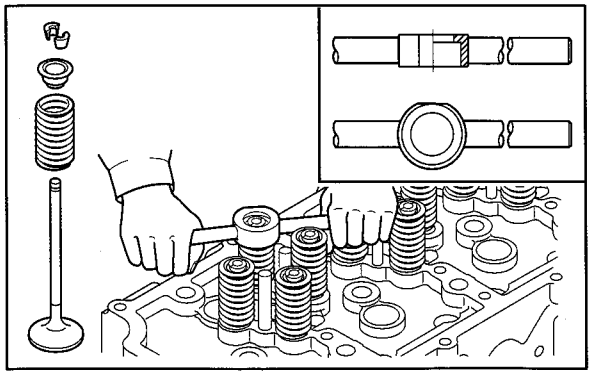
Removing cylinder head assembly

### 1.9 Removing valves and valve springs

(1) Using a valve spring pusher, compress the valve spring equally, and remove the valve cotter.

(2) Remove the valve retainer, valve spring and valve.

Note: If the valves are reusable, mark them so that their original positions are easily identified. Never change the combination of valve sheet and valve guide when reassembling.

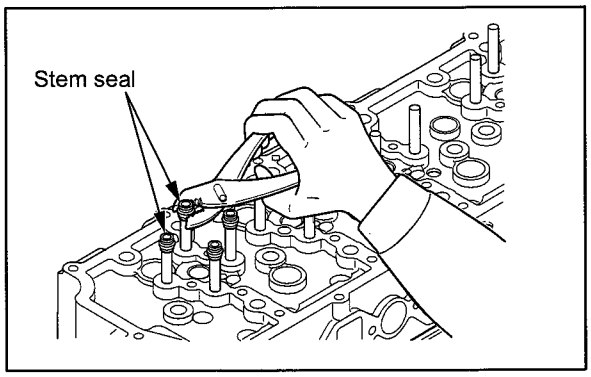


Removing valves and valve springs

### 1.10 Removing valve stem seal

Grab the stem seal with pliers and remove.

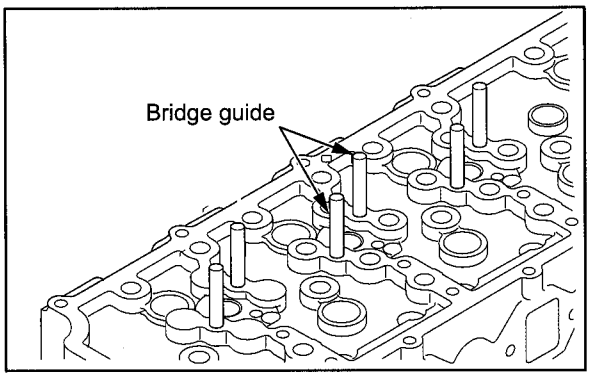
Note: Be sure to replace the stem seal when reassembling the valve and valve spring.




Removing valve stem seal

### 1.11 Bridge guide

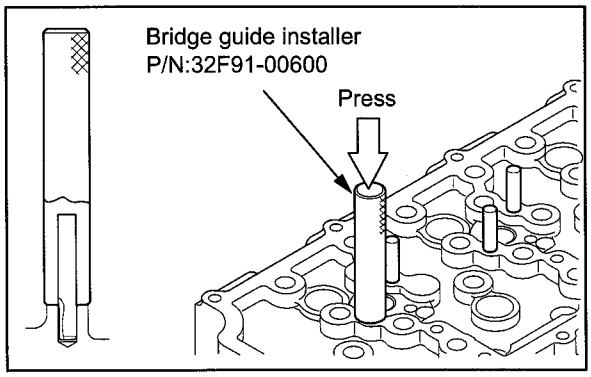
Do not remove bridge guides from the cylinder head unless it is necessary.




Bridge guide

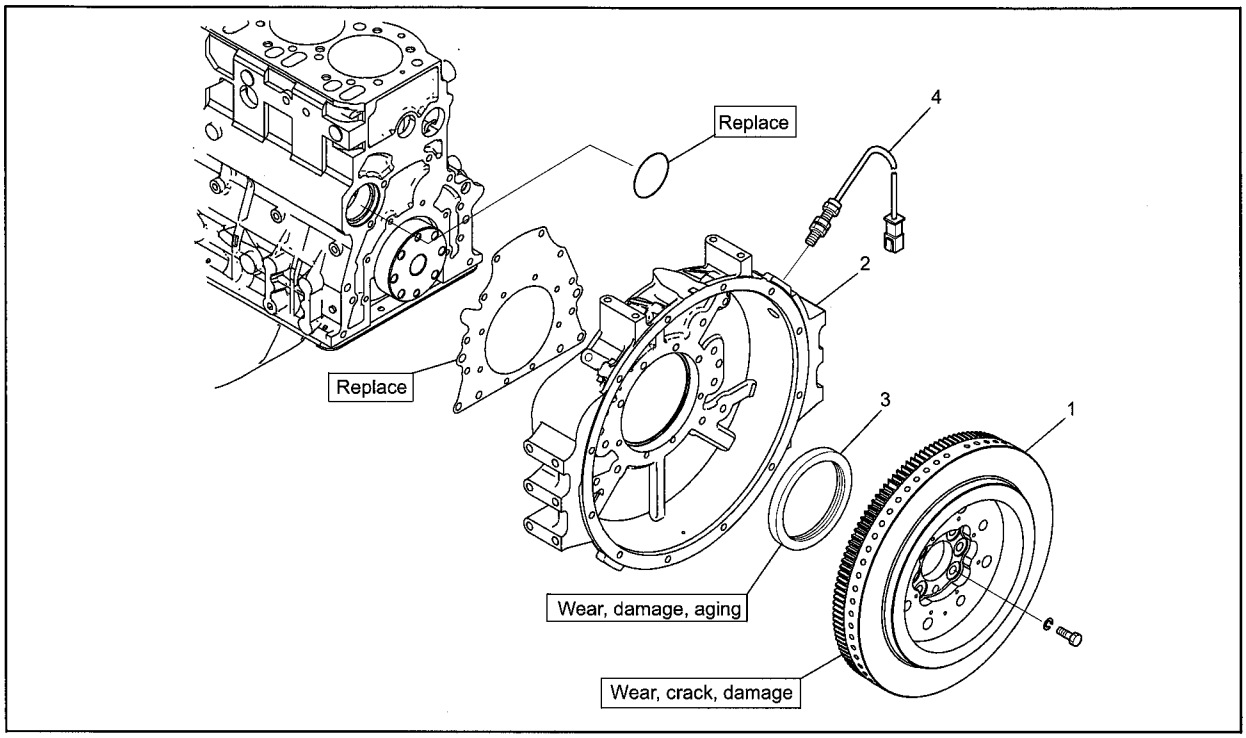
### 1.12 Installing bridge guide

If bridge guides have been removed, install bridge guides using a bridge guide installer.




Installing bridge guide

## 2. Disassembling and inspecting flywheel




Disassembling and inspecting flywheel

Disassembling sequence

1 Flywheel
2 Flywheel housing
3 Oil seal
4 Pick up

### 2.1 Removing flywheel

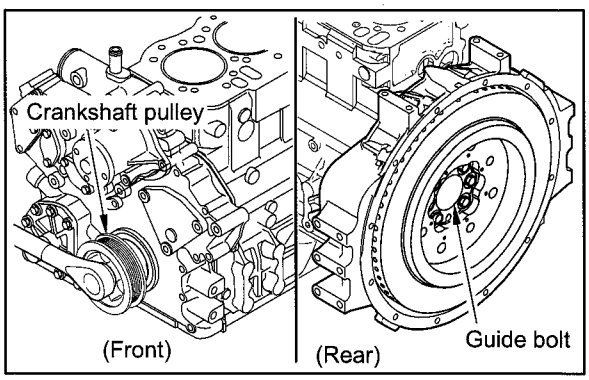
**⚠ CAUTION**

(a) Be careful not to cut your hands with the ring gear when pulling out the flywheel.
Be careful not to drop or hit the flywheel when removing.

(b) The personnel who holds the pulley must pay due attention to safety.
Also, personnel must stay in close contact with each other during work.

(1) One personnel must firmly hold the pulley with a wrench to prevent the flywheel from turning.
(2) Remove one bolt from the flywheel.
(3) Screw a guide bolt into the threaded hole of the bolt that has been removed.
(4) Remove remaining bolts from the flywheel.
(5) Hold the flywheel firmly with both hands, and by moving it back and forth, pull it out straight.

Note: The ring gear is shrink fitted to the flywheel. Do not remove it unless defective.




Removing flywheel

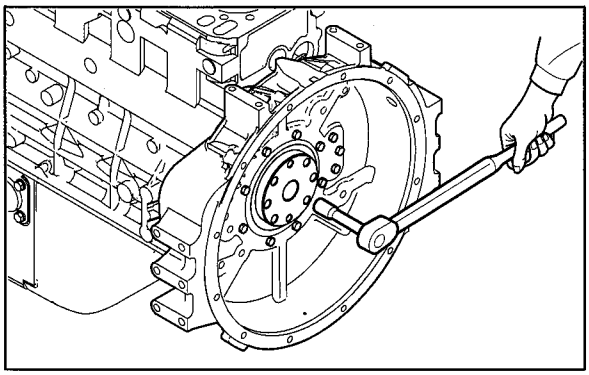
### 2.2 Removing flywheel housing

**CAUTION**

Be careful not to damage the oil seal.

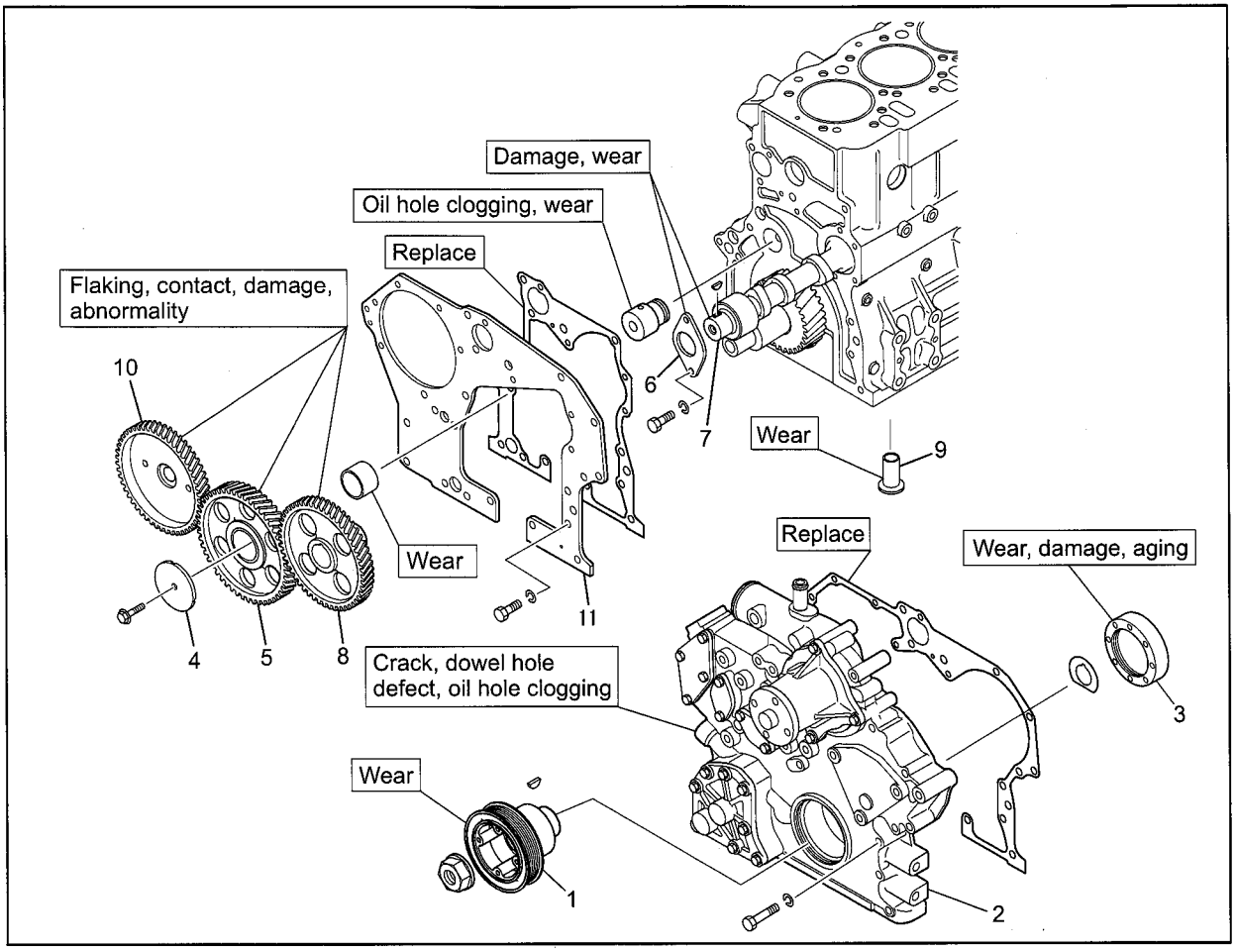
(1) Remove bolts from the flywheel housing.

(2) Remove the flywheel housing.



Removing flywheel housing

## 3. Disassembling and inspecting gear case, timing gear and camshaft




Disassembling and inspecting gear case, timing gear and camshaft

Disassembling sequence

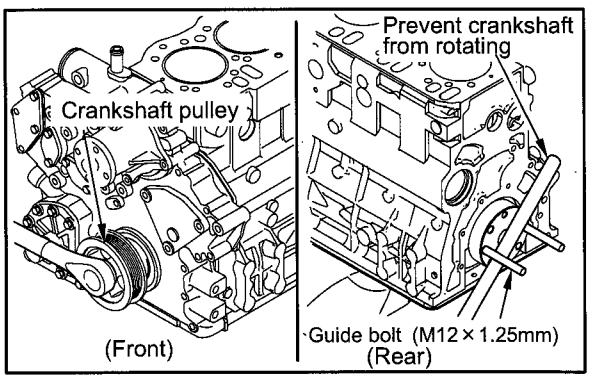
1 Crankshaft pulley
2 Timing gear case
3 Oil seal
4 Thrust plate
5 Idler gear
6 Thrust plate
7 Camshaft
8 Camshaft gear
9 Tappet
10 Fuel pump gear
11 Front plate

### 3.1 Removing crankshaft pulley

**⚠ CAUTION**

The bar serving as a stopper of the crankshaft may come off. Pay due attention to safety.

(1) Screw two guide bolts into the threaded holes at the rear end of the crankshaft. Use these bolts and a bar placed across them to prevent the crankshaft from rotating.
(2) Remove the crankshaft pulley.
(3) Take out the woodruff key of the crankshaft.




Removing crankshaft pulley

### 3.2 Removing timing gear case

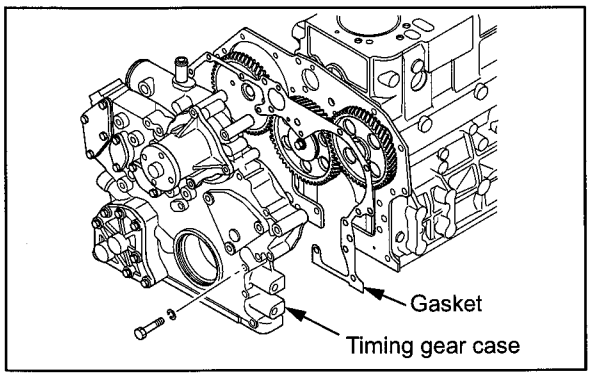
**CAUTION**

The front plate is bolted to the crankcase from inside the gear case. Do not attempt to remove the front plate by tapping it with the gear case.

(1) Remove bolts from the timing gear case.

(2) Remove the timing gear case.

Note: Bolts have different lengths. Pay attention to the positions of bolts to ensure correct reassembling.




Removing timing gear case

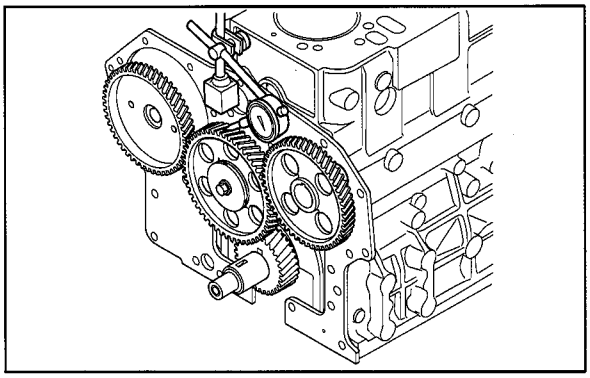
### 3.3 Measuring backlash of timing gears

To measure backlash, apply a dial gauge to the gear shaft circle at the right angle to the shaft, or insert feeler gauges into the meshing between two gears.

Replace the gear if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Backlash crankshaft gear and idler gear | 0.051 to 0.157 mm [0.0020 to 0.0062 in.] | 0.25 mm [0.0098 in.] |
| Backlash camshaft gear and idler gear | 0.052 to 0.158 mm [0.0021 to 0.0062 in.] | 0.25 mm [0.0098 in.] |
| Backlash Fuel injection pump gear and idler gear | 0.056 to 0.205 mm [0.0022 to 0.0081 in.] | 0.25 mm [0.0098 in.] |

Note: With the fuel pump gear attached to the pump, install the fuel pump gear to the front plate.



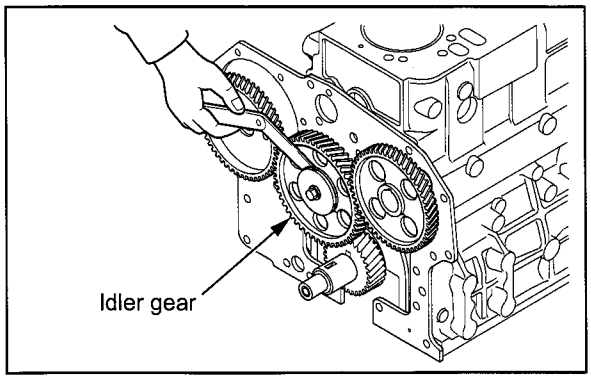
Measuring backlash of timing gears

### 3.4 Measuring idler gear end play

Using thickness gauge or dial gauge, measure the end play of idler gear.

If the measured value exceeds the limit, replace the idler gear with new gear.

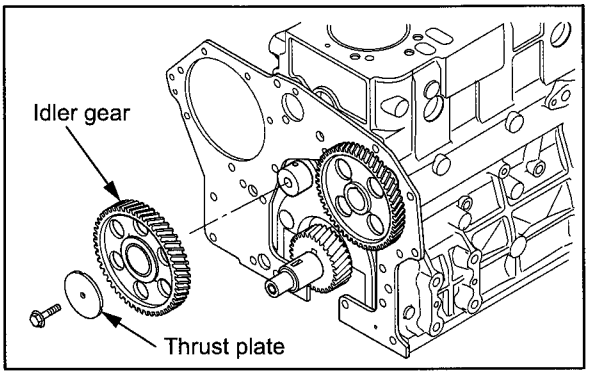
| Item | Standard | Limit |
|---|---|---|
| End play | 0.05 to 0.20 mm [0.0020 to 0.0079 in.] | 0.35 mm [0.0138 in.] |




Measuring idler gear end play

### 3.5 Removing idler gear

(1) Remove the thrust plate bolt.
(2) Remove the idler gear while turning the gear.



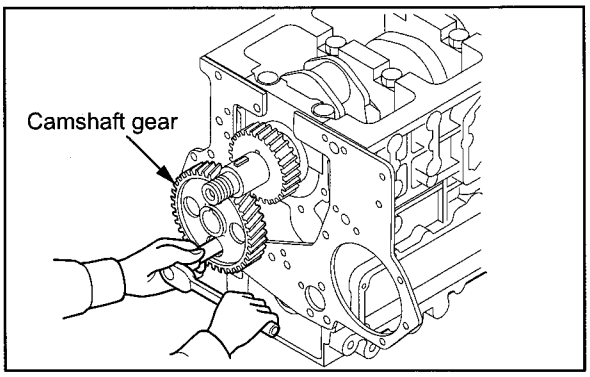

Removing idler gear

### 3.6 Removing camshaft

**CAUTION**

Be careful not to damage the cams of camshaft and the bushings.

(1) Reverse the crankcase.
(2) Remove the thrust plate bolt.
(3) Remove the camshaft from the crankcase.
(4) Remove the tappet.

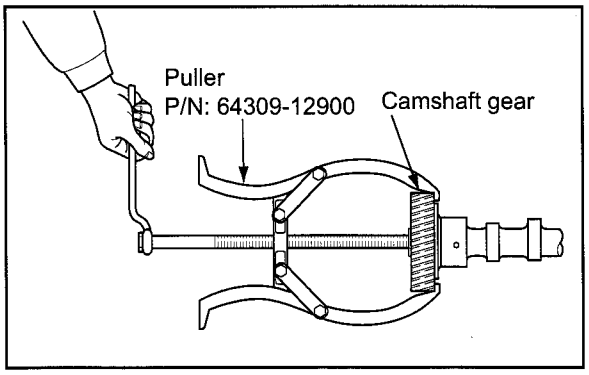



Removing camshaft

### 3.7 Separating camshaft gear

Using a puller, remove the camshaft gear and thrust plate from the camshaft.

Note: Do not remove the camshaft gear from the camshaft unless the camshaft gear or the thrust plate is defective.




Separating camshaft gear

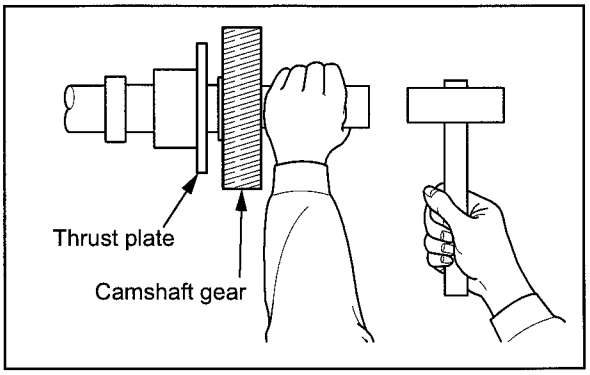
### 3.8 Installing camshaft gear and thrust plate

(1) Install the woodruff key and the thrust plate on the crankshaft.

Note: Be sure to install the thrust plate before installing the camshaft gear.

(2) Heat the camshaft gear with a gear heater to a temperature of about 250 ℃ [482°F].

(3) Install the camshaft gear into the crankcase by tapping with a plastic hammer.



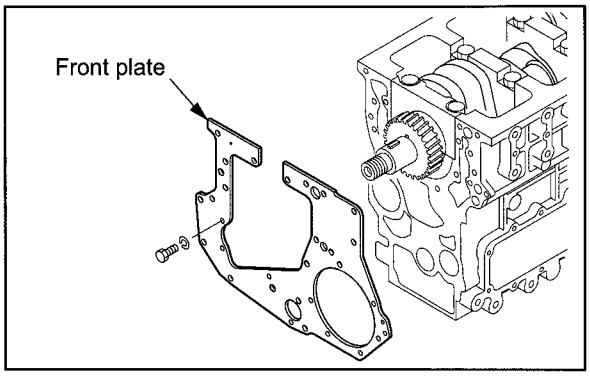

Installing camshaft gear and thrust plate

### 3.9 Removing front plate

(1) Remove the front plate bolts.

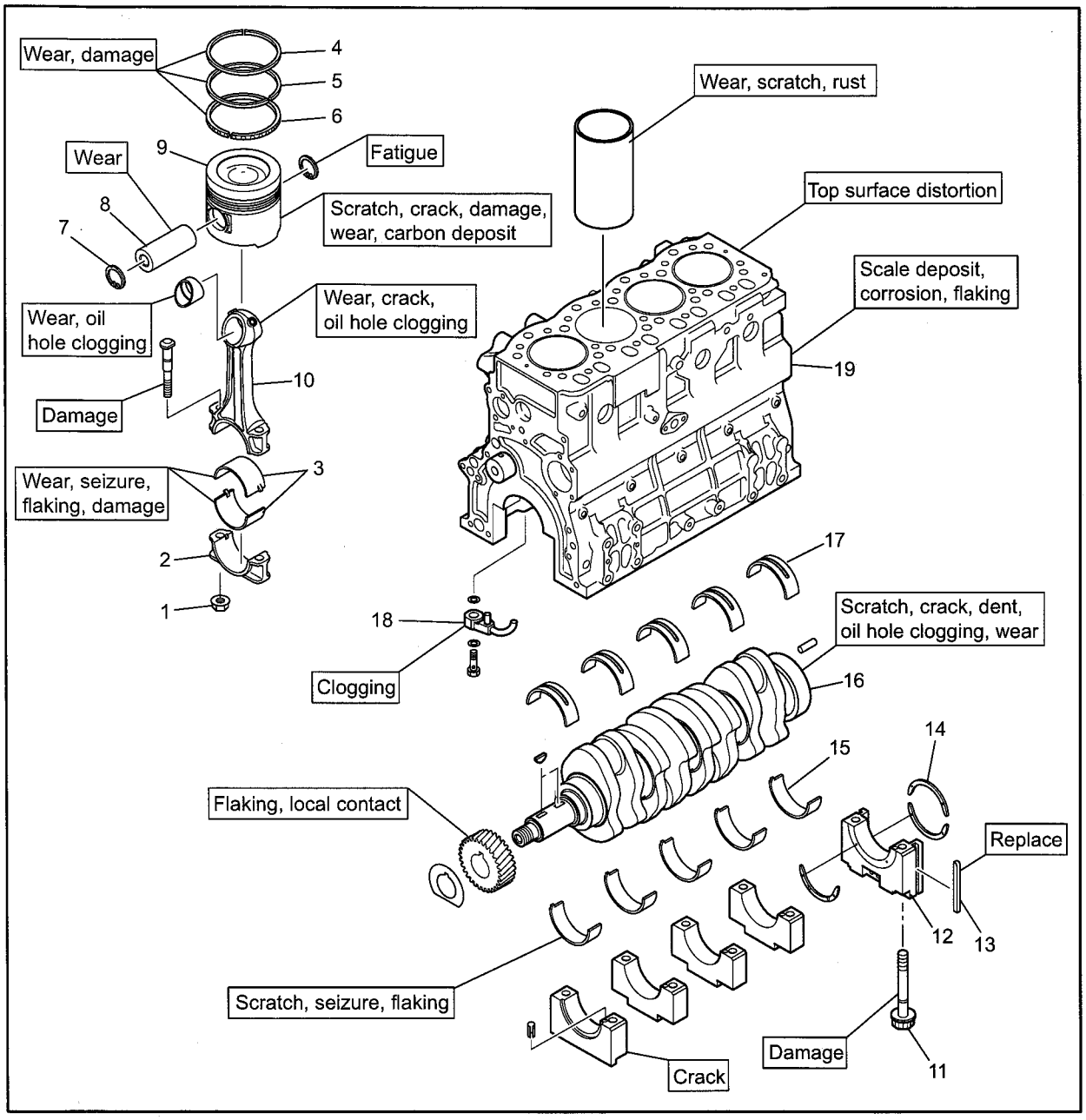
(2) Remove the front plate from the crankcase.

Note: If it is difficult to remove the front plate, lightly tap it with a plastic hammer.




Removing front plate

## 4. Disassembling and inspection crankcase, crankshaft and piston




Disassembling and inspection crankcase, crankshaft and piston

Disassembling sequence

1 Nut
2 Connecting rod cap
3 Connecting rod bearing
4 Compression ring, No. 1
5 Compression ring, No. 2
6 Oil ring
7 Snap ring
8 Piston pin
9 Piston
10 Connecting rod
11 Main bearing cap bolt
12 Main bearing cap
13 Side seal
14 Thrust plate
15 Main bearing (lower)
16 Crankshaft
17 Main bearing (upper)
18 Piston cooling nozzle
19 Crankcase

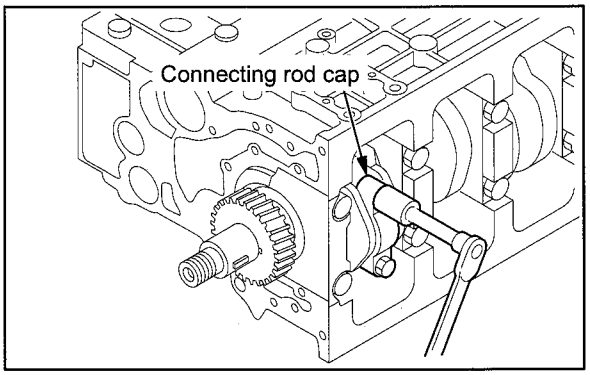
### 4.1 Removing connecting rod cap

(1) Lay the engine by its side.

(2) Mark the cylinder number on the connecting rod and connecting rod cap so that their combination is not changed when reassembling.

(3) Remove the connecting rod caps.

Note: Mark the cylinder No. and upper/lower on connecting rod bearings to ensure correct reassembling.

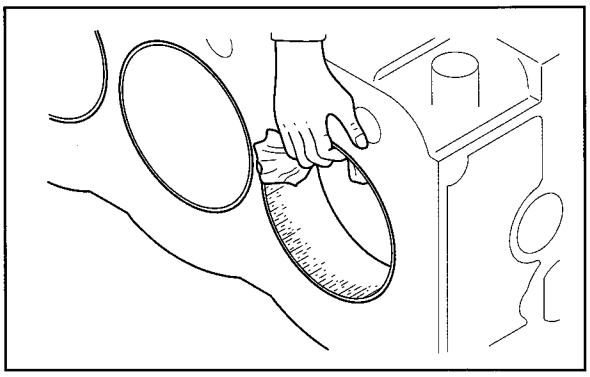



Removing connecting rod cap

### 4.2 Removing carbon deposit from cylinder sleeve upper area

Carbon deposits at the upper section of the cylinder sleeve will not only make the piston removal work difficult but also cause damage to the piston or piston ring when removing the piston.

Before removing the piston, be sure to remove the carbon deposits at the upper section of cylinder sleeve with a cloth or sand paper.

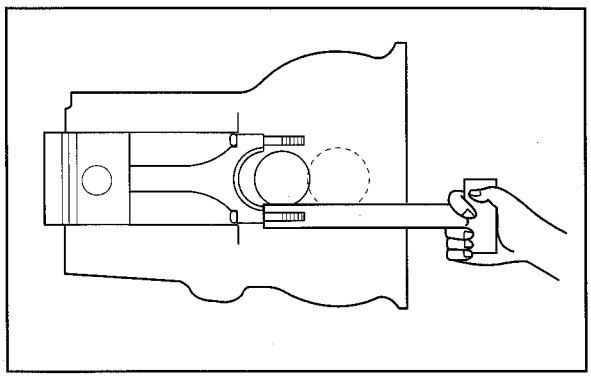


Removing carbon deposit from cylinder sleeve upper area

### 4.3 Pulling out piston

(1) Turn the crankshaft and place the piston to top dead center.

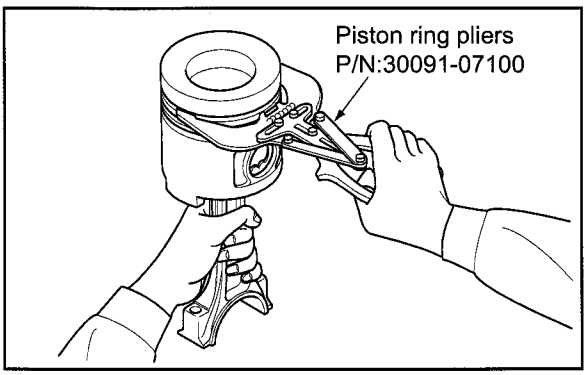
(2) Push the mating surface of the connecting rod cap with a piece of wood such a handle of a hammer and push out the piston and connecting rod upward of the cylinder.



Pulling out piston

### 4.4 Removing piston ring

Remove the piston rings using piston ring pliers.



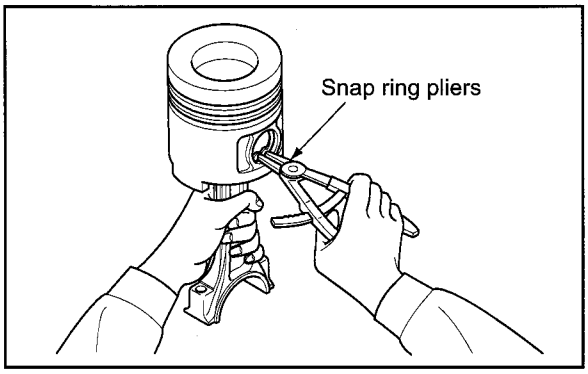

Removing piston ring

### 4.5 Removing piston pin

(1) Remove the snap ring using snap ring pliers.

(2) Remove piston pin, and separate piston from connecting rod.

Note: If the piston pin is stubborn, heat the piston with piston heater or hot water.




Removing piston pin

### 4.6 Removing main bearing cap

(1) Reverse the engine.

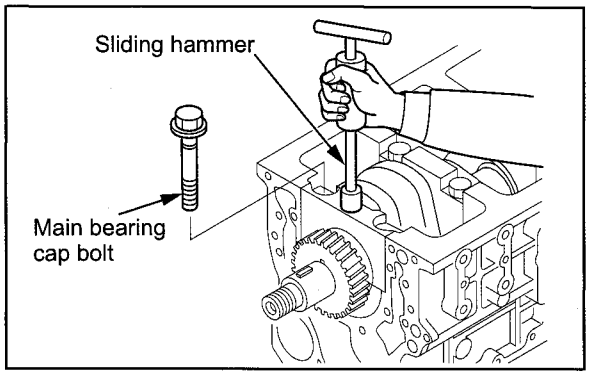
(2) Remove the main bearing cap bolt.

(3) Remove the main bearing cap together with the lower main bearing.

Use a sliding hammer to remove main bearing caps on the front and rear ends.

Note: (a) Be careful not to damage main bearings.

(b) Mark each main bearing with the cylinder number for reassembly.




Removing main bearing cap

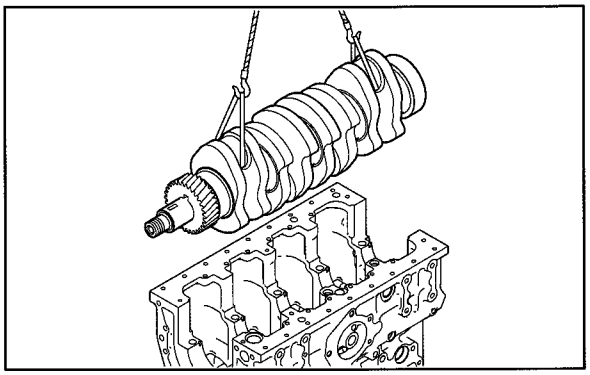
### 4.7 Removing crankshaft

Attach a sling to the crankshaft, hold it horizontally, and hoist the crankshaft slowly.

Note: (a) When lifting the crankshaft, do not allow wire chain to come into contact with the crankshaft. To avoid damage to the crankshaft when lifting, use a cloth belt or pad.

(b) Be careful not to damage main bearings.

(c) Mark each main bearing to the corresponding cylinder number for identification.



Removing crankshaft

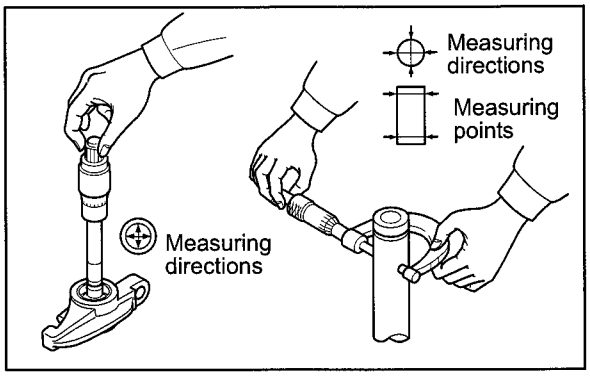
# INSPECTING AND REPAIRING ENGINE MAIN PARTS

# 1. Inspecting and repairing cylinder head and valve mechanism

## 1.1 Measuring clearance between rocker bushing and rocker shaft

Measure the rocker bushing inside diameter and the rocker shaft diameter. If the clearance exceeds the limit, replace either rocker bushing or rocker shaft with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Rocker bushing inside diameter | ø 25 mm [0.98 in.] | 24.949 to 24.975 mm [0.9822 to 0.9833 in.] | – |
| Rocker shaft outside diameter | ø 25 mm [0.98 in.] | 24.915 to 24.928 mm [0.9809 to 0.9814 in.] | – |
| Clearance between rocker bushing and shaft | – | 0.021 to 0.060 mm [0.0008 to 0.0024 in.] | 0.078 mm [0.0031 in.] |

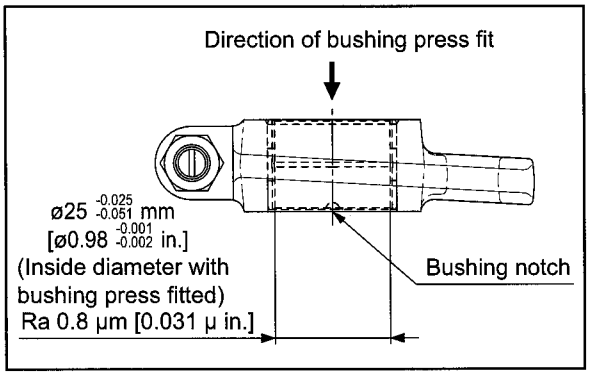



Measuring rocker bushing and rocker shaft

## 1.2 Replacing rocker bushing

To replace rocker bushings, use a hydraulic jack.

With the rocker bushing and the rocker arm oil holes mated, and the bushing joint faced upward, press fit the rocker bushing.

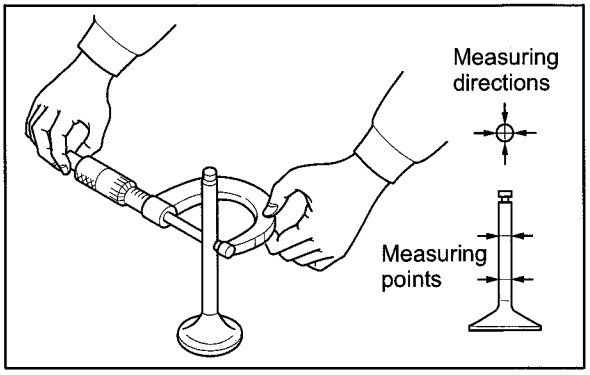



Replacing rocker bushing

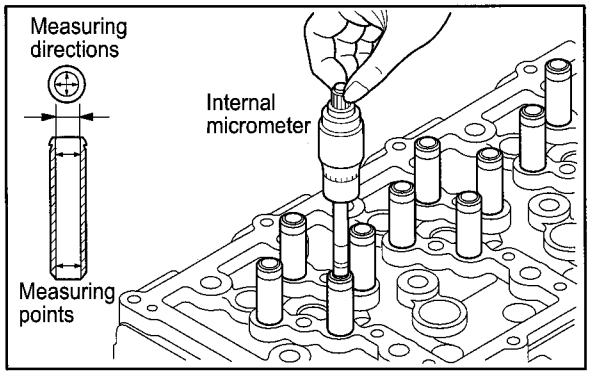
### 1.3 Measuring valve stem outside diameter and valve guide inside diameter

Measure the diameter at the top and bottom ends at right angles to the outer and inner surfaces, since valve stems and valve guides are subject to wear at both ends. If the outside diameter is less than the limit, or the clearance exceeds the limit, replace either the valve or the valve guide with a new one.

| Item | | Nominal | Standard | Limit |
|---|---|---|---|---|
| Valve stem outside diameter | Inlet | ø 6.6 mm [0.260 in.] | 6.565 to 6.580 mm [0.2585 to 0.2591 in.] | 6.500 mm [0.2559 in.] |
| | Exhaust | ø 6.6 mm [0.260 in.] | 6.530 to 6.550 mm [0.2571 to 0.2579 in.] | 6.500 mm [0.2559 in.] |
| Clearance between valve stem and valve guide | Inlet | – | 0.020 to 0.050 mm [0.0008 to 0.0020 in.] | 0.100 mm [0.0039 in.] |
| | Exhaust | – | 0.050 to 0.085 mm [0.0020 to 0.0034 in.] | 0.150 mm [0.0059 in.] |
| Valve guide mounting dimension | | ø 16 mm [0.63 in.] | – | – |




Measuring valve stem outside diameter



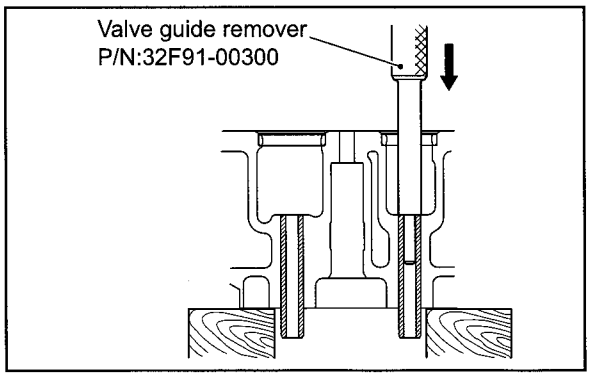

Measuring valve guide inside diameter

### 1.4 Replacing valve guide

**CAUTION**

Because valve guides must be inserted to the specified amount, be sure to use a valve guide installer.

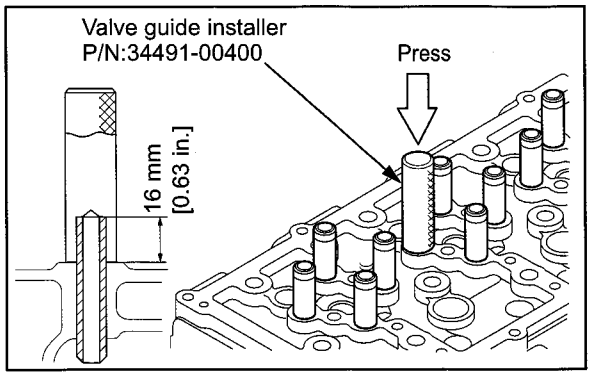
(1) To remove valve guides, use a valve guide remover.




Removing valve guide

(2) To press-fit valve guides, use a valve guide installer.

(3) Check contacts between valves and valve seats after replacing valve guides.




Press-fitting valve guide

### 1.5 Inspecting valve face

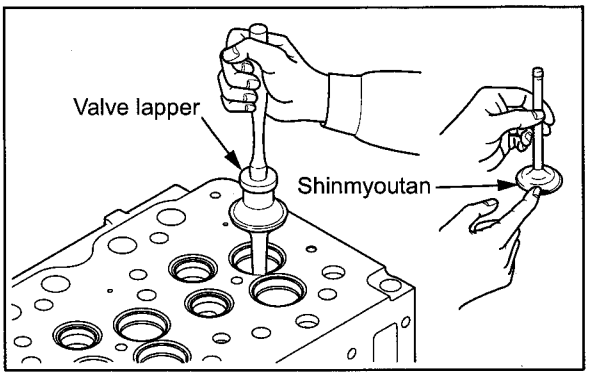
Apply a thin coat of Shinmyoutan or equivalent lead-free coloring paste on the valve face, and strike the valve face against the valve seat using a valve lapper to check if they make an even contact with each other. If no even contact is obtained or any other abnormalities are found, or if the limit is exceeded, reface or replace the valve.

Note: (a) Perform the valve face check only after checking the valve guide and replacing it as necessary.

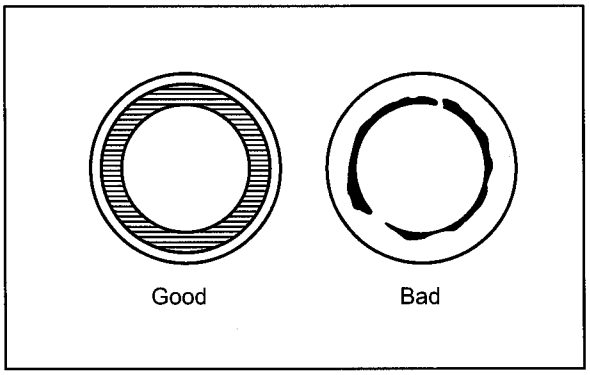
(b) Be careful not to rotate the valve when pressing the valve face coated with Shinmyoutan or equivalent lead-free dye against the valve seat.

(c) Be sure to lap the valve and valve seat whenever the valve is refaced or replaced.

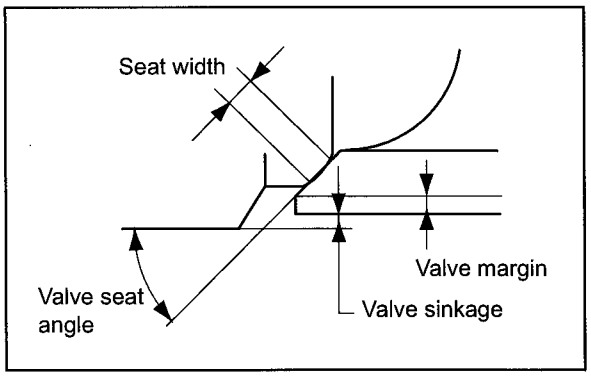
| Item | | | Nominal | Standard | Limit |
|---|---|---|---|---|---|
| Valve seat | Valve seat angle | Inlet | 30° | – | – |
| | | Exhaust | 45° | – | – |
| | Valve sinkage | Inlet | 0.3 mm [0.012 in.] | 0.2 to 0.4 mm [0.008 to 0.016 in.] | 1.1 mm [0.043 in.] |
| | | Exhaust | 0.3 mm [0.012 in.] | 0.2 to 0.4 mm [0.008 to 0.016 in.] | 1.1 mm [0.043 in.] |
| | Seat width | Inlet | 1.0 mm [0.039 in.] | – | 1.4 mm [0.055 in.] |
| | | Exhaust | 1.2 mm [0.047 in.] | – | 1.6 mm [0.063 in.] |
| Valve margin | | | 1.7 mm [0.067 in.] | 1.55 to 1.85 mm [0.0610 to 0.0728 in.] | Refacing permissible up to 1.2 mm [0.047 in.] |




Inspecting valve face




Contact between valve seat and valve



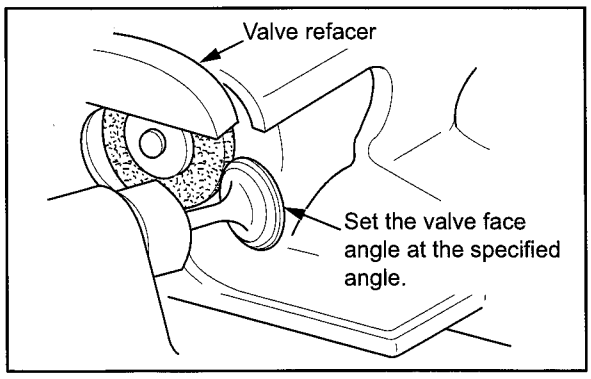

Measuring positions of valve seat and valve

### 1.6 Refacing valve face

Grind remarkably worn valve faces with a valve refacer.

Note: (a) Grind the valve face with a refacer at the specified angle.

(b) Secure the valve margin width equal to or greater than the limit. Replace valves with new ones if their dimensions after refacing do not meet the standard.




Refacing valve face

### 1.7 Refacing valve seat

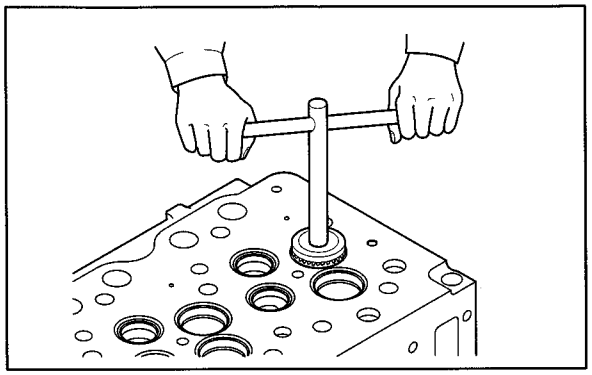
(1) Use the valve seat cutter or valve seat grinder to reface the valve seat. After refacing, grind the seat lightly using #400-grade sandpaper inserted between the cutter and valve seat.

(2) Lap the valve in the valve seat.

Note: (a) Grind the valve seat as little as possible.

(b) If the seat width exceeds the limit as a result of grinding, replace the valve seat.

(c) After lapping, if the valve sinkage exceeds the limit, replace the valve seat with a new one.



Refacing valve seat

### 1.8 Replacing valve seat

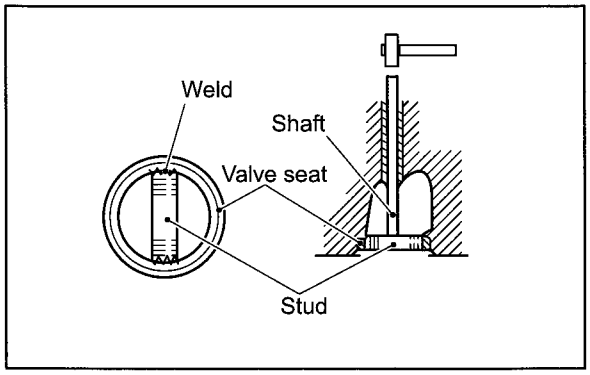
(1) To remove the valve seat, weld a stud to the valve seat as illustrated. Then, insert a rod into the valve guide hole from the top of the cylinder head, and press out the valve seat with the rod.

Note: Be careful not to allow spatters to adhere to the machined surface of the cylinder head during welding.

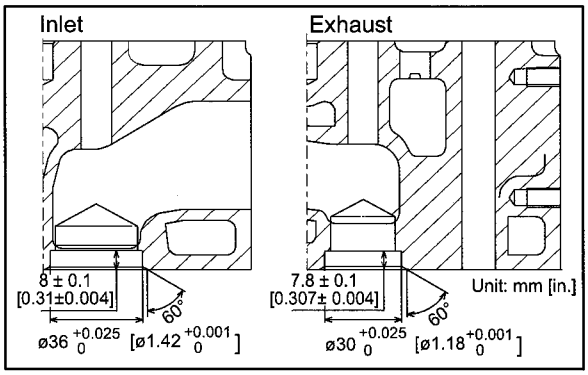
(2) Before inserting a new valve seat, measure the cylinder head bore diameter and valve seat outside diameter to make sure the clearance is within the clearance standard.

(3) Cool the valve seat for four minutes or more in liquid nitrogen (at approximately -170°C [-274°F]) before fitting it into the cylinder head, while keeping the cylinder head at room temperature. Or heat the cylinder head to 80 to 100°C [176 to 212°F] and cool the valve seat sufficiently in ether or alcohol mixed with dry ice before fiting it into the hot cylinder head.

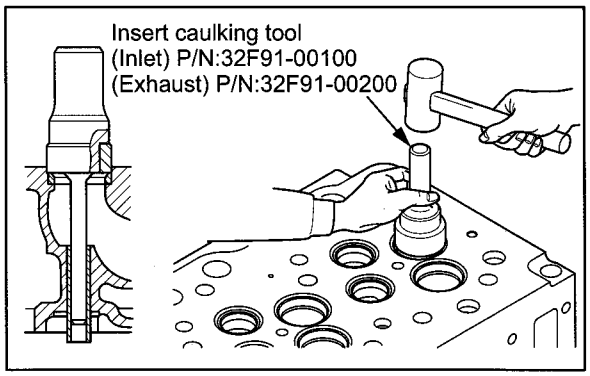
(4) Fit the cold valve seat into the cylinder head using a insert caulking tool.




Removing valve seat




Valve seat fitting bore




Installing valve seat

### 1.9 Lapping valve and valve seat

Always lap valves against valve seats after valve seat refacing or valve replacement.

(1) Apply a thin coat of lapping compound evenly to the valve face to be lapped.

Note: (a) Do not allow the compound to adhere on the valve stem.

(b) Compound spreads more evenly if it is mixed with a small amount of engine oil.

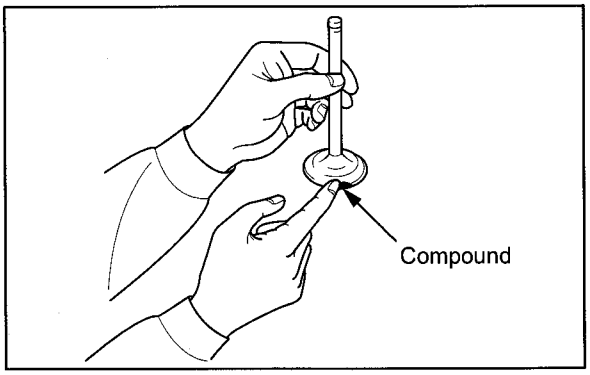
(c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

(2) Use a valve lapper for lapping. Strike the valve against the valve seat while rotating the valve little by little.

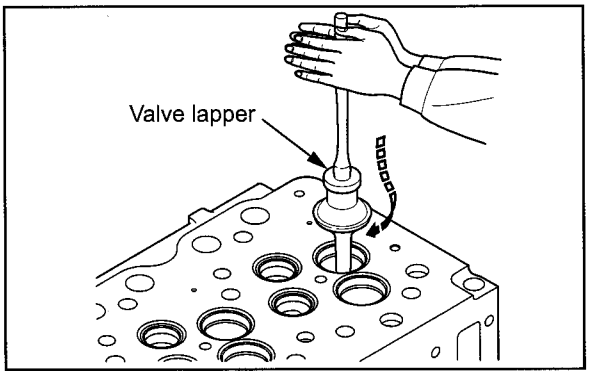
(3) Wash off the compound with diesel fuel.

(4) Coat the contact surface of the valve with engine oil, then lap the valve again.

(5) Check valve face contact.




Coating valve with lapping compound

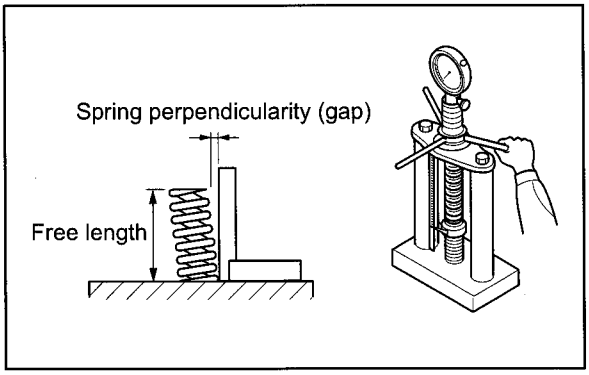



Lapping valve and valve seat

### 1.10 Measuring perpendicularity and free length of valve spring

Measure the perpendicularity and free length of the valve spring. Replace the valve spring if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Free length | 48.7 mm [1.917 in.] | 47.3 mm [1.862 in.] |
| Perpendicularity | $\theta$ = 2.0° or less<br>Less than $\Delta$ = 1.8 [0.071 in.]<br>Lf = 48.7 mm [1.917 in.] | Entire length<br>$\Delta$ = 1.8 mm [0.071 in.] |
| Mounting length/load | 42.5 mm [1.673 in.]/112.1 to 125.9 N {11.3 to 12.7 kgf} [24.9 to 27.9 lbf] | 42.5 mm [1.673 in.]/ 103 N {10.5 kgf} [23.1 lbf] |




Measuring spring perpendicularity and free length

### 1.11 Measuring distortion of cylinder head bottom face

**CAUTION**

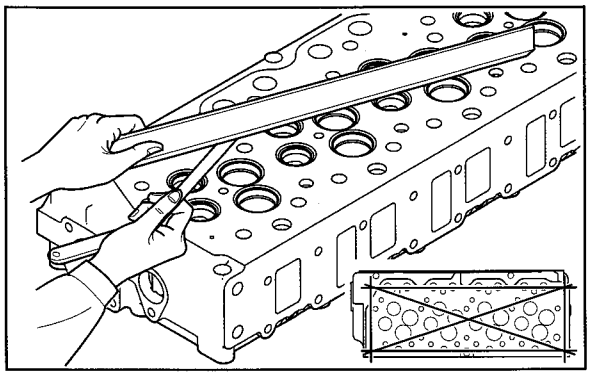
Limit the depth of surface grinding of cylinder head to a necessary minimum.

If the surface of cylinder head is ground more than specified, it may result in defects such as defective combustion and stamping (contact between piston and valve).

With a straight edge placed on the bottom face of the cylinder head, measure the bottom face distortion with a feeler gauge. If the measurement exceeds the limit, grind the bottom face with a surface grinder.

| Item | Standard | Limit |
|---|---|---|
| Bottom surface distortion | 0.05 mm [0.0020 in.] or less | 0.20 mm [0.008 in.] |

Note: Do not grind the surfaces more than 0.2 mm [0.008 in.] in total (cylinder head bottom surface plus crankcase top surface).

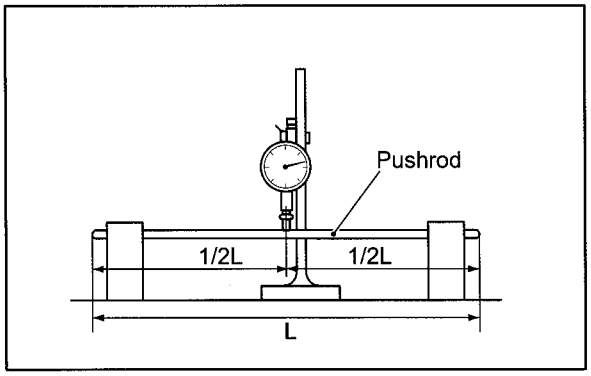


Measuring distortion of cylinder head bottom surface

### 1.12 Measuring pushrod runout

Measure the runout of each pushrod. Replace if the limit is exceeded.

| Item | Standard | Limit | Remark |
|---|---|---|---|
| Pushrod runout | 0.4 mm [ 0.016 in.] or less | 0.4 mm [0.016 in.] | TIR |




Measuring pushrod runout

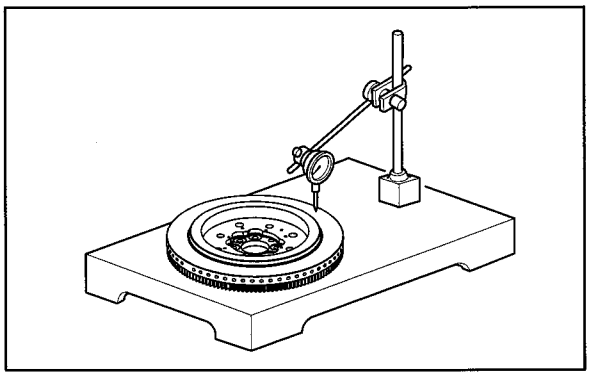
## 2. Inspecting and repairing flywheel

### 2.1 Measuring flatness of flywheel

Place the flywheel on a surface plate and move a dial gauge on the friction surface of the flywheel to measure the flatness.

Grind the friction surface of the flywheel if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Flywheel flatness | 0.15 mm [0.0059 in.] or less | 0.50 mm [0.0197 in.] |

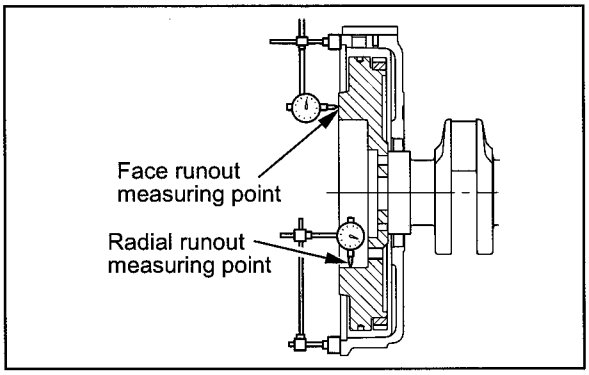


Measuring flatness of flywheel

### 2.2 Measuring flywheel face runout and radial runout

Measure the runouts of the flywheel in the installed condition. If any of the measurements exceeds the standard, check the flywheel for loosened bolts and foreign matter accumulation on the mounting face.

| Item | Standard | Limit |
|---|---|---|
| Flywheel face runout and radial runout | Within 0.15 mm [0.0059 in.] | 0.50 mm [0.0197 in.] |




Measuring flywheel face runout and radial runout

### 2.3 Inspecting ring gear

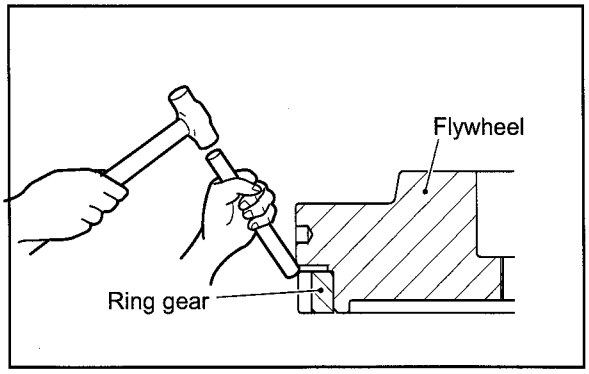
Replace the ring gear if missing or abnormally worn teeth are found by inspection.

### 2.4 Replacing ring gear

#### 2.4.1 Removing ring gear

(1) Heat the ring gear evenly using an acetylene torch or other appropriate heat source.

(2) With a rod placed on the periphery of ring gear, tap the rod with a hammer evenly around the ring gear, and remove the ring gear.




Removing ring gear

#### 2.4.2 Installing ring gear

(1) Heat the ring gear evenly up to approx. 150°C [176°F] with an appropriate heater.

(2) Install the ring gear onto the flywheel with the no-gear-chamfering side faced to the flywheel.

Note: Do not heat the ring gear excessively.

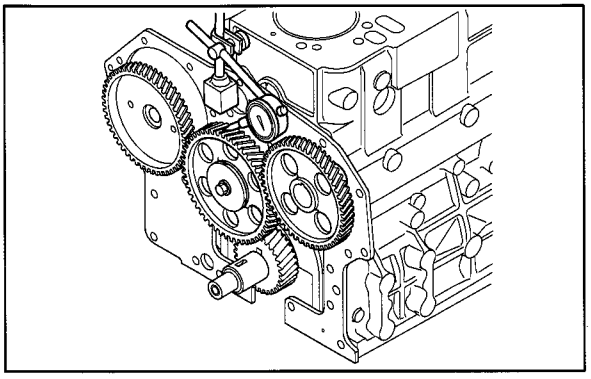
# 3. Inspecting and repairing timing gears and camshaft

## 3.1 Measuring backlash of timing gear

Measure the backlash of the timing gears by using one of the following two methods; measure the gear play with the dial gauge plunger applied to a tooth flank on the pitch circle at a right angle to the tooth axis, or measure the clearance between gears by inserting a feeler gauge between the gears at the tooth-to-tooth contacting area. Replace the faulty gear pair if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Backlash crankshaft gear and idler gear | 0.051 to 0.157 mm [0.0020 to 0.0062 in.] | 0.25 mm [0.0098 in.] |
| Backlash camshaft gear and idler gear | 0.052 to 0.158 mm [0.0021 to 0.0062 in.] | 0.25 mm [0.0098 in.] |
| Backlash Fuel injection pump gear and idler gear | 0.056 to 0.205 mm [0.0022 to 0.0081 in.] | 0.25 mm [0.0098 in.] |

Note: With the fuel pump gear attached to the pump, install the fuel pump gear to the front plate.

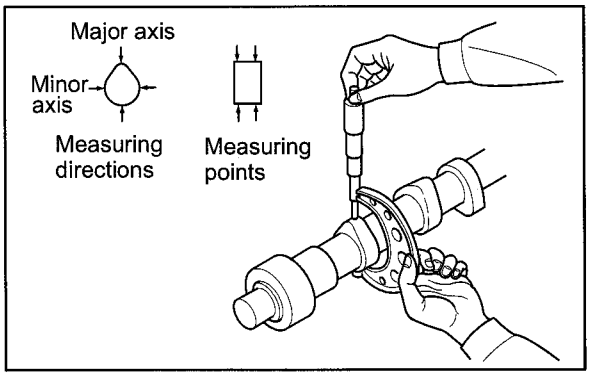


Measuring backlash of timing gear

## 3.2 Measuring cam lift

Measure the minor and major axes of cam using a micrometer to determine cam lobe lift. If the lift is less than the limit, replace the camshaft with a new one.

| Item | | Nominal | Standard | Limit |
|---|---|---|---|---|
| Cam lift | Inlet | Major axis $46.446\ ^{+0.1}_{-0.3}$ mm [$1.8286\ ^{+0.004}_{-0.012}$ in.] | Major axis – Minor axis = 6.154 mm [0.2423 in.] | Major axis – Minor axis = 5.654 mm [0.2226 in.] |
| | Exhaust | Major axis $46.137\ ^{+0.1}_{-0.3}$ mm [$1.8164\ ^{+0.004}_{-0.012}$ in.] | Major axis – Minor axis = 7.463 mm [0.2938 in.] | Major axis – Minor axis = 6.963 mm [0.2741 in.] |



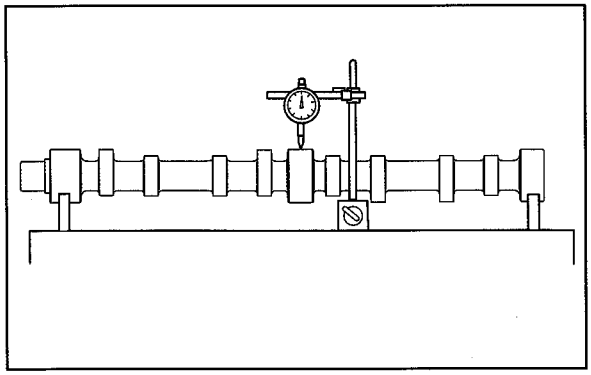

Measuring cam lift

## 3.3 Measuring camshaft runout

Measure the camshaft runout with a dial gauge. If the limit is exceeded, correct the camshaft using a press or replace the camshaft.

Note: With a dial gauge set on the camshaft, rotate the camshaft one turn and read the gauge indication.

| Item | Standard | Limit | Remark |
|---|---|---|---|
| Camshaft runout | 0.04 mm [0.016 in.] or less | 0.10 mm [0.0039 in.] | TIR |

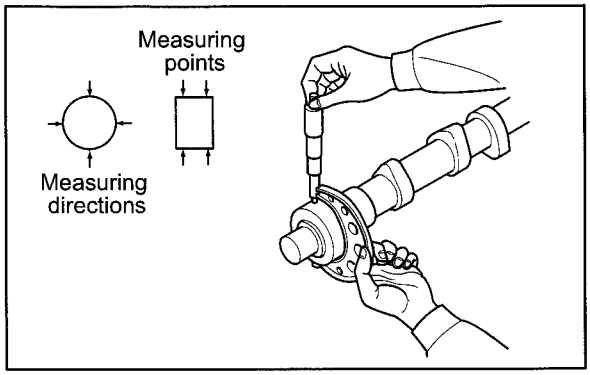


Measuring camshaft runout

### 3.4 Measuring camshaft journal outside diameter

Measure the diameter of each camshaft journal in two direction at right angles to each other. Replace the camshaft if the limit is exceeded.

| Item | | Standard | Limit |
|---|---|---|---|
| Camshaft journal outside diameter | No.1, 2, 3 | 53.94 to 53.96 mm [2.1236 to 2.1244 in.] | 53.90 mm [2.1220 in.] |
| | No.4 | 52.94 to 52.96 mm [2.0842 to 2.0850 in.] | 52.90 mm [2.0827 in.] |

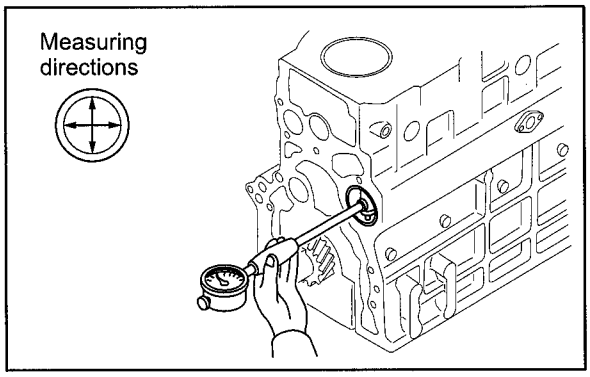



Measuring camshaft journal outside diameter

### 3.5 Measuring camshaft bushing inside diameter

With the camshaft bushings installed in the crankcase, measure the inside diameters with a cylinder gauge. If the limit is exceeded, replace the bushing.

| Item | | Standard | Limit |
|---|---|---|---|
| Clearance between camshaft journal and camshaft bushing | Front, Middle | 0.04 to 0.09 mm [0.0016 to 0.0035 in.] | 0.15 mm [0.0059 in.] |
| | Rear | 0.04 to 0.119 mm [0.0016 to 0.0047 in.] | |



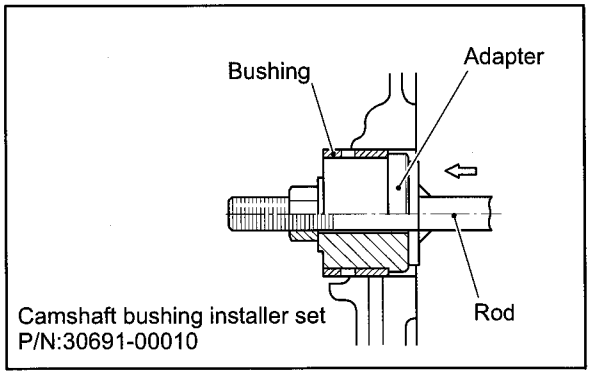

Measuring camshaft bushing inside diameter

### 3.6 Replacing camshaft bushing

#### 3.6.1 Removing camshaft bushing

(1) Install a camshaft bushing installer set to the camshaft bushing.

(2) Remove the camshaft bushing by tapping the end of the rod of camshaft bushing installer set.

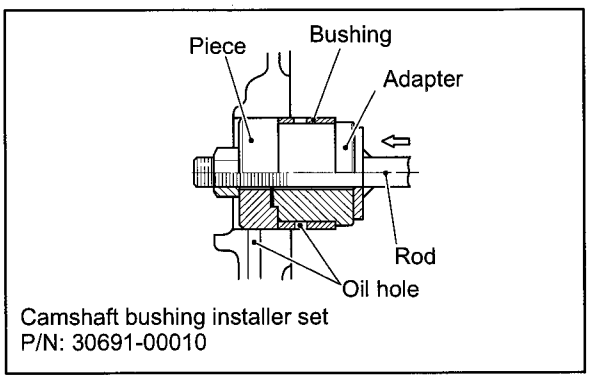



Removing camshaft bushing

### 3.6.2 Installing camshaft bushing

(1) Install the camshaft bushing to a camshaft bushing installer set.

(2) When driving in a bushing, tap the end of rod of camshaft bushing installer set so that the oil hole in the bushing aligns with the oil hole to the oil gallery.




Installing camshaft bushing

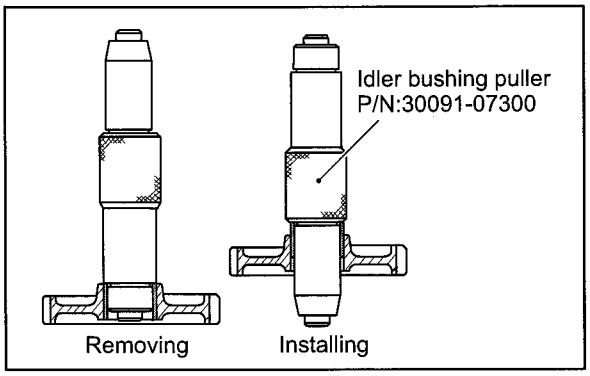
## 3.7 Measuring idler bushing inside diameter and idler shaft outside diameter

Measure the idler bushing inside diameter and the idler shaft outside diameter. If the inside diameter is larger than the limit, replace the idler bushing, and if the outside diameter is smaller than the limit, replace the idler shaft.

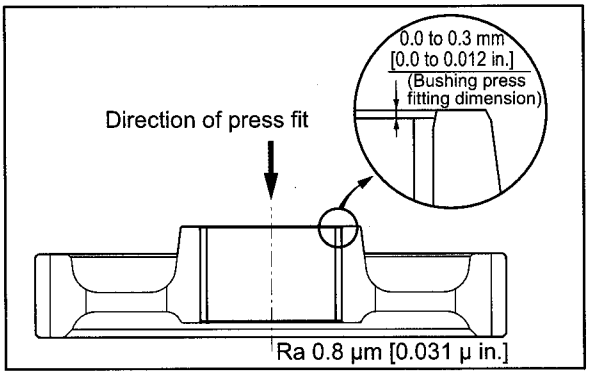
| Item | Standard | Limit |
|---|---|---|
| Clearance between idler bushing and idler shaft | 0.009 to 0.050 mm [0.0004 to 0.0020 in.] | 0.100 mm [0.0039 in.] |

### 3.8 Replacing idler bushing

(1) Use the idler bushing puller to replace idler bushing.
(2) To install the bushing, drive it from the boss side so that it is flush with the gear boss face.
(3) After installing the bushing, measure the bushing inside diameter, and if the inside diameter exceeds the standard, ream the bushing.




Replacing idler bushing

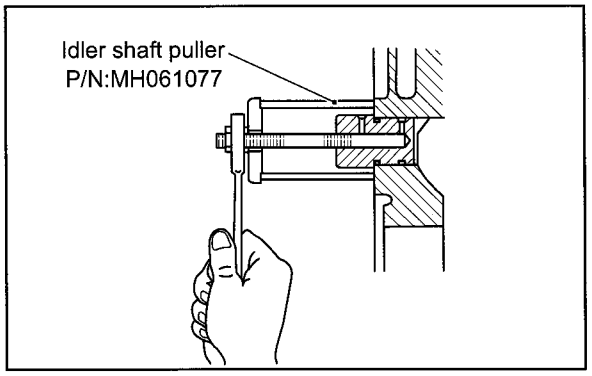



Idler bushing press fitting dimension

### 3.9 Replacing idler shaft

To remove the idler shaft, use the idler shaft puller.

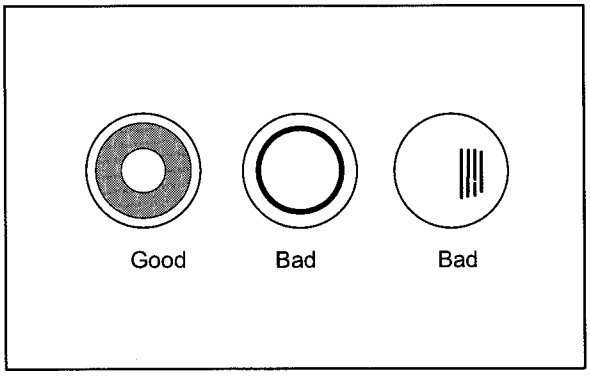
Note: When installing the idler shaft into the crankcase, orient the idler shaft so that its oil hole faces the upper crankcase.




Removing idler shaft

### 3.10 Inspecting tappet

Check the camshaft sliding surface of each tappet for uneven wear. If a defect is found, replace the tappet.

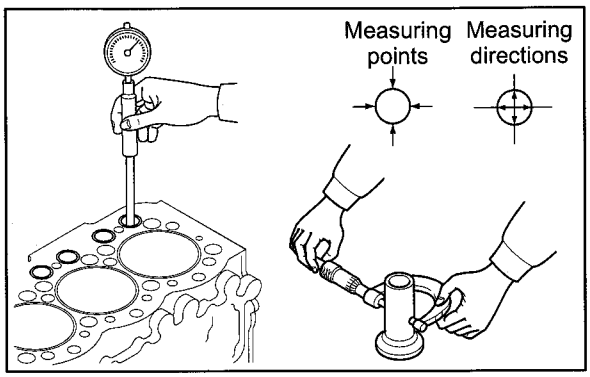



Tappet surface in contact with camshaft

### 3.11 Measuring clearance between tappet and tappet guide hole

Measure clearance between the tappet and tappet hole.
Replace the tappet with a new one if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Tappet hole inside diameter | 22.000 to 22.021 mm [0.8661 to 0.8670 in.] | 22.10 mm [0.8701 in.] |
| Clearance between tappet and tappet hole | 0.035 to 0.086 mm [0.0014 to 0.0034 in.] | 0.12 mm [0.0047 in.] |




Measuring clearance between tappet and tappet guide hole

## 4. Inspecting and repairing piston, connecting rod, crankshaft and crankcase

### 4.1 Measuring distortion of crankcase top surface

**CAUTION**

Limit the depth of surface grinding of crankcase to a necessary minimum.

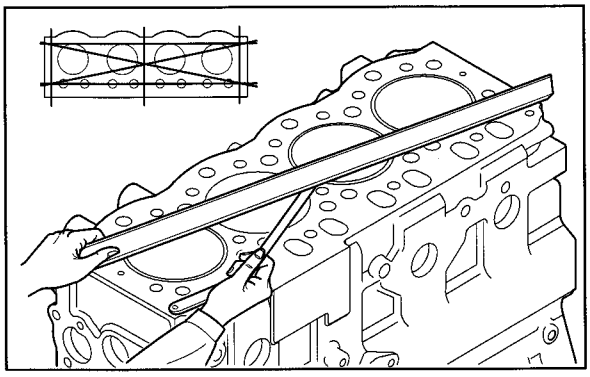
If the surface of crankcase is ground more than specified, it may result in defects such as defective combustion and stamping (contact between piston and valve).

Apply a straight edge to the top surface of the crankcase and measure its distortion with thickness gauges. If the distortion exceeds the limit, grind the cylinder head with a surface grinder.

Note: The grinding depth is limited so that the piston protrusion may not exceed the standard value.

| Item | Standard | Limit |
|---|---|---|
| Distortion of crankcase top surface | 0.05 mm [0.0020 in.] or less | 0.20 mm [0.008 in.] |

Note: Do not grind the surfaces more than 0.2 mm [0.008 in.] in total (cylinder head bottom surface plus crankcase top surface).



Measuring distortion of crankcase top surface

### 4.2 Measuring cylinder inside diameter

(1) Measure the inside diameter of the cylinder at three levels, i.e., upper (with much stepped wear), middle, and lower levels, in both directions parallel to and perpendicular to the crankshaft direction.

(2) If the measurement is between the repair limit and replacement limit, re-bore the cylinder to +0.25 mm [0.0098 in.] or +0.5 mm [0.0197 in.] oversize. Hone the re-bored cylinder to the accuracy of the standard.

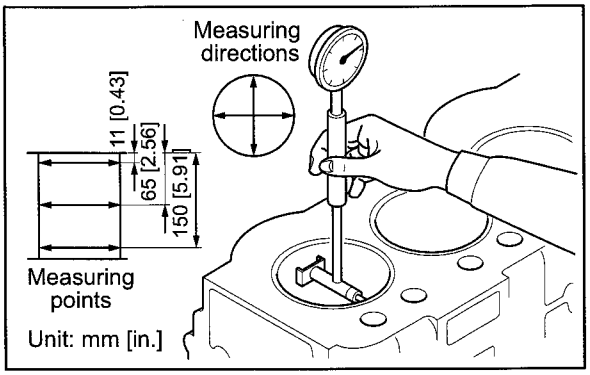
(3) Use an oversize piston and piston rings to fit the re-bored cylinder.

(4) If the cylinder is worn unevenly, select an oversize that ensures complete cylindricity when the cylinder is re-bored to the maximum. All cylinders must be re-bored to the same oversize if one cylinder is re-bored.

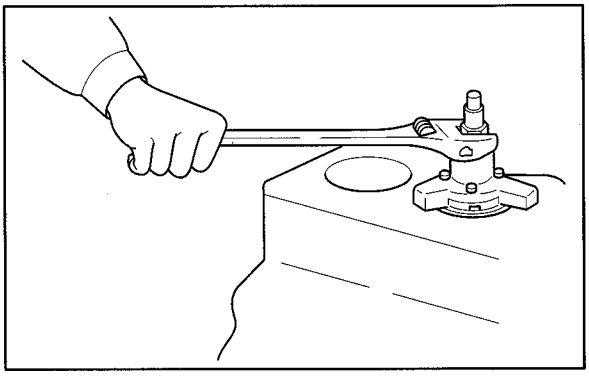
(5) If the cylinder has a slight wear and is reused after replacing only the piston rings, remove the steps in worn portion in the upper part of the cylinder using a ridge reamer. Hone it as necessary.

| Item | Standard | Limit |
|---|---|---|
| Cylinder sleeve inside diameter | 102.010 to 102.045 mm [4.0161 to 4.0175 in.] | Repair limit: 102.200 mm [4.0236 in.] Replacement limit: 102.700 mm [4.0433 in.] |
| Circularity | 0.01mm [0.0004 in.] or less | – |
| Cylindricity | 0.015 mm [0.0006 in.] or less | – |

Note: The roughness of cylinder sleeve inner surface is Ra 6.3 μm [0.248 μ in.]




Measuring cylinder sleeve inside diameter



Refacing using a ridge reamer

### 4.3 Replacing cylinder sleeve

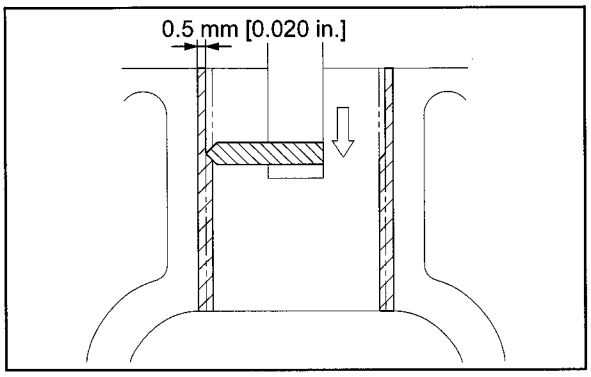
If the inside diameter of a cylinder sleeve exceeds the limit or a clinder is found defective, replace the cylinder sleeve only, provided that the defective cylinder has no effects on the other cylinders.

#### 4.3.1 Removing cylinder sleeve

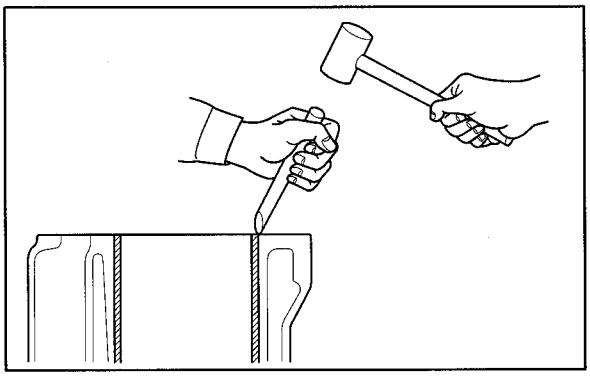
(1) Set up a boring machine on the crankcase by aligning it with the center of the less-worn area of the sleeve at the bottom.

(2) Bore the sleeve until its stock thickness becomes approximately 0.5 mm [0.020 in.].

(3) Carefully break and remove the sleeve, taking care not to cause damage to the inside surface of crankcase.




Boring cylinder sleeve



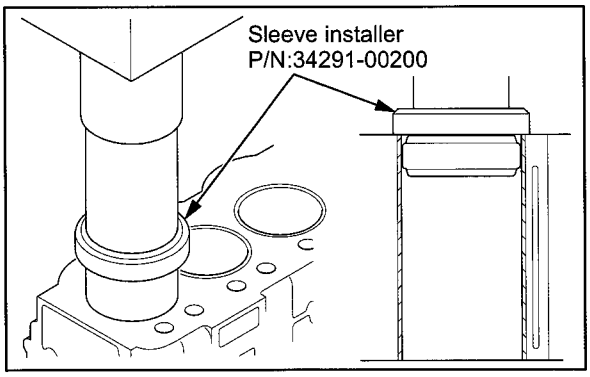
Removing cylinder sleeve

#### 4.3.2 Installing cylinder sleeve

(1) Use a cylinder sleeve installer to install a sleeve.

(2) Put the sleeve into the crankcase, leaving a protrusion of 0.3 to 0.5 mm [0.012 to 0.020 in.] at the top. Then make it flush with the crankcase top.

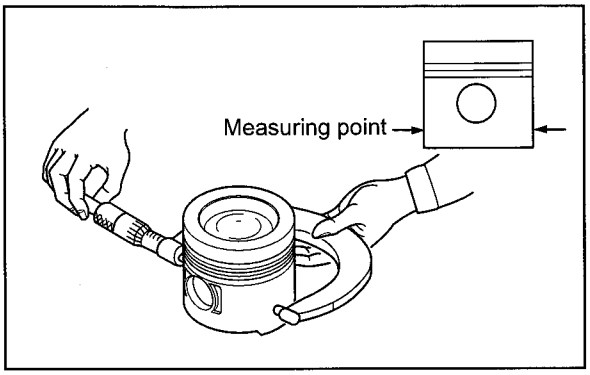
(3) Bore and hone the sleeve to the specified diameter.




Installing cylinder sleeve

### 4.4 Measuring piston outside diameter

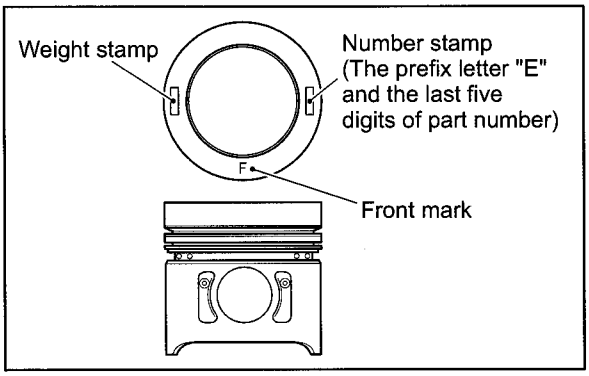
(1) Measure the piston outside diameter at the skirt perpendicular to the piston pin. If it is less than the limit, replace with a new part. At this time, do not forget to select a piston which allows the piston weight difference in one engine to be within the tolerance.




Measuring piston outside diameter

(2) The piston weight is stamped on the piston head.

| Item | | Standard | Limit |
|---|---|---|---|
| Piston outside diameter (iskirt) | STD | 101.915 to 101.945 mm [4.0124 to 4.0136 in.] | 101.730 mm [4.0051 in.] |
| | 0.25 OS | 102.165 to 102.195 mm [4.0222 to 4.0234 in.] | 101.980 mm [4.0150 in.] |
| | 0.50 OS | 102.415 to 102.445 mm [4.0321 to 4.0333 in.] | 102.230 mm [4.0248 in.] |
| Weight difference per piston | | 5g [0.2 oz.] or less | – |



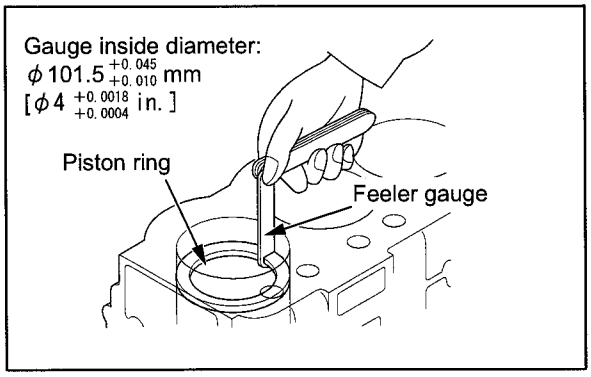

Piston weight stamp location

### 4.5 Measuring piston ring end gap

Place the piston ring in a gauge or a new sleeve to measure the ring end gap. If the limit is exceeded, replace all the rings as a set.

Note: Use a piston to push the piston ring squarely into the gauge or the sleeve.

| Item | | Standard | Limit |
|---|---|---|---|
| Piston ring end gap | Compression ring | 0.30 to 0.45 mm [0.0118 to 0.0177 in.] | 1.50 mm [0.0591 in.] |
| | Oil ring | 0.30 to 0.50 mm [0.0118 to 0.0197 in.] | |



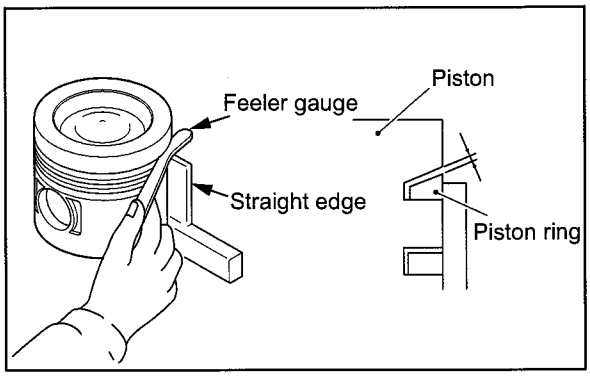

Measuring piston ring end gap

### 4.6 Measuring clearance between piston ring groove and piston ring

**CAUTION**

Remove carbon deposits from pistons and check the piston ring grooves over the entire circumference of the piston.

(1) Remove deposits such as carbon from each ring groove.
(2) Check each ring groove for wear or damage. If faulty, replace the ring.
(3) Insert the piston ring into the piston ring groove. Apply a straight edge and insert thickness gauges to measure the clearance between ring and ring groove.
If the limit is exceeded, replace the piston ring with a new one.
(4) If the piston ring was replaced with a new one, measure the clearance again, and if the limit is exceeded, then replace the piston with a new one.



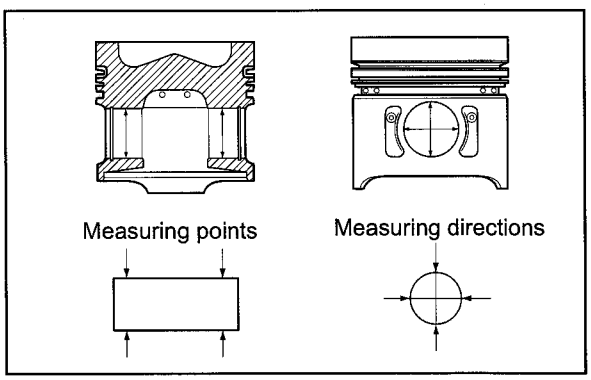

Measuring clearance between piston ring groove and piston ring

| Item | | Standard | Limit |
|---|---|---|---|
| Clearance between piston ring and ring groove | Compression ring, No. 1 | 0.08 to 0.12 mm [0.0031 to 0.0047 in.] | 0.200 mm [0.0079 in.] |
| | Compression ring, No.2 | 0.08 to 0.12 mm [0.0031 to 0.0047 in.] | 0.150 mm [0.0059 in.] |
| | Oil ring | 0.025 to 0.065 mm [0.0010 to 0.0026 in.] | 0.150 mm [0.0059 in.] |

### 4.7 Measuring piston pin bore diameter and piston pin outside diameter

Measure the piston pin bore diameter and piston pin outside diameter. Replace if the limit is exceeded.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Piston pin outside diameter | ø 34 mm [1.34 in.] | 33.991 to 33.997 mm [1.3382 to 1.3385 in.] | – |
| Clearance between piston pin bore and piston pin | – | 0.005 to 0.021 mm [0.0002 to 0.0008 in.] | 0.050 mm [0.0020 in.] |




Measuring piston pin bore and piston pin

### 4.8 Measuring piston protrusion

**CAUTION**

The piston protrusion is a very important factor for proper engine operation and must always be kept as specified. Too much piston protrusion can cause the piston to interfere with the valves.

Measure the protrusion of each piston as follows: If the measurement does not conform to the standard, the clearances between various parts concerned must be checked.

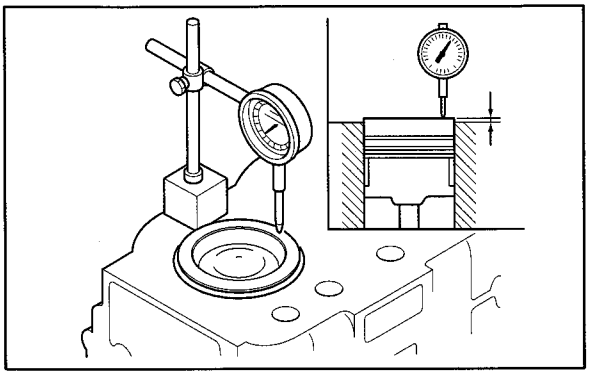
(1) Bring the piston to the top dead center.

(2) Apply the dial gauge plunger to the top surface of the crankcase, and zero the dial gauge.

(3) Measure the protrusion at four points on the piston head, and calcurate the mean value.

Note: Subtract the mean value from the thickness of the gasket compressed by tightening the cylinder head, and the clearance between the piston top and cylinder head will be determined.

| Item | Standard |
|---|---|
| Piston protrusion | 0.8 mm<br>[0.031 in.] |
| Compressed thickness of cylinder head gasket | 1.7 ± 0.5 mm<br>[0.067 ± 0.022 in.] |



Measuring piston protrusion

### 4.9 Measuring clearance between connecting rod bearing and crankpin

**CAUTION**

When grinding crank pins, be sure to grind all the pins to the same size.

Finish the fillet radius to the specified dimension.

(1) Reassemble the bearing into the big end of the connecting rod.

(2) Tighten the connecting rod cap bolts to the specified torque.

(3) Measure the inside diameter of the connecting rod bearing.

(4) Measure the outside diameter of the crank pin.

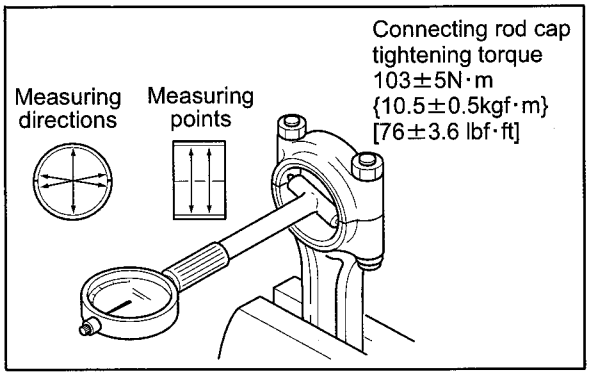
(5) Calculate the clearance from the difference between the inside diameter of the connecting rod bearing and outside diameter of the crank pin.

(6) Replace the connecting rod bearing if the clearance exceeds the limit.

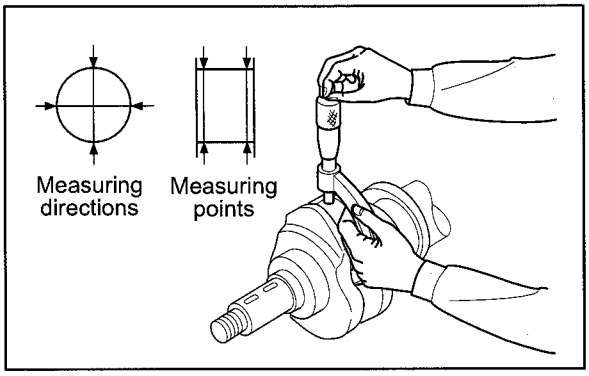
(7) Measure the clearance between the connecting rod bearing and the crank pin again. Use the undersize bearing if the limit is exceeded.

(8) If an undersize bearing is used, grind the crank pin to the specified undersize.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Crankpin outside diameter | ø 65 mm [0.026 in.] | 64.945 to 64.965 mm [2.5569 to 2.5577 in.] | 64.800 mm [2.5512 in.] |
| Clearance between crankpin and connecting rod bearing | – | 0.035 to 0.100 mm [0.014 to 0.0039 in.] | 0.200 mm [0.0079 in.] |




Measuring connecting rod bearing inside diameter

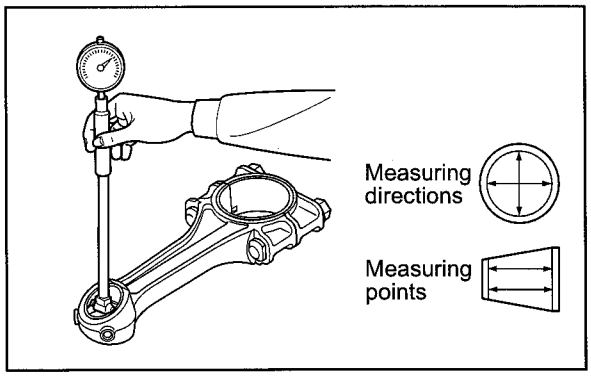



Measuring crank pin diameter

### 4.10 Measuring clearance between connecting rod bushing and piston pin

Measure the inside diameter of the connecting rod bushing and the outside diameter of the piston pin. Replace if the limit is exceeded.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Bushing inside diameter | ø 34 mm [1.34 in.] | 34.020 to 34.045 mm [1.3394 to 1.3404 in.] | – |
| Clearance between bushing and piston pin | – | 0.023 to 0.054 mm [0.0009 to 0.0021 in.] | 0.080 mm [0.0031 in.] |



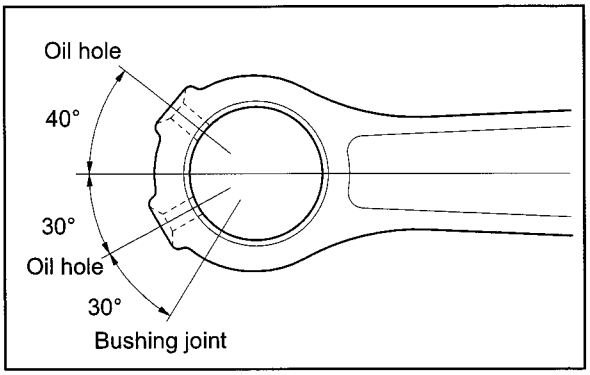

Measuring connecting rod bushing inside diameter

### 4.11 Replacing connecting rod bushing

(1) Use a connecting rod bushing installer to replace the connecting rod bushing.

(2) Align the oil holes of the bushing and connecting rod. Position the joint of the bushing as shown in the diagram.

(3) After installation, insert the piston pin and make sure the pin rotates freely without rattling.




Replacing connecting rod bushing

### 4.12 Removing connecting rod bushing

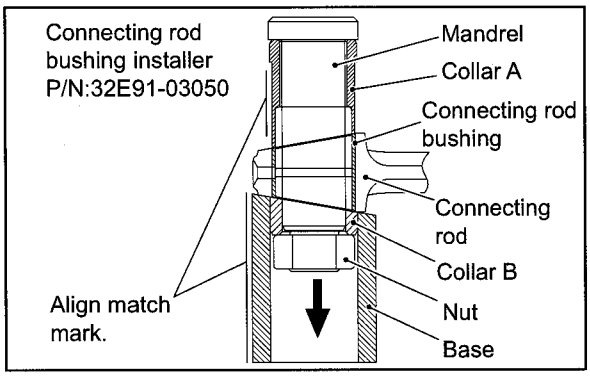
(1) Apply engine oil to the inner surface of the connecting rod bushing.

(2) Install the collar A to the connecting rod bushing.

(3) Install the collar A and B to the mandrel, and tighten the nut.

(4) Align the match mark (red line) on the collar A with the match mark on the base.

(5) Using a press, apply pressure slowly on the head of the mandrel to force out the connecting rod bushing.



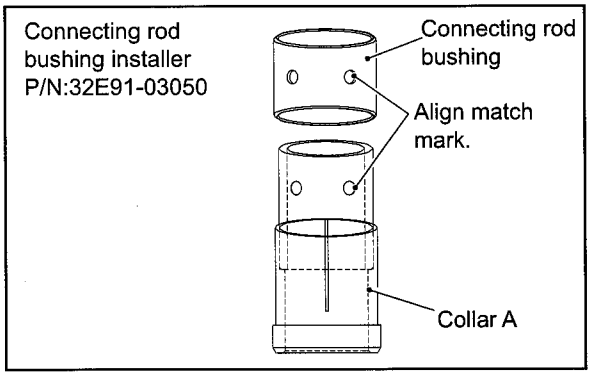

Removing connecting rod bushing

### 4.13 Installing connecting rod bushing

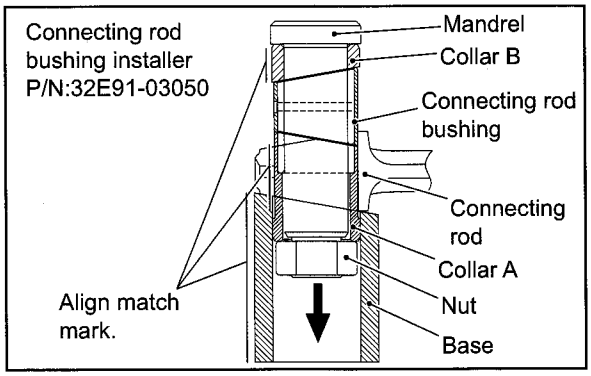
(1) With the oil hole of busing aligned with the match mark on the collar A, install the new connecting rod bushing onto the collar A.

(2) Install the collars A and B to the mandrel, and tighten the nut.

(3) Apply engine oil to the outer periphery of the connecting rod bushing. Align the oil hole in the connecting rod bushing with the match mark (red line) on the collar, then press the bushing into the connecting rod.




Installing connecting rod bushing 1




Installing connecting rod bushing 2

### 4.14 Inspecting connecting rod bend and twist

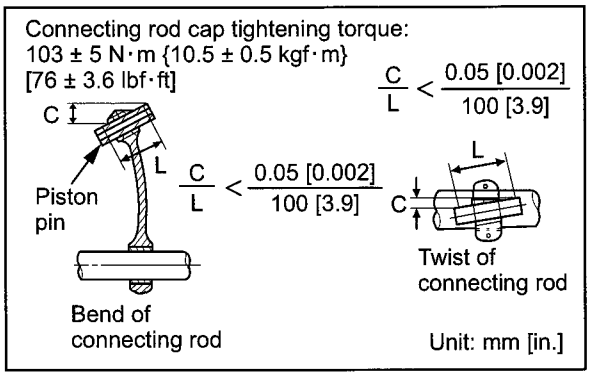
(1) Measure C and L as shown in the diagram to check the connecting rod bend and twist. If the value is out of the standard value, straighten the connecting rod with a press.
If the limit is exceeded, replace the connecting rod.

(2) In general, connecting rod bend and twist are checked by the connecting rod aligner.

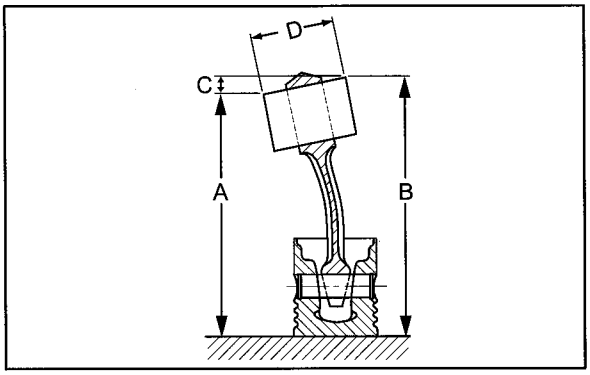
Note: Before inspecting bend, install the cap to the connecting rod, then tighten the cap bolts to the specified torque.

(3) To inspect the connecting rod assembled with the piston, place the piston on a surface plate, insert a round bar having the same diameter as the crankpin into the big-end bore, then measure the height of the bar with a dial gauge.

| Item | Standard | Limit |
|---|---|---|
| Connecting rod bend and twist | 0.05/100 mm [0.0020/3.94 in.] or less | 0.15 mm [0.0059 in.] |



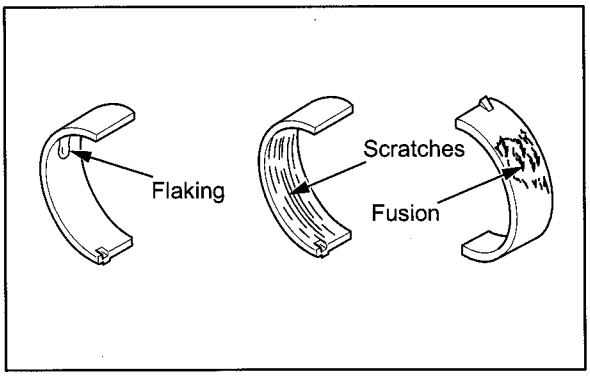

Inspecting connecting rod bend and twist




Measuring with a dial gauge

### 4.15 Inspecting connecting rod bearing

Check the connecting rod bearings and replace the damaged bearings with new ones.

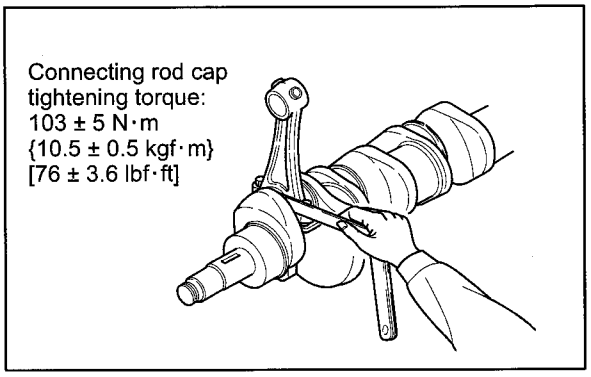



Inspecting connecting rod bearing

### 4.16 Measuring connecting rod end play

(1) Install the connecting rods onto the respective crankpins and tighten the connecting rod cap bolts to the specified torque.
(2) Measure the clearance to the crank arm (end play) at two positions (above and below the crankpin).
(3) Replace the connecting rod if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Connecting rod end play | 0.15 to 0.35 mm [0.0059 to 0.0138 in.] | 0.50 mm [0.0197 in.] |

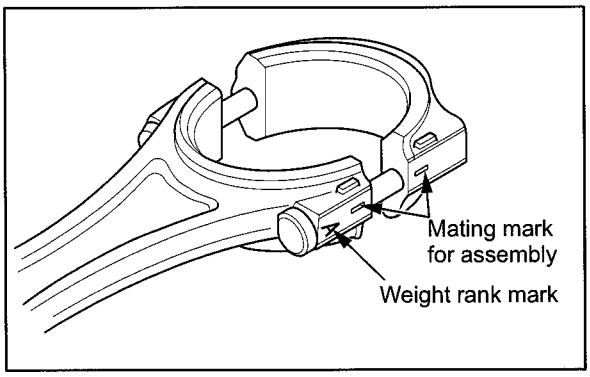



Measuring connecting rod end play

### 4.17 Weight difference of connecting rod assembly in one engine

When replacing a connecting rod, be sure to check the weight rank of the connecting rod. In one engine, all the connecting rods must be of the same weight rank.

| Item | Tolerance on weight |
|---|---|
| Weight difference of connecting rod assembly | 10 g [0.4 oz.] or less per engine |

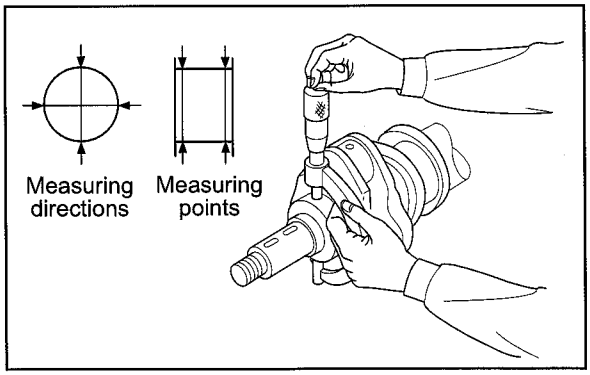



Weight difference in connecting rod assembly

### 4.18 Measuring crankshaft journal outside diameter

Measure the crankshaft journal diameter using a micrometer. Check the crankshaft journal for circularity, cylindricality and the clearance with the bearing. If the measurement value is below the repair limit, grind the journal to fit the undersize bearing. If the measurement value is below the service limit, replace the crankshaft with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Diameter | ø 90 mm [3.54 in.] | 89.95 to 89.97 mm [3.5413 to 3.5421 in.] | Repair limit = 89.85 mm [3.5374 in.] Service limit = 89.10 mm [3.5079 in.] |
| Circularity | — | 0.01 mm [0.0004 in.] or less | 0.03 mm [0.0012 in.] |
| Cylindricity | — | 0.01 mm [0.0004 in.] or less | 0.03 mm [0.0012 in.] |
| Parallelism | — | Deviation of 0.01 mm [0.0004 in.] or less over entire pin length | — |

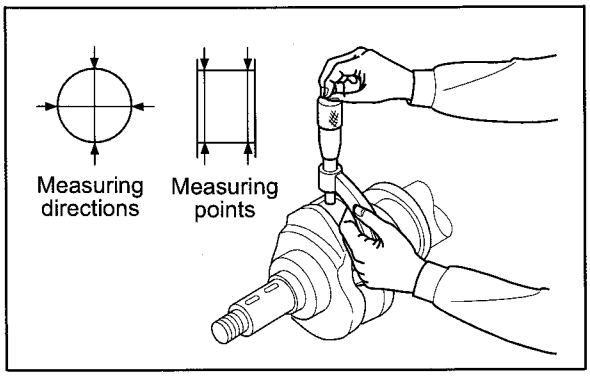



Measuring crankshaft journal outside diameter

### 4.19 Measuring crankshaft crankpin outside diameter

Measure the crankpin outside diameter using a micrometer. Check the crankpin for circularity, cylindricality, and the clearance with the bearing. If the measurement value is below the limit, grind the journal to fit the undersize bearing. If the measurement value is below the service limit, replace the crankshaft with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Diameter | ø 65 mm [2.56 in.] | 64.945 to 64.965 mm [2.5569 to 2.5577 in.] | Service limit = 64.800 mm [2.5512 in.] |
| Circularity | – | 0.01 mm [0.0004 in.] or less | 0.03 mm [0.0012 in.] |
| Cylindricity | – | 0.01 mm [0.0004 in.] or less | 0.03 mm [0.0012 in.] |
| Parallelism | – | Deviation of 0.01 mm [0.0004 in.] or less over entire pin length | – |



Measuring crank pin diameter

### 4.20 Grinding crankshaft

Grind the crankshaft journals (or pins) to the diameter matching the inside diameter of the next undersize main (or connecting) bearing, and the fitness check with an actual bearing will become omissible.

When grinding, be careful not to change the fillet radius and width. If the surface hardness is considered to have been reduced considerably, re-harden the crankshaft and check for flaws by means of magnetic particle inspection.

Ensure that the surface finish accuracy of the crankpins and journals is kept within the standard even after the correction by grinding.

| Item | Undersize | Finished size |
|---|---|---|
| Crank journal | 0.25 mm [0.0098 in.] | 89.70 to 89.72 mm [3.5315 to 3.5323 in.] |
| | 0.50 mm [0.0197 in.] | 89.45 to 89.47 mm [3.5216 to 3.5224 in.] |
| | 0.75 mm [0.0295 in.] | 89.20 to 89.22 mm [3.5118 to 3.5126 in.] |
| Crankpin | 0.25 mm [0.0098 in.] | 65.695 to 65.715 mm [2.5864 to 2.5872 in.] |
| | 0.50 mm [0.0197 in.] | 65.445 to 65.465 mm [2.5766 to 2.5774 in.] |
| | 0.75 mm [0.0295 in.] | 65.195 to 65.215 mm [2.5667 to 2.5675 in.] |

### 4.21 Measuring crankshaft end play

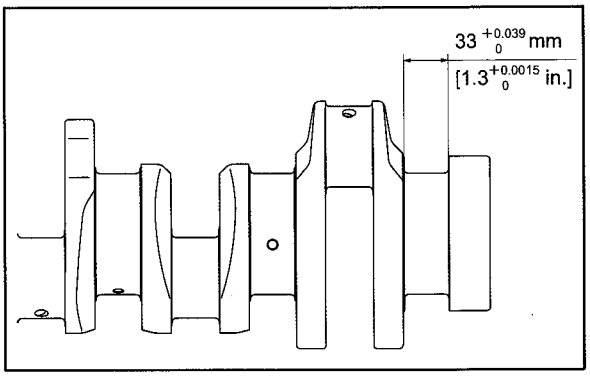
(1) Check the crankshaft end play (clearance between the crank arm at the thrust force receiving journal and the bearing cap with thrust plate attached), and replace the thrust plate with a new one if the limit is exceeded.

(2) Use an oversize thrust plate if the limit is still exceeded even after a new thrust plate is installed.

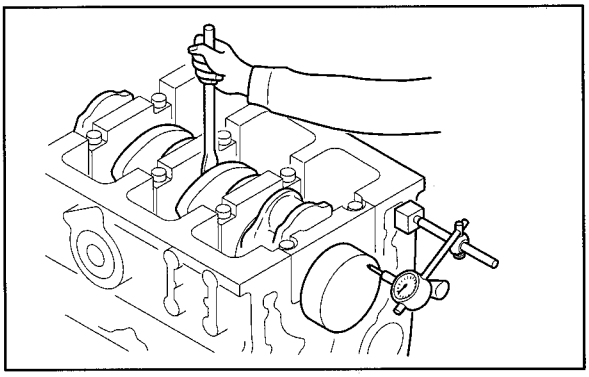
Note: In general, the rear thrust bearing wears faster than the front thrust bearing. Therefore, in most cases, the correction is achieved by replacing the rear thrust plate with a next oversize one.

| Item | Standard | Limit |
|---|---|---|
| Crankshaft end play | 0.100 to 0.246 mm [0.0039 to 0.0104 in.] | 0.300 mm [0.0118 in.] |

| Crankshaft thrust size after grinding | | | |
|---|---|---|---|
| Item | OS, used on one side | OS, used on both sides | Tolerance |
| +0.15 mm [+0.0059 in.] OS | 33.15 mm [1.3051 in.] | 33.30 mm [1.3110 in.] | 0 to 0.039 mm [0 to 0.0015 in.] |
| +0.30 mm [+0.0118 in.] OS | 33.30 mm [1.3110 in.] | 33.45 mm [1.3169 in.] | |
| +0.45 mm [+0.0177 in.] OS | 33.45 mm [1.3169 in.] | 33.60 mm [1.3228 in.] | |




Width of crankshaft thrust journal



Measuring crankshaft end play

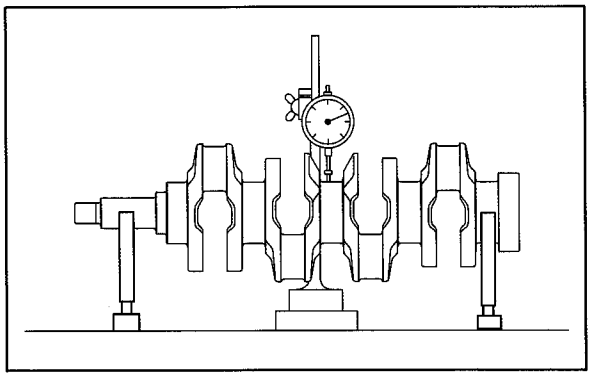
### 4.22 Measuring crankshaft runout

Support the crankshaft at the front and rear journals with V-blocks, and measure the crankshaft deflection (radial runout at the center journal) with a dial gauge. If the runout deviates from the standard only slightly, correct it by grinding the crankshaft. If the runout is a little large, straighten the crankshaft using a press.

Replace the crankshaft if the limit is exceeded.

If the crankshaft has been repaired by grinding or pressing, inspect its various parts for cracks and other harmful damage with a magnetic particle examination.

| Item | Standard | Limit | Re-mark |
|---|---|---|---|
| Crankshaft runout | 0.04 mm [0.0016 in.] or less | 0.10 mm [0.0039 in.] or less | TIR |



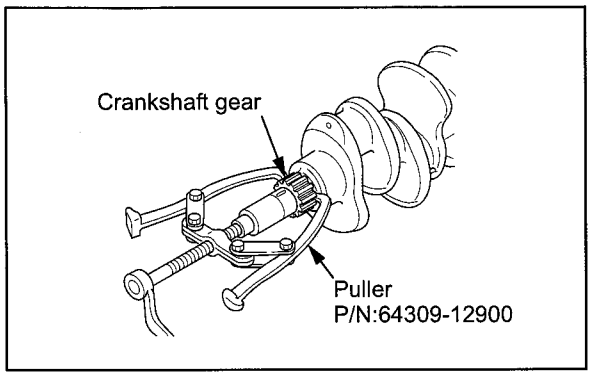
Measuring crankshaft runout

### 4.23 Replacing crankshaft gear

#### 4.23.1 Removing crankshaft gear

Using the gear puller, remove the gear from the crankshaft.

Note: Do not remove the gear by hitting it with a hammer.

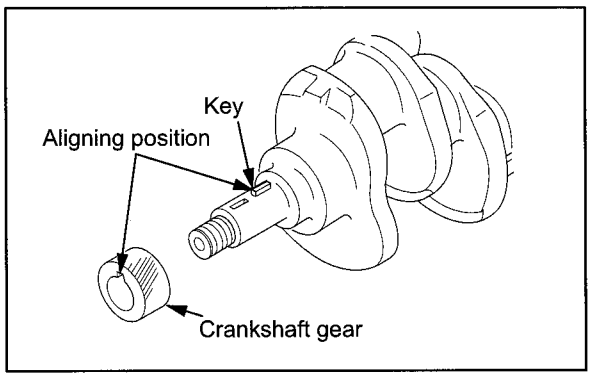



Removing crankshaft gear

#### 4.23.2 Installing crankshaft gear

(1) Install the key on the crankshaft.

(2) Press-fit the gear fully in alignment with the key.




Installing crankshaft gear

### 4.24 Replacing front oil seal

**CAUTION**

Be careful not to damage the crankshaft pulley with a chisel when breaking the sleeve. Be careful not to dent or scratch the outer surface of sleeve.

When a oill leaks from the oil seal, replace both sleeve and oil seal with new ones.

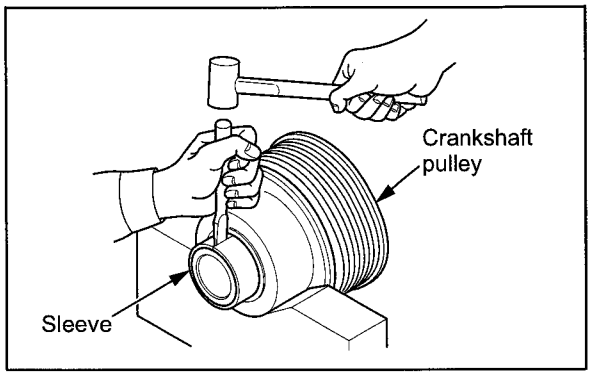
(1) Removing sleeve

Apply a chisel at right angles to the end surface of the sleeve and strike it with a hammer at three locations to loosen the sleeve and then remove the sleeve.

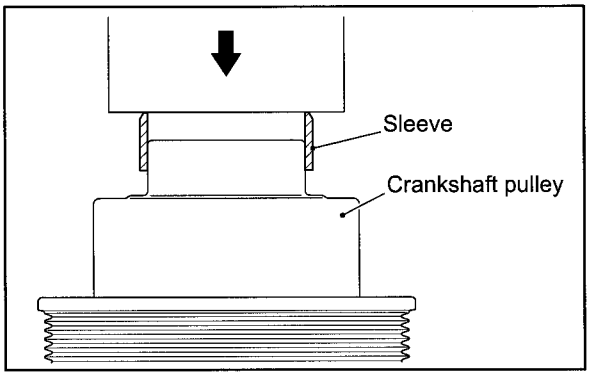
Note: If the sleeve cannot be removed, apply the chisel to the sleeve in the axial direction of the sleeve and tap it lightly to make a cut and remove crankshaft-to-sleeve interference.

(2) Installing sleeve

Install the sleeve using a press so that the end of pulley becomes flush.




Removing front sleeve




Installing front sleeve

### 4.25 Replacing rear oil seal

**CAUTION**

Be careful not to damage the crankshaft when removing the rear oil seal.

When a oill leaks from the oil seal, replace the oil seal with a new one.

(1) Removing rear oil seal

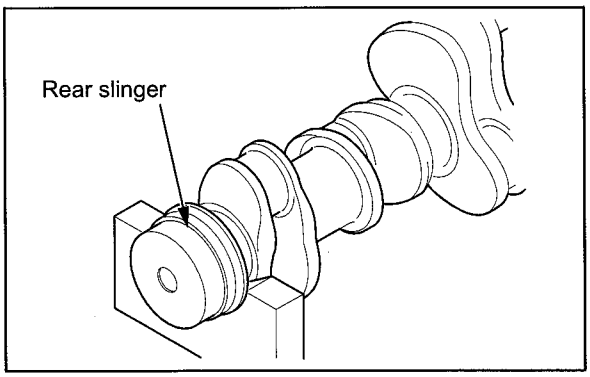
Remove the oil seal with a puller.

(2) Installing rear side oil seal

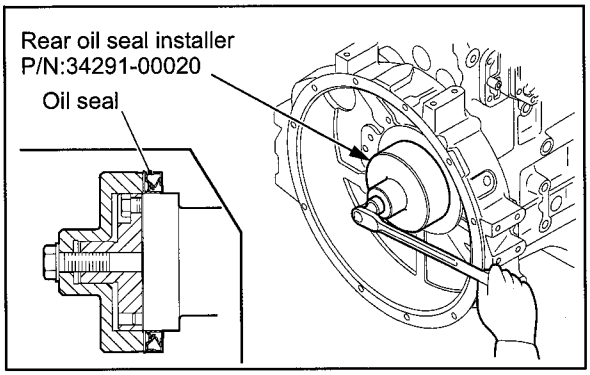
Apply an oil on the slinger inner surface of oil seal.

Install the oil seal with an oil seal installer.

Note: The oil seal is united with the slinger.



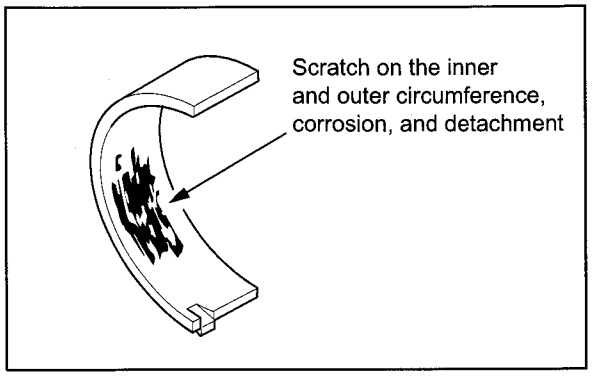

Removing oil seal (rear side)




Installing oil seal (rear side)

### 4.26 Inspecting main bearing surface

Check the inside surface of each main bearing shell for abnormal contact signs, scratches and corrosion resulting from foreign matter intrusion, coating delamination, etc.Also check the outside surface of each bearing shell which contacts with the crankcase or main bearing cap for abnormal seating signs.




Inspecting main bearing surface

### 4.27 Measuring clearance between main bearing and crankshaft journal

**CAUTION**

(a) When grinding crank journals, be sure to grind all the journals to the same size.

(b) Finish the fillet radius to the specified dimension.

(1) Reassemble main bearings.

(2) Tighten the main bearing caps to the specified torque.

(3) Measure the inside diameter of the main bearings.

(4) Measure the outside diameter of the crank journal.

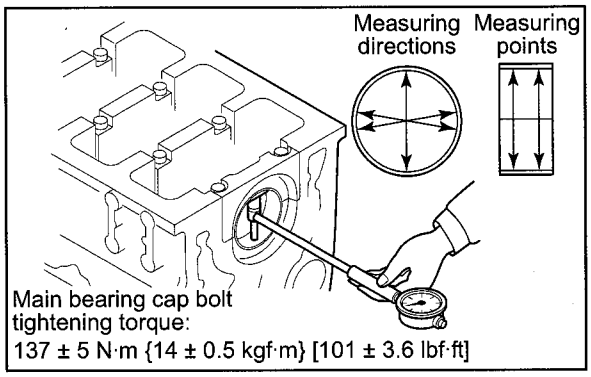
(5) Calculate the clearance between the inside diameter of the main bearing and outside diameter of the crank journal.

(6) Replace the main bearing if the clearance exceeds the limit.

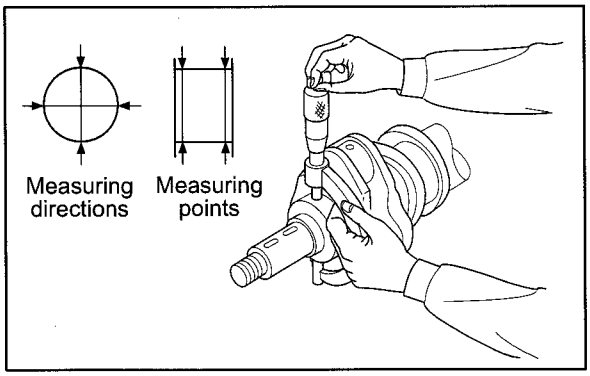
(7) Measure the clearance between the main bearing cap and the crank journal again. Use the undersize bearing if the limit is exceeded.

(8) If an undersize bearing is used, grind the crank journal to the specified undersize.

| Item | Standard | Limit |
|---|---|---|
| Clearance between main bearing and crankshaft journal | 0.050 to 0.118 mm [0.0020 to 0.0046 in.] | 0.200 mm [0.0079 in.] |




Measuring inside diameter of lower hole of main bearing




Measuring crank journal outside diameter

# REASSEMBLING ENGINE MAIN PARTS

# 1. Reassembling piston, connecting rod, crankshaft and crankcase

## 1.1 Installing main bearing

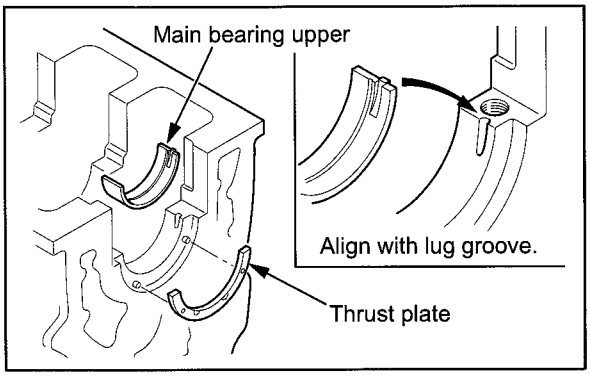
**CAUTION**

Do not apply oil to the bearing outer surface, as the oil may cause the bearing seizure.

(1) Fit the main bearings (upper halves) into the lug grooves in the crankcase.

Note: The oil holes in the bearings and crankcase are aligned when the bearings are installed as described above.

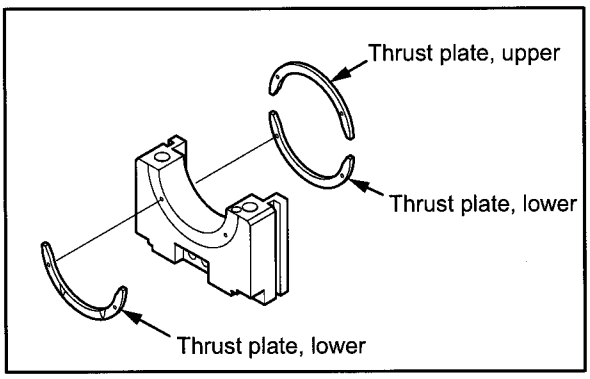
(2) Apply a small amount of engine oil to each bearing.




Installing main bearing upper

## 1.2 Installing thrust plate

(1) Install the thrust plates to the crankcase outside face of rearmost bearing and to the main bearing cap with their goorves faced outside.




Installing thrust plate

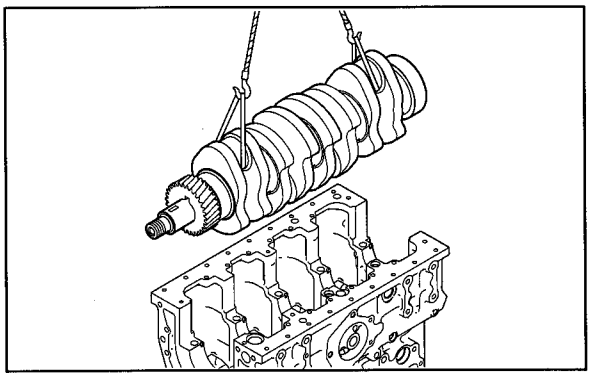
## 1.3 Installing crankshaft

(1) Wash the crankshaft thoroughly with cleaner, and dry it with compressed air.

Note: When washing the crankshaft, be sure to clean the oil holes and make sure they are not clogged with dust or foreign particles.

(2) Hold the crankshaft horizontally with a hoist, then carefully place it into the crankcase.

(3) Apply a small amount of engine oil to the crankshaft journals.



Installing crankshaft

### 1.4 Installing main bearing caps

**CAUTION**

Install the foremost and rearmost caps so that they are flush with the crankcase surface.

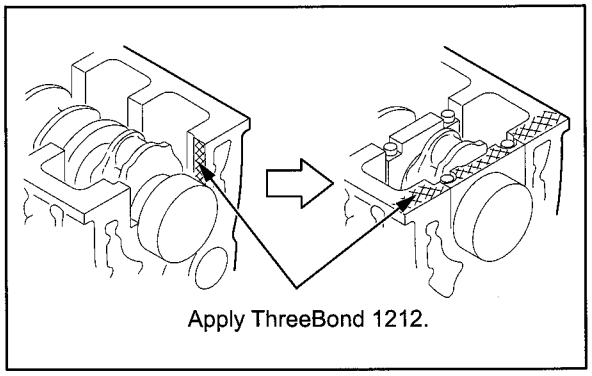
Install the main bearing caps from the front side in the order of the numbers marked on them.

(1) Apply engine oil to lower main bearings and install them to the main bearing caps.

(2) Apply ThreeBond 1212 to the mating surface of the foremost and rearmost caps and the crankcase mating faces before installing the main bearing caps.

Note: Do not apply ThreeBond 1212 any other area other than the mating surfaces of the foremost and rearmost caps and the crankcase mating faces.

(3) Install the main bearing caps and temporarily tighten bolts.




Installing main bearing cap

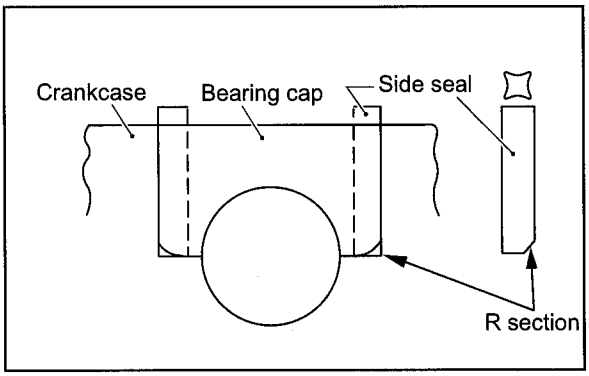
### 1.5 Inserting side seal

(1) Apply a sealant to the circumference of new side seals.

| | |
|---|---|
| Sealant | THREEBOND 1212 or 1211 |

(2) With roundings of the side seals facing outward, push them in the front and rear caps to some extent by hands.

(3) When the side seals are pushed-in to some extent, use a tool with flat surface such as flat-head screwdriver to completely push them in, taking care not to bend them.

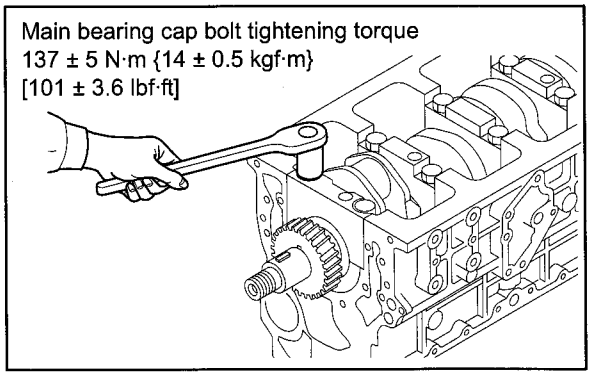



Inserting side seal

### 1.6 Installing main bearing cap bolt

(1) Tighten the main bearing cap bolts alternately and progressively to the specified torque.

(2) Make sure that the crankshaft rotates smoothly.



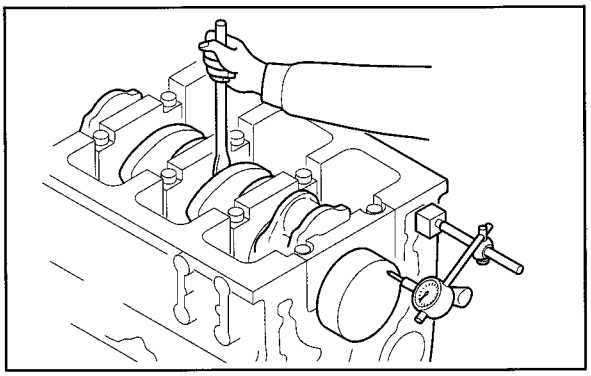

Installing main bearing cap bolt

### 1.7 Measuring crankshaft end play

Apply a dial gauge to the tip of the crankshaft to measure the end play.

If the end play is out of the standard value, loosen the main bearing cap bolts and tighten them again

| Item | Standard | Limit |
|---|---|---|
| Crankshaft end play | 0.100 to 0.264 mm [0.0039 to 0.0104 in.] | 0.300 mm [0.0118 in.] |



Measuring crankshaft end play

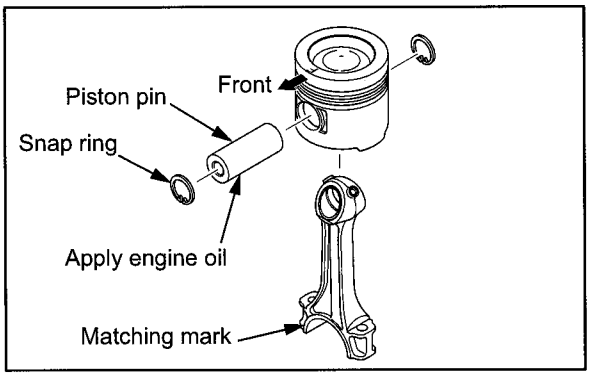
### 1.8 Reassembling piston and connecting rod

(1) Apply engine oil to the piston pin.

(2) With the matching mark on the connecting rod oriented on the right side of piston when facing the piston top front mark "F", assemble the connecting rod and the piston, and secure them with the piston pin.

(3) Install each snap ring into the ring groove of the piston using ring pliers. Check snap rings for tension and seating condition in the groove.

(4) Orient the split of each snap ring toward the bottom of the piston.




Reassembling piston and connecting rod

### 1.9 Installing piston ring

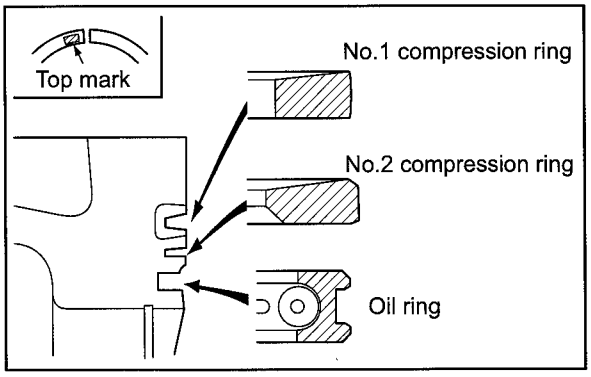
**CAUTION**

A marking such as "R" is stamped near the end gap to indicate the top face of piston ring. Install all piston rings with the mark faced upward.

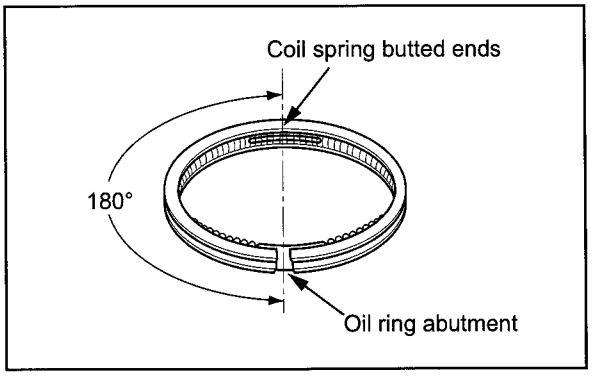
If piston rings are assembled wrong side up, it will cause malfunctions such as increase of oil consumption or engine seizure.

(1) Install the piston rings to the piston with a ring expander.

(2) Install the oil ring spring so that its joint is 180° away from the oil ring end gap as shown in the illustration.




Reassembling piston and piston ring

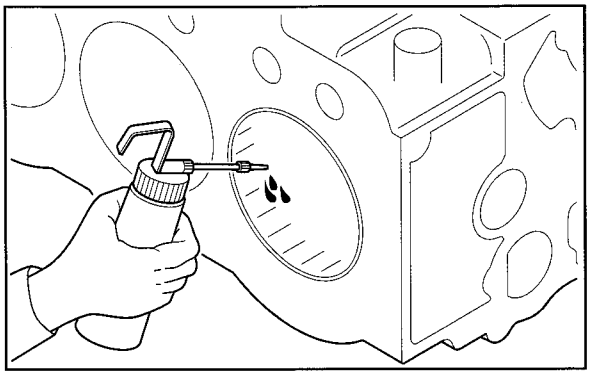



Reassembling oil ring

### 1.10 Preparation for Installing Pistons

(1) Lay the engine along its side.

(2) Clean the cylinder sleeve inner surface and the crank pin with a cloth, and apply engine oil to them.



Cleaning and lubricating cylinder sleeve inner surface

### 1.11 Installing connecting rod bolt and connecting rod bearing

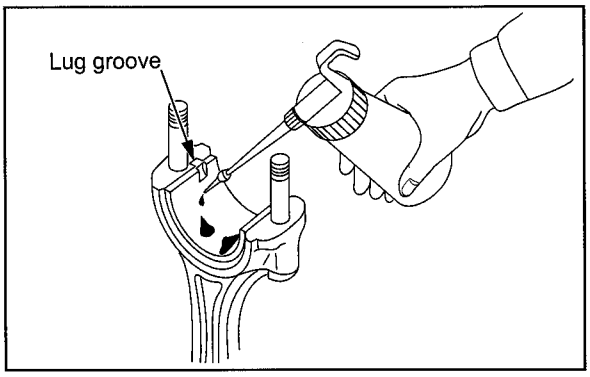
(1) Press fit the connecting rod bolts into the connecting rod.

Note: When press fitting the bolt, make sure that the bolt fully contacts its seating position without any interference with the shoulder of mounting surface.

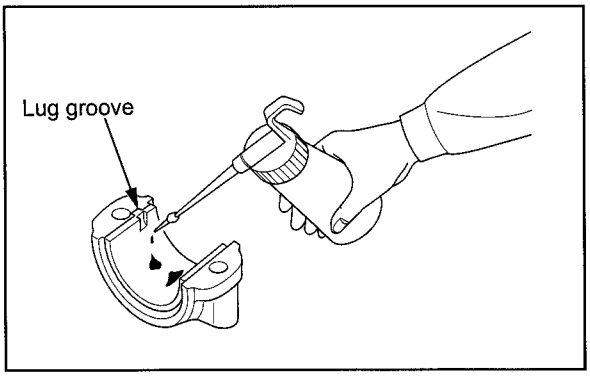
(2) Install the upper connecting rod bearing with its lug fitted in the lug groove of connecting rod.

(3) Install the lower connecting rod bearing with its lug fitted in the lug groove of connecting rod cap.

(4) Apply engine oil to the inner surface of bearing.




Installing connecting rod bolt and upper bearing




Installing lower connecting rod bearing

### 1.12 Installing Pistons

**CAUTION**

Do not forcefully insert the piston. It may cause damage to the piston rings and crank pin.

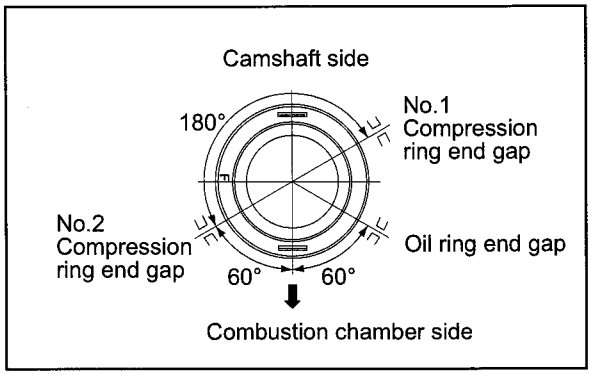
(1) Apply engine oil to the circumference of the piston and piston rings.

(2) Orient the ring end gaps diagonally opposite each other avoiding the piston pin direction and its right angle direction.

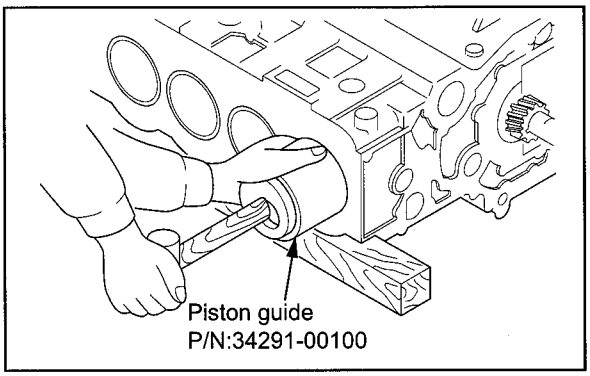
(3) Turn the crankshaft to bring the crank pin of the cylinder to the top dead center.

(4) Orient the front mark on the top of piston toward engine front.

(5) Using a piston guide, insert the piston from the top face of crankcase into the cylinder sleeve.




Orientation of piston ring end gap




Installing piston

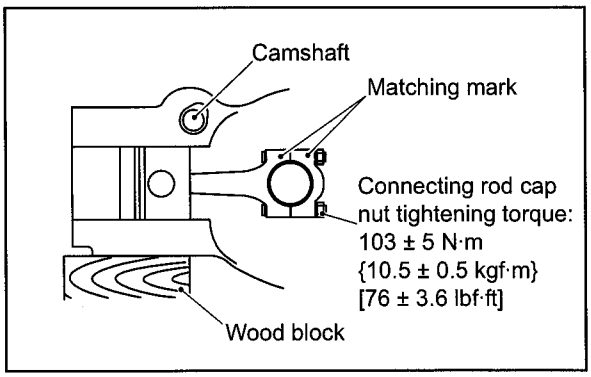
### 1.13 Installing connecting rod cap

(1) When the big end of the connecting rod comes into contact with the crank pin, turn the crankshaft 180° while pressing the piston head.

(2) Install the connecting rod cap with its match mark facing on the same side as the match mark on the connecting rod.

(3) Tighten the connecting rod cap nuts evenly and progressively to the specified torque.

(4) Inspect end play of the connecting rod. Loosen the cap nuts and retighten them if end play is small.

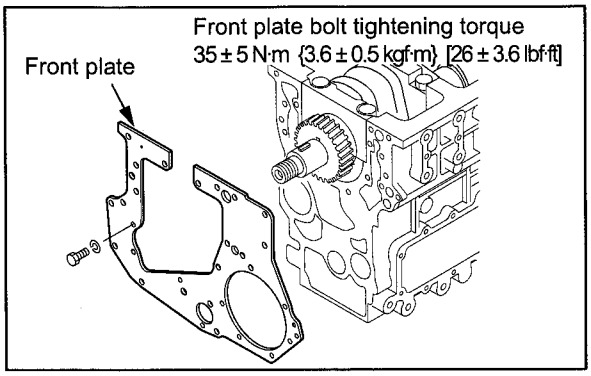



Installing connecting rod cap

## 2. Reassembling timing gear and camshaft

### 2.1 Installing front plate

(1) Clean the mounting surface of the gasket.
(2) Apply sealant to the gasket to prevent falling.
(3) Install the gasket.
(4) Install the front plate, and secure it with mounting bolts.




Installing front plate

### 2.2 Installing tappet

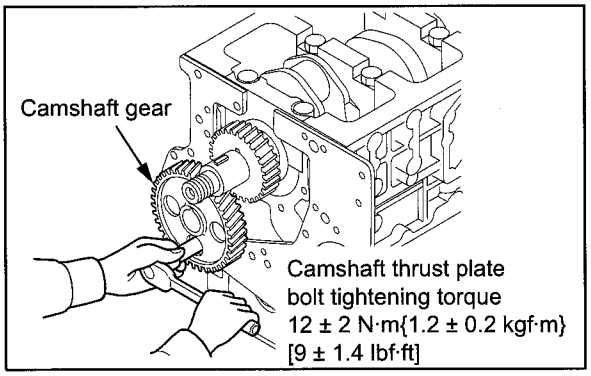
Coat the periphery of tappets with engine oil, insert them into the tappet holes and place them gently on the camshafts.

### 2.3 Installing camshaft

**⚠ CAUTION**

Be careful not to damage camshaft journals, cams and camshaft holes during insertion.

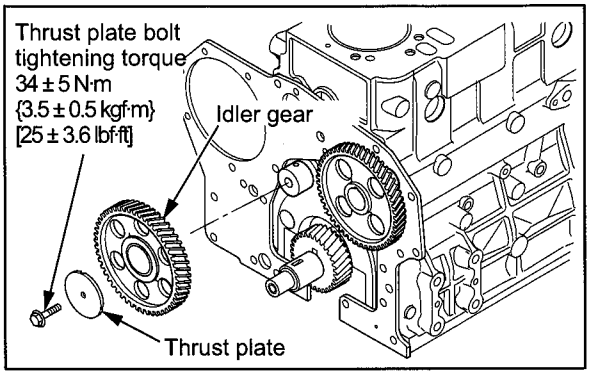
(1) Apply engine oil to the camshaft journals and cams.
(2) Slowly insert the camshaft assembly.
(3) Tighten the thrust plate bolt to the specified torque.
(4) Make sure that the camshaft rotates lightly. Move the camshaft gear back and forth, and make sure there is end play.



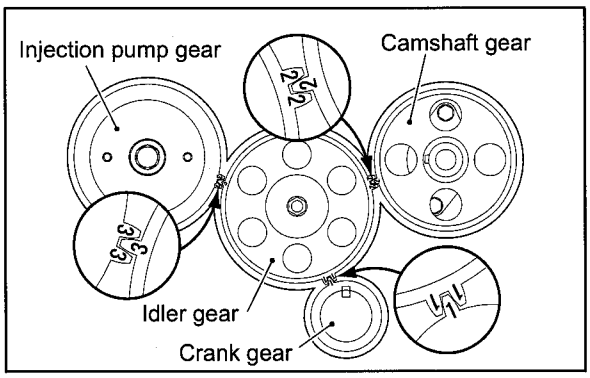

Installing camshaft

### 2.4 Installing idler gear

(1) Apply engine oil to the idler gear shaft evenly.
(2) Install the idler gear with its match marks aligned with the marks on the crankshaft and camshaft gears.
(3) Install the thrust plate to the idler gear, and tighten the mounting bolt to the specified torque.




Installing idler gear



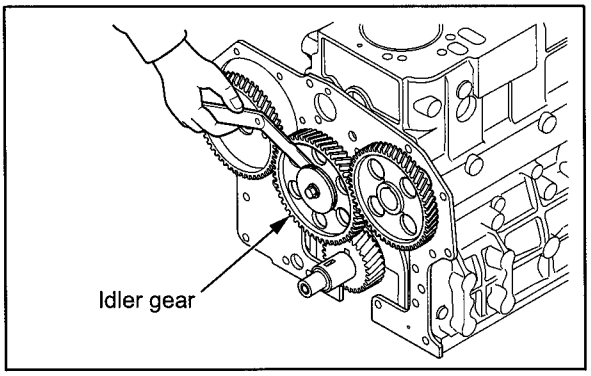

Timing gear train

### 2.5 Inspecting and adjusting timing gear after installation

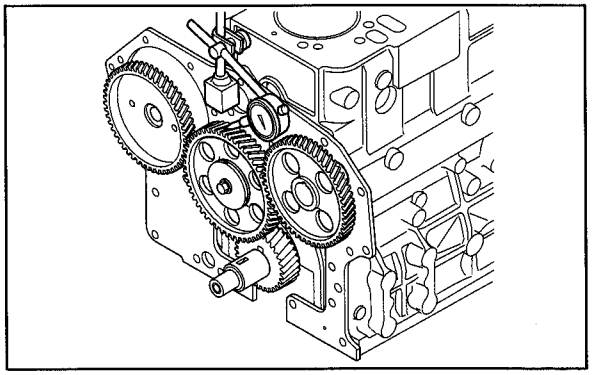
Be sure to inspect and adjust the timing gear when the timing gear has been reassembled.

#### 2.5.1 Inspecting backlash and end play

After installing the timing gears, be sure to inspect and adjust the backlash and end play between gears.



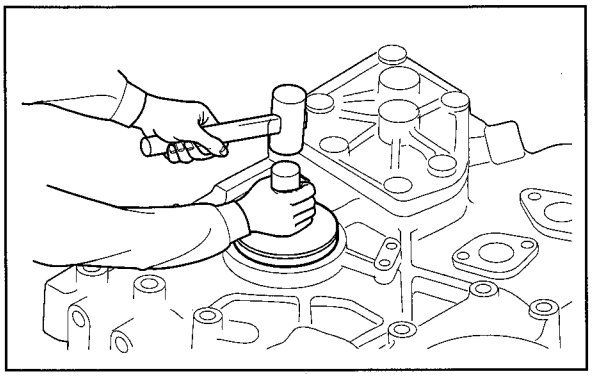

Measuring idler gear end play



Measuring backlash of timing gear

### 2.6 Installing front oil seal

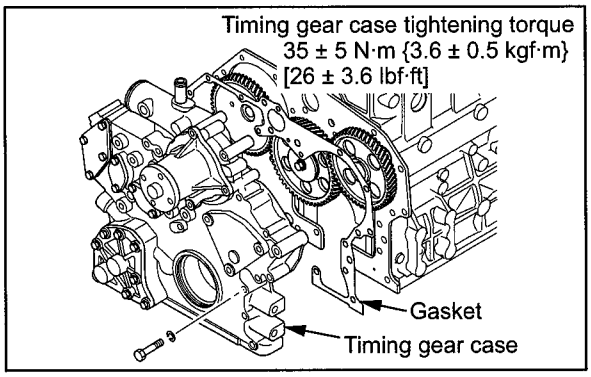
Using an installer, install new oil seal in the timing gear case. Make sure the oil seal is flush with the gear case.



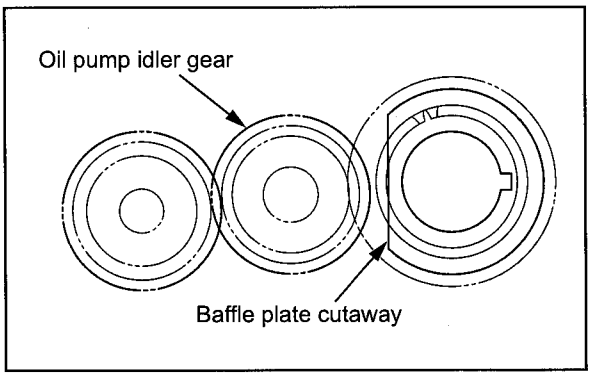
Installing front oil seal

### 2.7 Installing timing gear case

(1) Install the baffle plate to the front end of crankshaft.
(2) Apply sealant to the gasket to prevent it from displacing and install the gasket on the front plate.
(3) Apply engine oil to the oil seal lip.
(4) Orient the cutaway of the baffle plate so that the baffle plate does not overlap the oil pump idler gear.
(5) Install the timing gear case, and secure it with the bolts.




Installing timing gear case



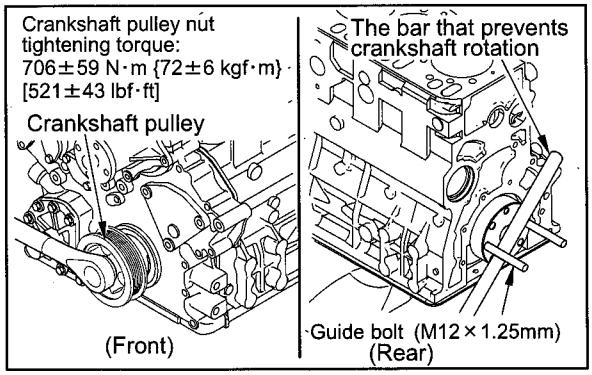

Baffle plate cutaway position

### 2.8 Installing crankshaft pulley

**⚠ CAUTION**

The bar could come off. Be very careful.

(1) Screw two guide bolts into the threaded holes at the rear end of the crankshaft. Use these bolts and a bar placed across them to prevent the crankshaft from rotating.
(2) Install the woodruff key on the crankshaft.
(3) Install the crankshaft pulley and tighten the nuts to the specified torque.



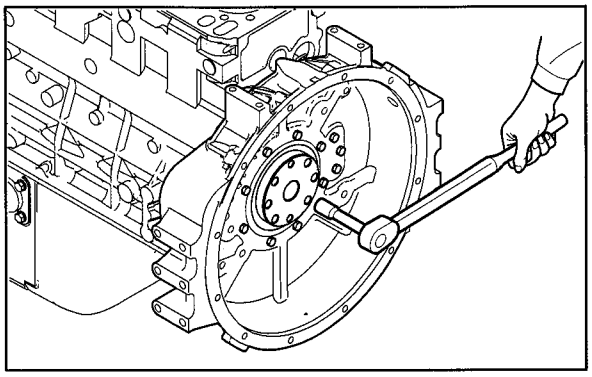

Installing crankshaft pulley

## 3. Reassembling Flywheel

### 3.1 Installing flywheel housing

(1) Clean the mounting surface of the gasket.
(2) Apply sealant to prevent the gasket from falling off.
(3) Install the gasket.
(4) Install the flywheel housing, aligning its dwel pin holes and dowel pins, and tighten the bolts.

Note: When the dowel pins are worn or the flywheel housing is replaced, replace the dowel pins with new ones.



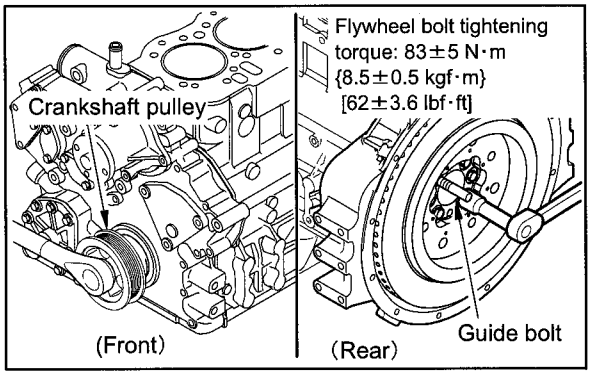
Installing flywheel housing

### 3.2 Installing flywheel

**⚠ CAUTION**

The person who holds the pulley must be very careful to assure safety by communicating with the person who is installing the flywheel.

(1) One person must firmly hold the pulley with a wrench to prevent the crankshaft from turning.
(2) Screw the guide bolt into the rear end of the crankshaft.
(3) Align the bolt hole of flywheel with the guide bolt and install the flywheel to the crankshaft.
(4) Temporarily tighten bolts.
(5) Remove the guide bolt and temporarily tighten the last bolt.
(6) Tighten the flywheel bolts to the specified torque.



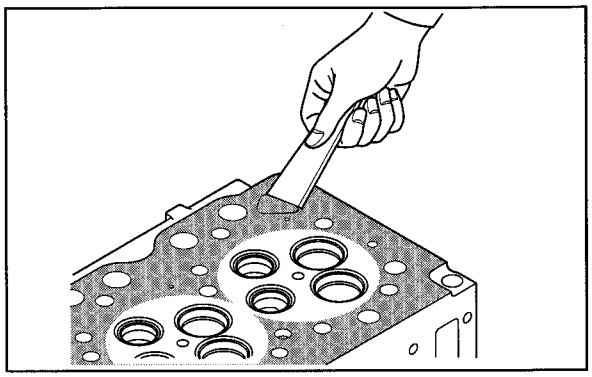

Installing flywheel

## 4. Reassembling cylinder head and valve mechanism

### 4.1 Cleaning cylinder head bottom surface

Taking care not to damage the cylinder head bottom surface, remove gasket residue.

Note: First, roughly scrape off the residue using a scraper. Then, grind off remaining residue using an engine-oil immersed oil stone.



Cleaning cylinder head bottom surface

### 4.2 Installing valve stem seal

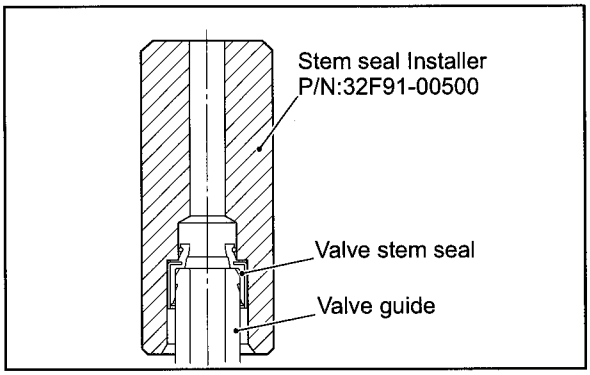
**CAUTION**

Do not apply oil or liquid gasket to the inner side of stem seal that comes in contact with the valve guide.

(1) Apply engine oil to the lip of new valve stem seal.

(2) Push the shoulder of the valve stem seal and fit the valve stem steal into the valve guide.

(3) Insert the valve stem seal into the valve guide using the valve stem seal installer.

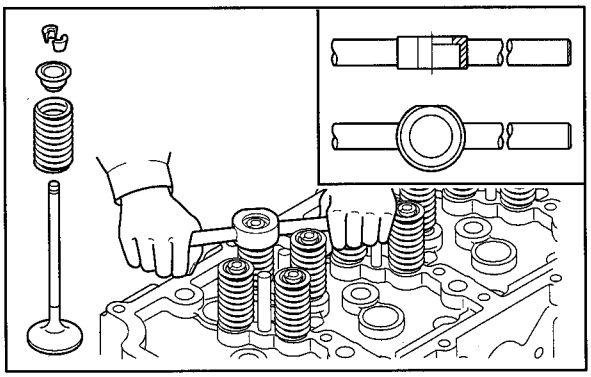



Installing valve stem seal

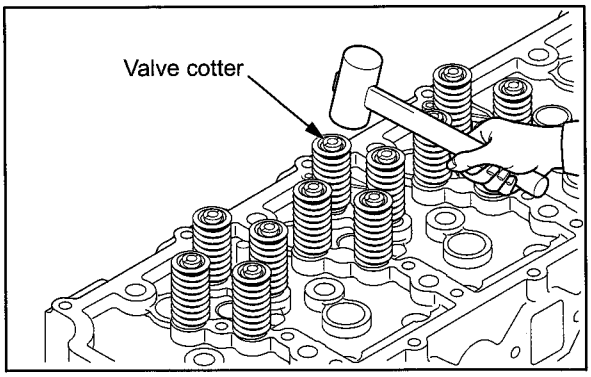
### 4.3 Installing valve and valve spring

(1) Install the valve spring and retainer on the valve guide. Install the valve cotter using a valve spring pusher.

(2) Tap the valve stem top lightly several times with a soft hammer to make sure that the valve spring and valve cotter are properly installed and seated firmly.



Installing valve and valve spring




Installing valve cotter

### 4.4 Installing cylinder head gasket

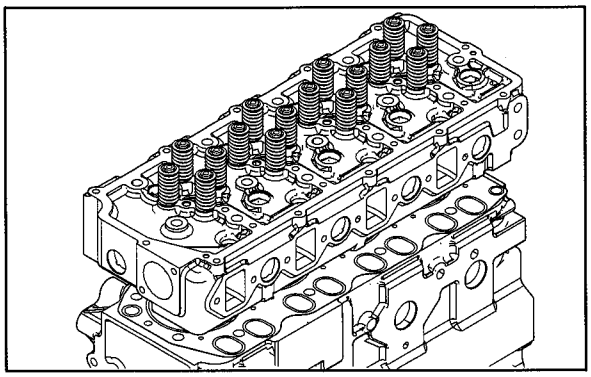
(1) Make sure that there is no dirt or dents on the top surfaces of the crankcase and pistons.

(2) Place new gasket on the crankcase by aligning it with dowel pins on the crankcase.

### 4.5 Installing cylinder head assembly

Install the cylinder head on the crankcase by aligning it with the dowel pins.

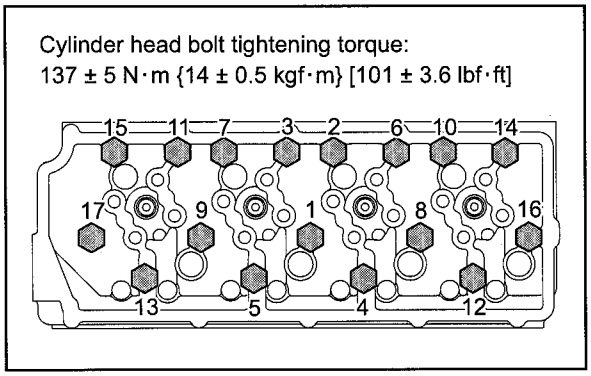
Note: Be careful not to displace the cylinder gasket when installing.



Installing cylinder head assembly

### 4.6 Tightening cylinder head bolts

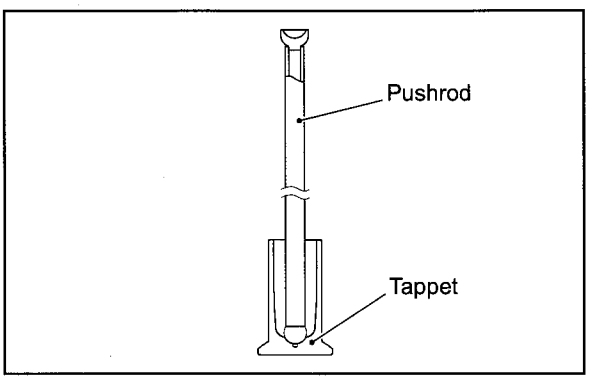
In the numerical order as shown in the illustration, tighten cylinder head bolts progressively to the specified torque.




Tightening order of cylinder head bolt

### 4.7 Inserting pushrod

(1) Insert each pushrod into its hole in the cylinder head.
(2) Make sure that the ball end of each pushrod is placed correctly on the tappet cup.



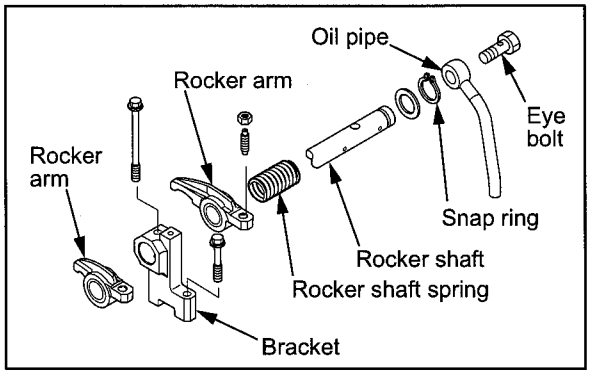

Inserting pushrod

### 4.8 Reassembling rocker shaft assembly

(1) Apply engine oil to the rocker shaft.
(2) When reassembling, arrange the rocker shaft assembly as it was before disassembly.

Note: If the arrangemen is different from the original arrangement, the clearance becomes different, and it may result in a defect such as wear increase.

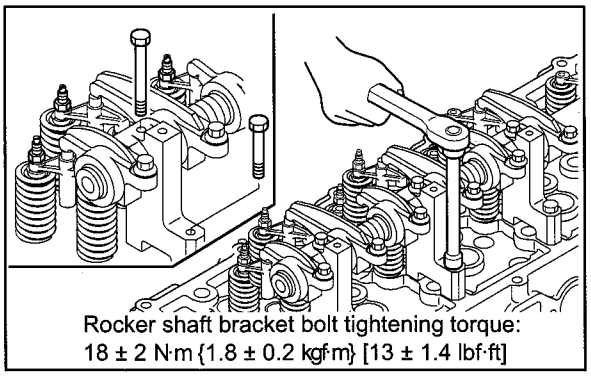
(3) After reassembling, make sure the rocker arms and oil pipes move lightly.




Reassembling rocker shaft assembly

### 4.9 Installing rocker shaft assembly

(1) Install the valve caps on the valve heads.
(2) Tighten the long bolts of the rocker bracket to the specified torque.
(3) Tighten the short bolts of the rocker bracket.

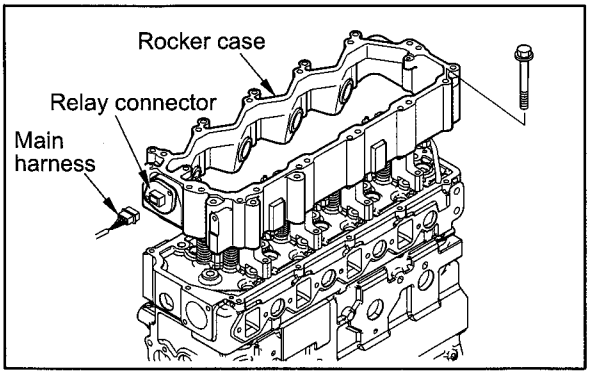



Installing rocker shaft assembly

### 4.10 Installing rocker case

(1) Install the rocker case to the cylinder head.

(2) Press fit the injection pipe seal into the rocker case until the seal plate portion contacts the rocker case.

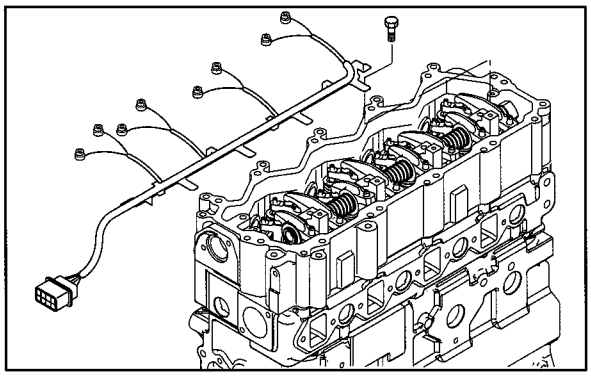



Installing rocker case

### 4.11 Installing harnesse

(1) Connect the harness bracket and harness to the rocker shaft assembly.

(2) Connect the harness to the fuel injection nozzle.



Installing harness

### 4.12 Installing injector

(1) Install the O-ring to the injector. Apply grease to the O-ring.

(2) Install the gasket to the injector.

(3) Install the injector with the nozzle gland to the cylinder head.

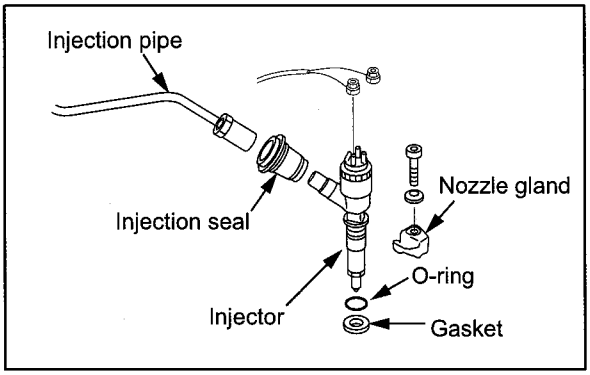
(4) Install the injection seal.

(5) Install the injection pipe.

(6) With the washer spherical side faced toward nozzle gland, install the washer, and secure it by tightening the hexagon socket head bolt to the specified torque.

Note: Make sure that the injector is reassembled into the same cylinder that it was.

When replacing the injector with a new one, refer to "Troubleshooting."

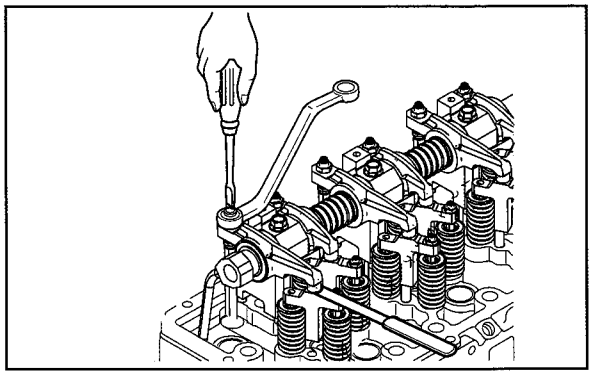



Installing fuel injection nozzle

### 4.13 Adjusting valve clearance

Adjust the valve clearance.

For adjusting procedures, refer to "Adjusting Engine, Inspecting and Adjusting Valve Clearance."

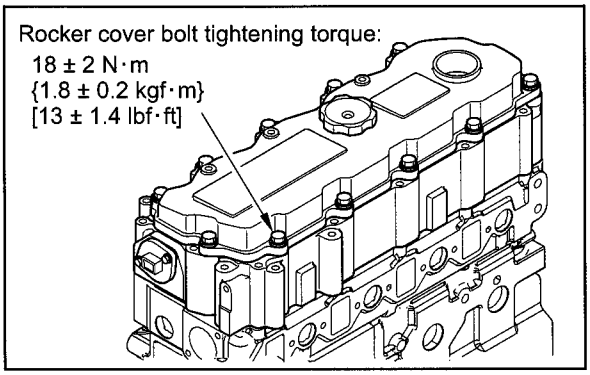


Adjusting valve clearance

### 4.14 Installing rocker cover

(1) Make sure that the gasket is correctly reassembled to the rocker cover.

(2) Tighten the rocker cover mounting nuts to the specified torque.




Installing rocker cover

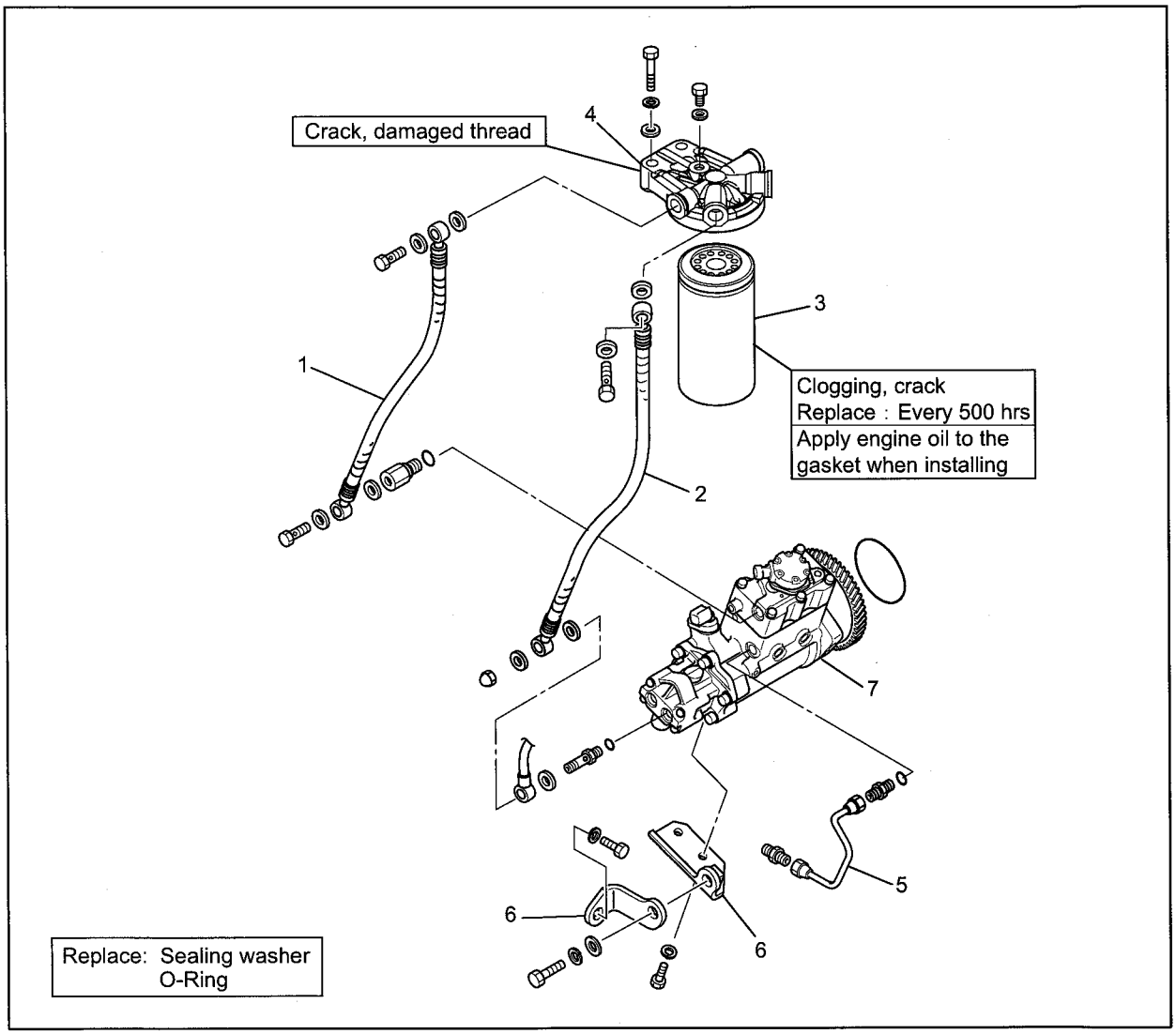
# FUEL SYSTEM

## 1. Removing fuel system

**CAUTION**

(a) Keep open flame or heat away from fuel system before conducting the removal work. It could cause a fire.
(b) Wipe off any spilled fuel. Spilled fuel could cause a fire.
(c) Cover or plug any inlet and outlet openings to prevent dust from entering the fuel system.
(d) For fuel pump, common rail, and injector, have a specialized maintenance shop do the maintenance work.

### 1.1 Removing fuel system (Part 1)

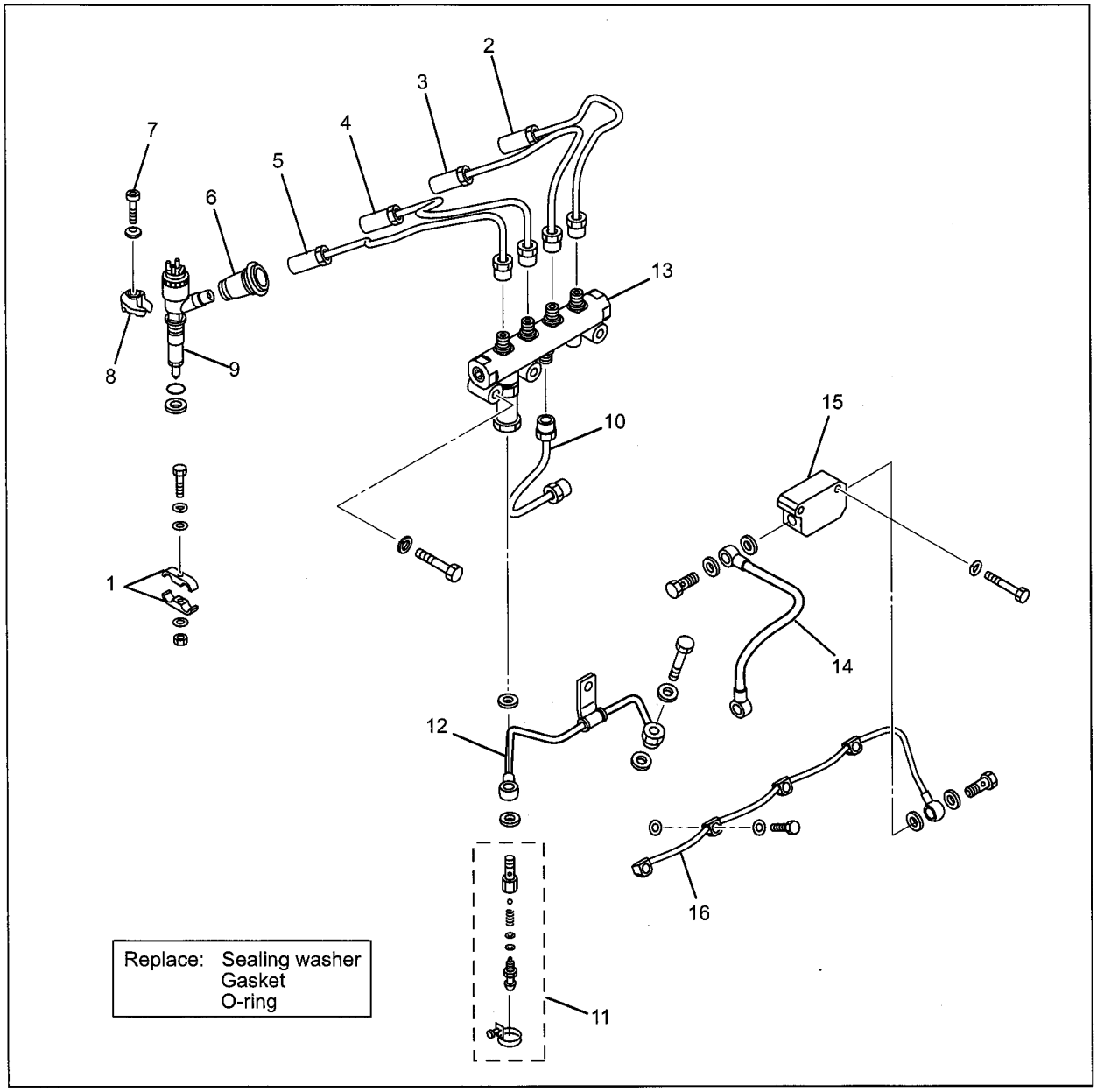



Removing fuel system (Part 1)

Removing sequence

1 Spiral tube
2 Spiral
3 Fuel filter element
4 Fuel filter bracket
5 Oil pipe
6 Pump bracket
7 Fuel pump

## 1.2 Removing fuel system (Part 2)




Removing fuel system (Part 2)

Removing sequence

1 Pipe clamp
2 No.1 injection pipe
3 No.2 injection pipe
4 No.3 injection pipe
5 No.4 injection pipe
6 Injection seal
7 Hexagon head bolt
8 Nozzle gland
9 Injector
10 Pump pipe
11 Check valve
12 Relief pipe
13 Common rail
14 Fuel outlet pipe
15 Fuel relief block
16 Fuel pipe

## 2. Assembling fuel system

### 2.1 Installing fuel filter

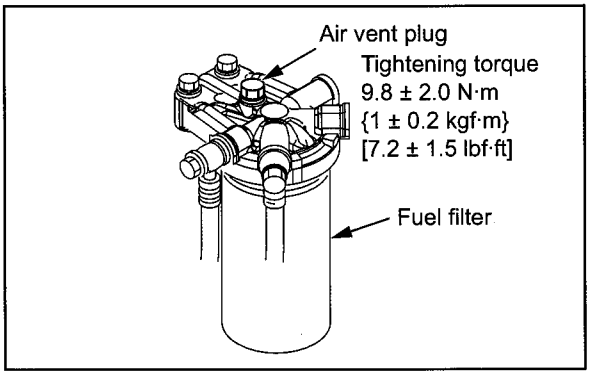
**⚠ WARNING**

(a) When handling a fuel, make sure to keep any open flames or heat away from fuel, as it may cause fire hazard.
(b) Thoroughly wipe off any spilled fuel, as it may cause a fire.
(c) Do not use the filter that has a dent on its case. A dented filter may be damaged during operation, resulting in a fuel leakage, and eventually a fire.

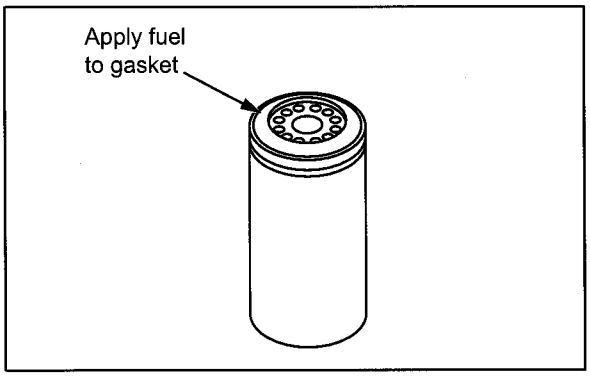
**CAUTION**

(a) When installing the fuel filter, do not use a filter wrench. Tighten the fuel filter by hand.
(b) Be careful not to dent or scratch the fuel filter surface.

(1) Prepare a new fuel filter, and make sure that the gasket is properly fitted in its groove.
(2) Apply a clean fuel oil to the gasket.
(3) Install the fuel filter to the filter bracket. When the fuel filter gets contact with the bracket mounting surface, tighten the fuel filter about three fourth to one turn.
(4) Bleed the fuel filter.
(5) Start and operate the engine at idling speed for several minutes.
(6) Check for fuel leakage from the fuel filter mounting surface. If fuel leakage is found, loosen the fuel filter, check the gasket for damage and retighten the fuel filter.



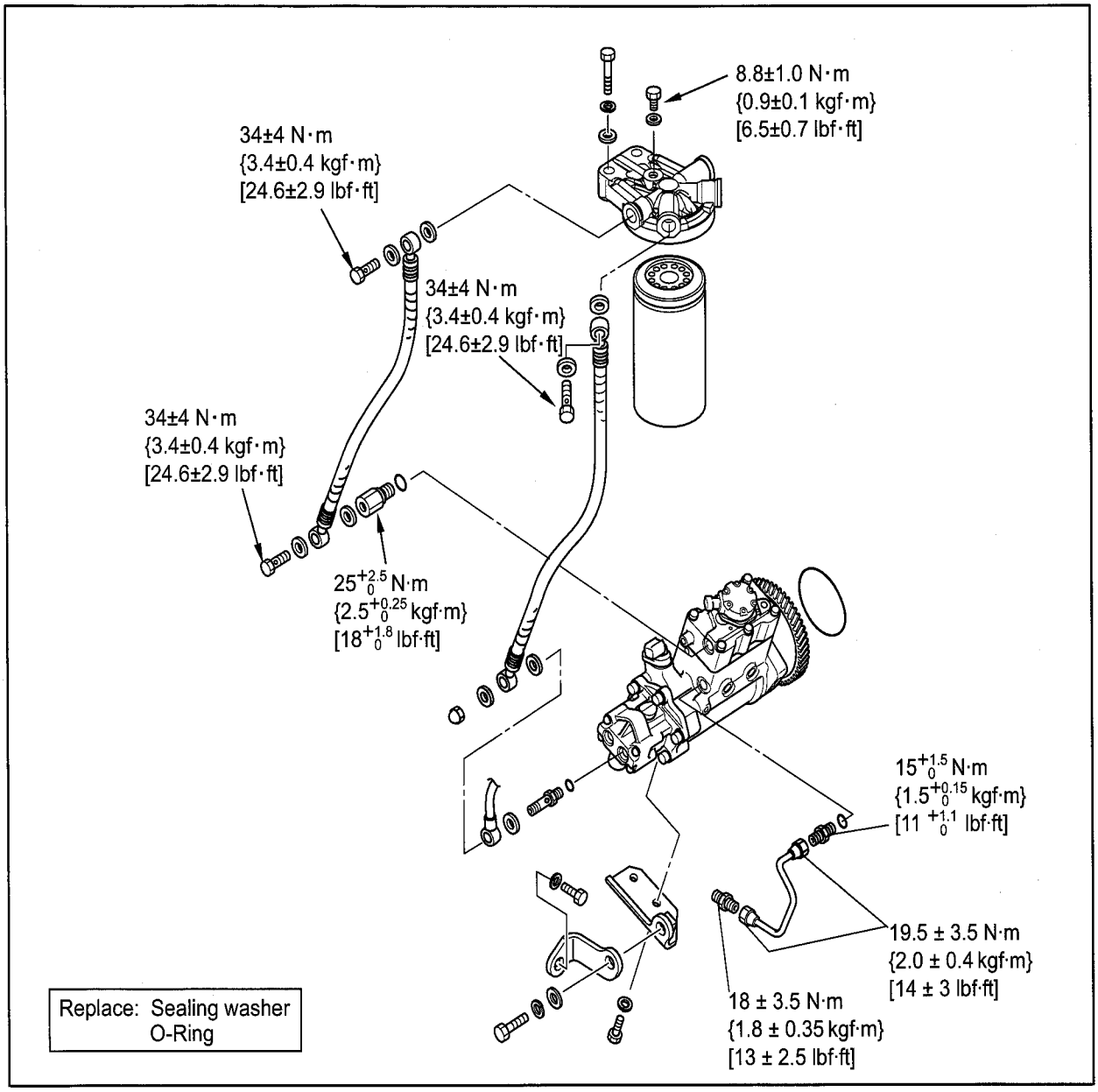

Replacing fuel filter




Fuel filter

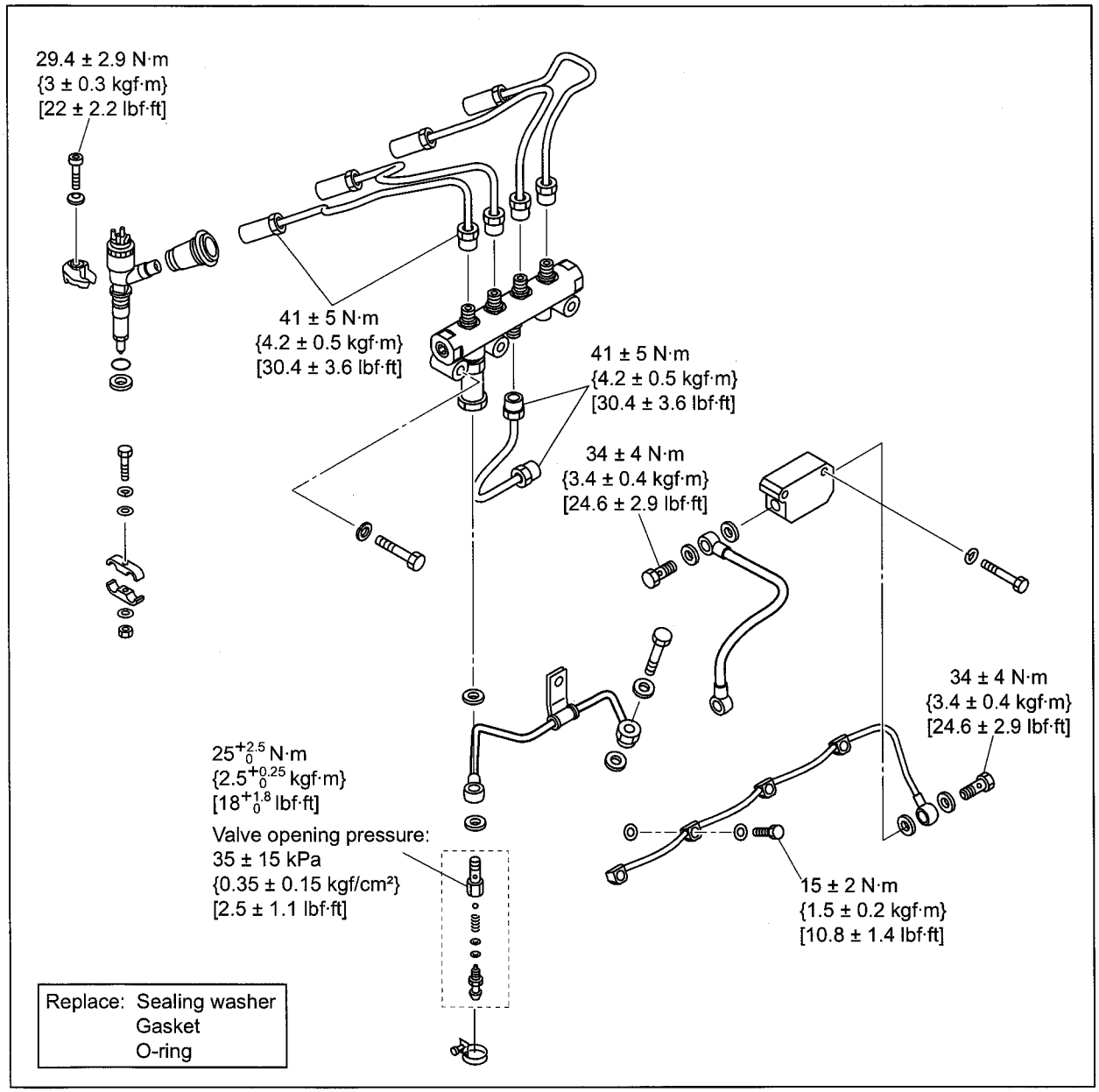
## 3. Installing fuel system

### 3.1 Installing fuel system (Part 1)




Installing fuel system (Part 1)

### 3.2 Installing fuel system (Part 2)

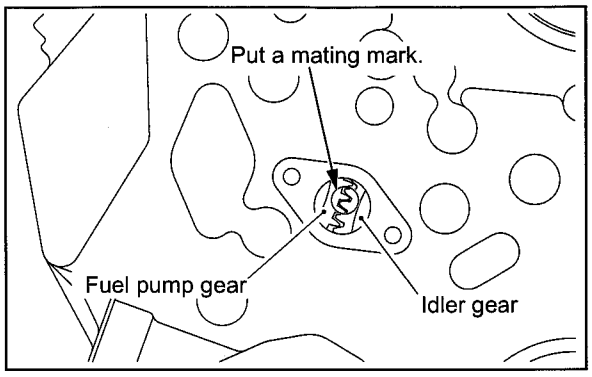



Installing fuel system (Part 2)

## 3.3 Replacing fuel pump

### 3.3.1 Removing fuel pump

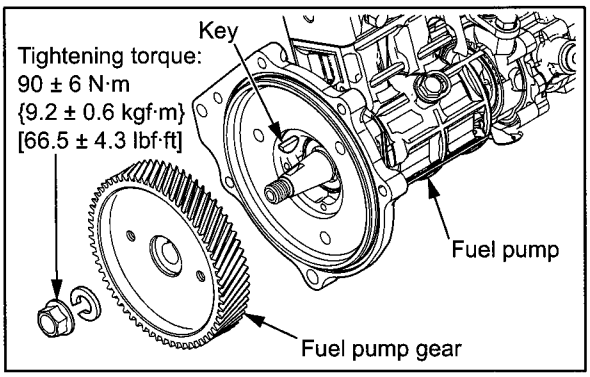
(1) Remove the inspection cover for fuel pump gear and idler gear from the timing gear case.
(2) Put a mating mark on the idler gear and pump gear with white paint.
(3) Disconnect fuel pipe and oil pipe from the fuel pump.
(4) Remove the harness connector.
(5) Remove the fuel pump.




Removing fuel pump

### 3.3.2 Replacing fue fuel pump gear

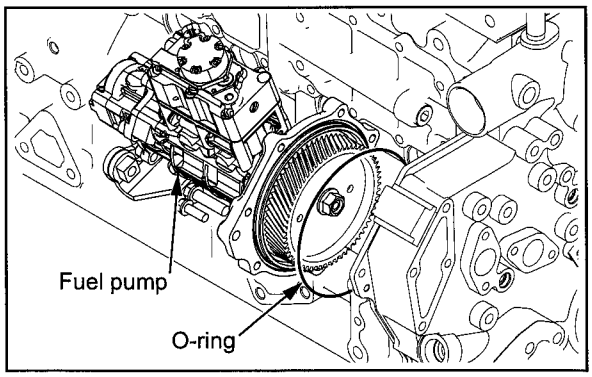
(1) Remove the fuel pump gear.
(2) Put a matching mark on the new fuel pump gear at the same position the removed fuel pump gear was marked.
(3) Install the new fuel pump gear, aligning with the fuel pump shaft key.
(4) Install and tighten the fuel pump gear mounting nut to the specified torque.




Replacing fuel pump gear

### 3.3.3 Installing fuel pump

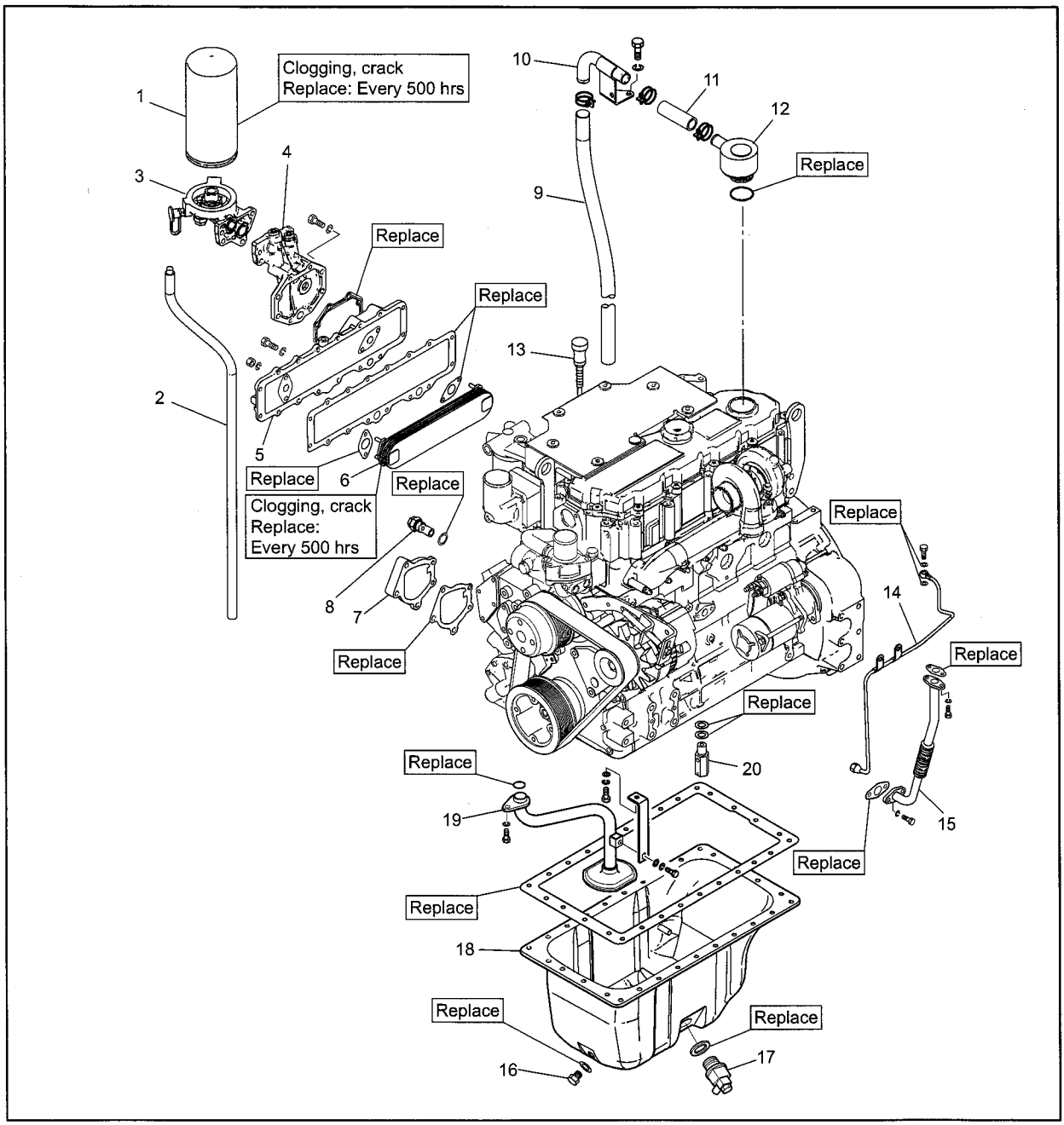
(1) Install the O-ring to the fuel pump.
(2) With the match marks on the idler gear and the pump gear aligned, install the fuel pump to the timing gear case.
(3) Connect the harness connector.
(4) Install the fuel pipe and the oil pipe, and tighten to the specified torque.
(5) Install the pump gear inspection cover to the timing gear case.




Installing fuel pump

# LUBRICATION SYSTEM

## 1. Removing and inspecting lubrication system



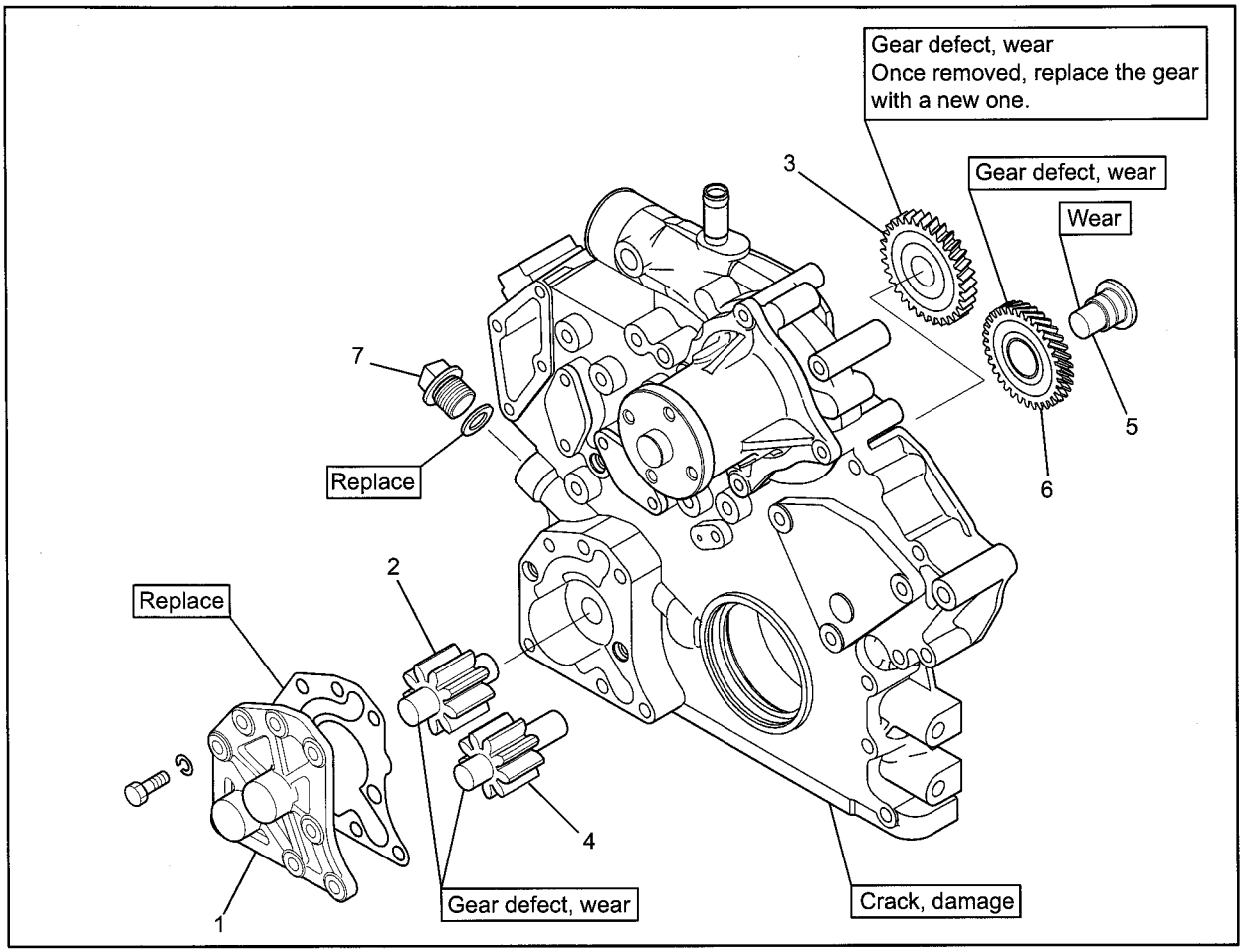

Removing and inspecting lubrication system

Removing sequence

1 Oil filter
2 Drain hose
3 Filter bracket
4 Filter base
5 Oil cooler cover
6 Oil cooler element
7 Cover
8 Relief valve
9 Breather hose
10 Breather pipe
11 Vinyl tube
12 Breather
13 Oil level gauge
14 Oil pipe
15 Oil drain pipe
16 Drain plug
17 Drain cock
18 Oil pan
19 Oil strainer
20 Safety valve

## 2. Disassembling, inspecting and reassembling lubrication system

### 2.1 Disassembling and inspecting oil pump




Disassembling and inspecting oil pump

Disassembling sequence

| | | | |
|---|---|---|---|
| 1 Gear cover | 3 Oil pump gear | 5 Spindle | 7 Plug |
| 2 Driven gear | 4 Drive gear | 6 Idler gear assembly | |

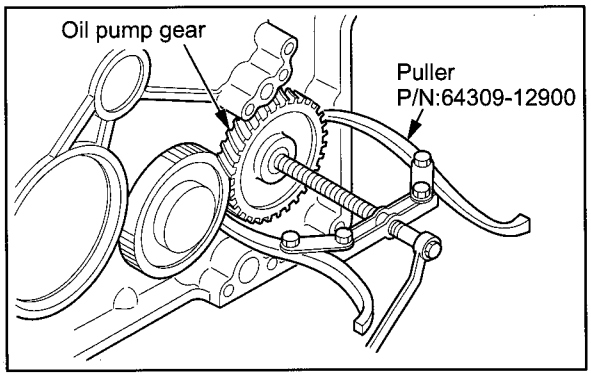
Note: Inspect the oil pump prior to the removal of gears.

#### 2.1.1 Removing oil pump gear

**CAUTION**

Once the oil pump gear is removed, the oil pump gear and the drive gear are no longer reusable. Replace them with new ones.

Remove the oil pump gear with a puller.

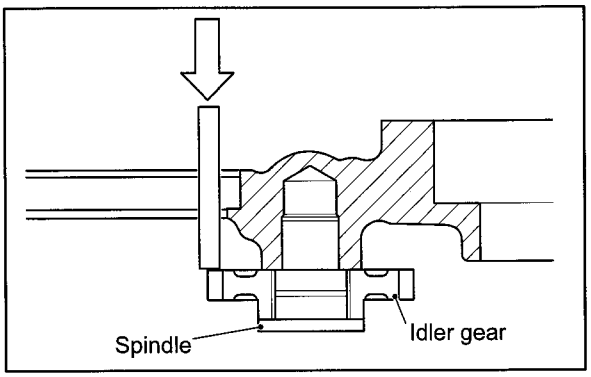



Removing oil pump gear

### 2.1.2 Removing spindle and idler gear

Remove the spindle and the idler gear as a unit. Remove the spindle and the idler gear by tapping the edge of idler gear with a wood rod inserted through the oil seal mounting hole of timing gear case.

Note: When tapping the idler gear with a wood rod, turn the gear.



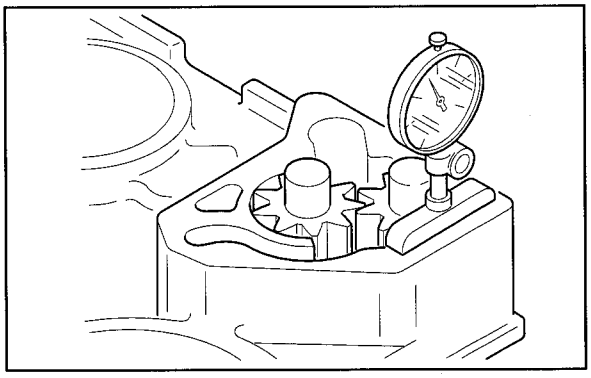

Removing spindle and idler gear

## 2.2 Inspecting and adjusting oil pump

### 2.2.1 Measuring end clearance between gears and case

Measure the end clearance between gear width and case depth with a dial gauge placed as shown in the illustration. If the limit is exceeded, replace the drive and driven gear assemblies.

| Item | Standard | Limit |
|---|---|---|
| End clearance between gear width and case depth | -0.01 to 0.054 mm [-0.0004 to 0.0021 in.] | 0.150 mm [0.0059 in.] |

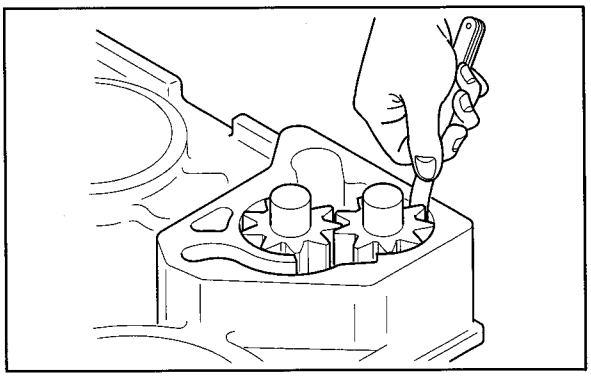


Measuring clearance between gear and case

### 2.2.2 Measuring side clearance between gears and case

Measure the side clearance between gear teeth and case bore with feeler gauges. If the limit is exceeded, replace the drive and driven gear assemblies.

| Item | Standard | Limit |
|---|---|---|
| Side clearance between gear teeth and case bore | 0.05 to 0.098 mm [0.0020 to 0.0039 in] | 0.100 mm [0.0039 in.] |



Measuring clearance between gear teeth and case

### 2.2.3 Measuring clearance between outside diameter of gear shaft and inside diameters of pump body and pump cover

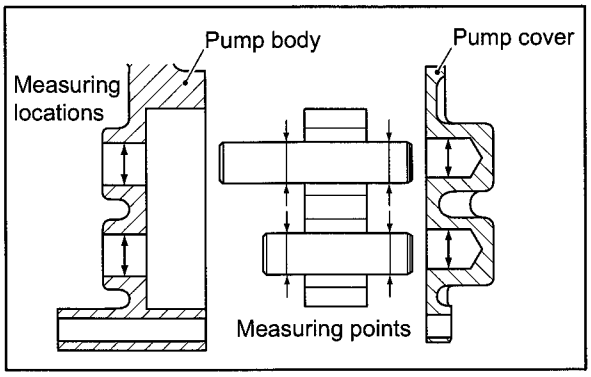
**CAUTION**

When replacing drive and driven gears, replace the gear assemblies.

(1) Check gear teeth for condition. If the teeth are defective, replace the gear assemblies.

(2) Measure the inside diameters of pump body (cover) and the diameter of gear shafts. If the clearance is more than the limit, replace the gear assemblies, pump body, and pump cover whichever is badly worn.

| Item | Standard | Limit |
|---|---|---|
| Clearance between gear shafts and pump body (cover) | 0.04 to 0.07 mm [0.0016 to 0.0028 in.] | 0.15 mm [0.0059 in.] |

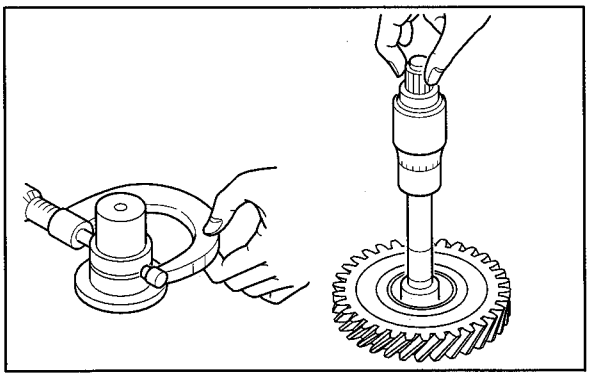



Measuring clearance between gear shaft outside diameter and pump body, pump cover inside diameter

### 2.2.4 Measuring spindle outside diameter and idler bushing inside diameter

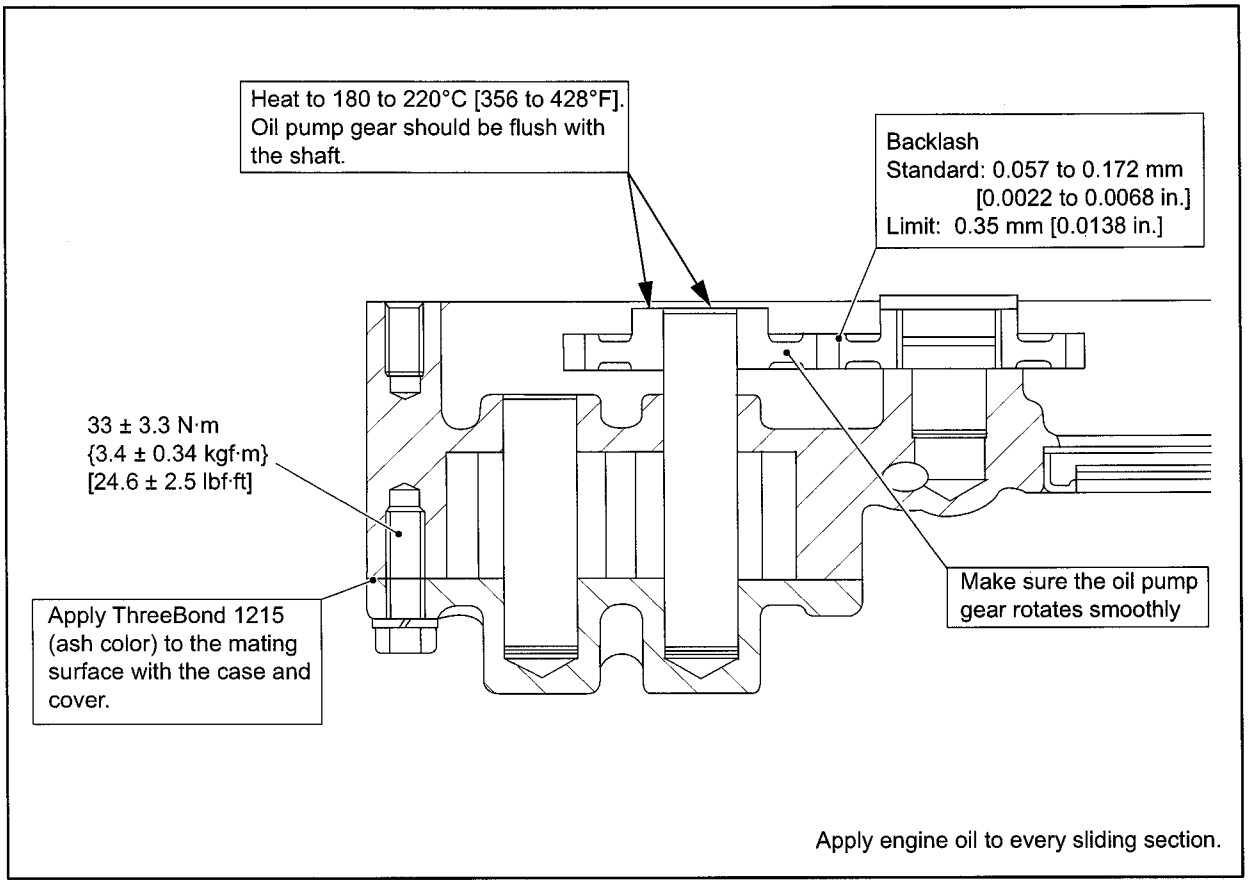
Measure the spindle outside diameter and the idler bushing inside diameter. If excessive wear is found, replace the part with a new one.

| Item | Nominal | Standard |
|---|---|---|
| Spindle outside diameter | ø 25 mm [0.98 in.] | 24.939 to 24.960 mm [0.9818 to 0.9827 in.] |
| Bushing inside diameter | ø 25 mm [0.98 in.] | 25.000 to 25.021 mm [0.9843 to 0.9851 in.] |



Measuring spindle outside diameter and idler gear bushing inside diameter

## 2.3 Reassembling oil pump




Reassembling oil pump

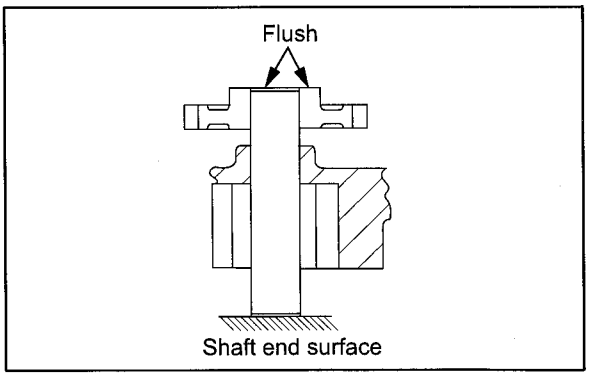
### 2.3.1 Reassembling oil pump gear and drive gear assembly

**CAUTION**

The oil pump gear and drive gear assembly is nonreusable parts. Replace the assembly with a new one.

(1) Heat the oil pump gear between 180 to 220°C [356 to 428°F]

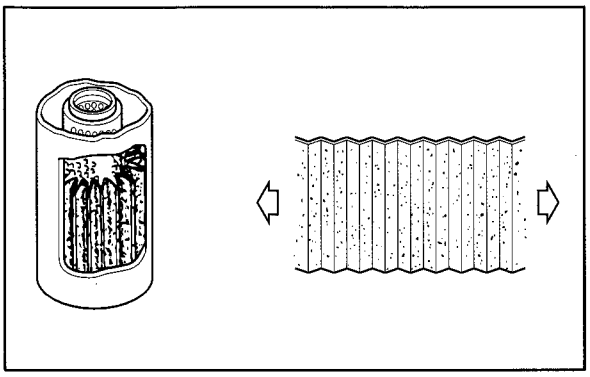
(2) Support the shaft at end and force the gear onto the shaft until its end face is flush with the end of shaft.




Reassembling oil pump gear and drive gear assembly

### 2.4 Inspecting oil filter

When replacing the oil filter, sample the oil (500 mL [30.5 cu.in.]) and check for metal and other particles. If metal or other particles are found, cut and unfold the element, and inspect the color and shape of metal particles trapped in the element to identify the cause.



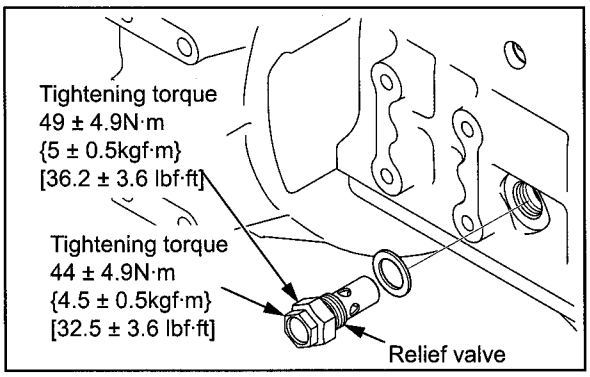
Inspecting oil filter

### 2.5 Inspecting relief valve

(1) Check the relief valve and its seat for contact. Check the spring for fatigue and damage. If faulty, replace the relief valve with new one.

(2) Measure the relief valve opening pressure. If the pressure does not fall within the standard range, replace the relief valve with new one.

| Item | Standard |
|---|---|
| Relief valve opening pressure | 0.35 ± 0.05 MPa {3.5 ± 0.5 kgf/cm² } [49.8 ± 7.1 psi] |



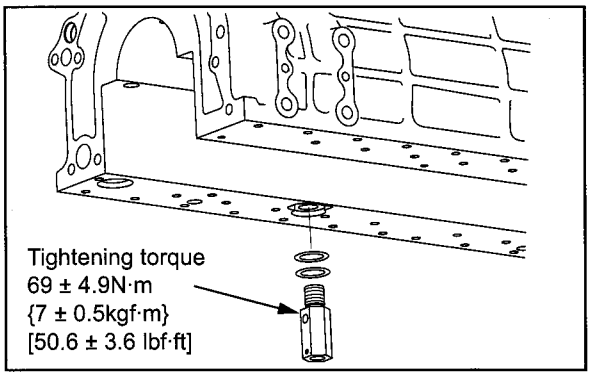

Inspecting relief valve

### 2.6 Inspecting safety valve

(1) Make sure that the steel ball inside safety valve slides smoothly. If faulty, replace the safety valve with new one.

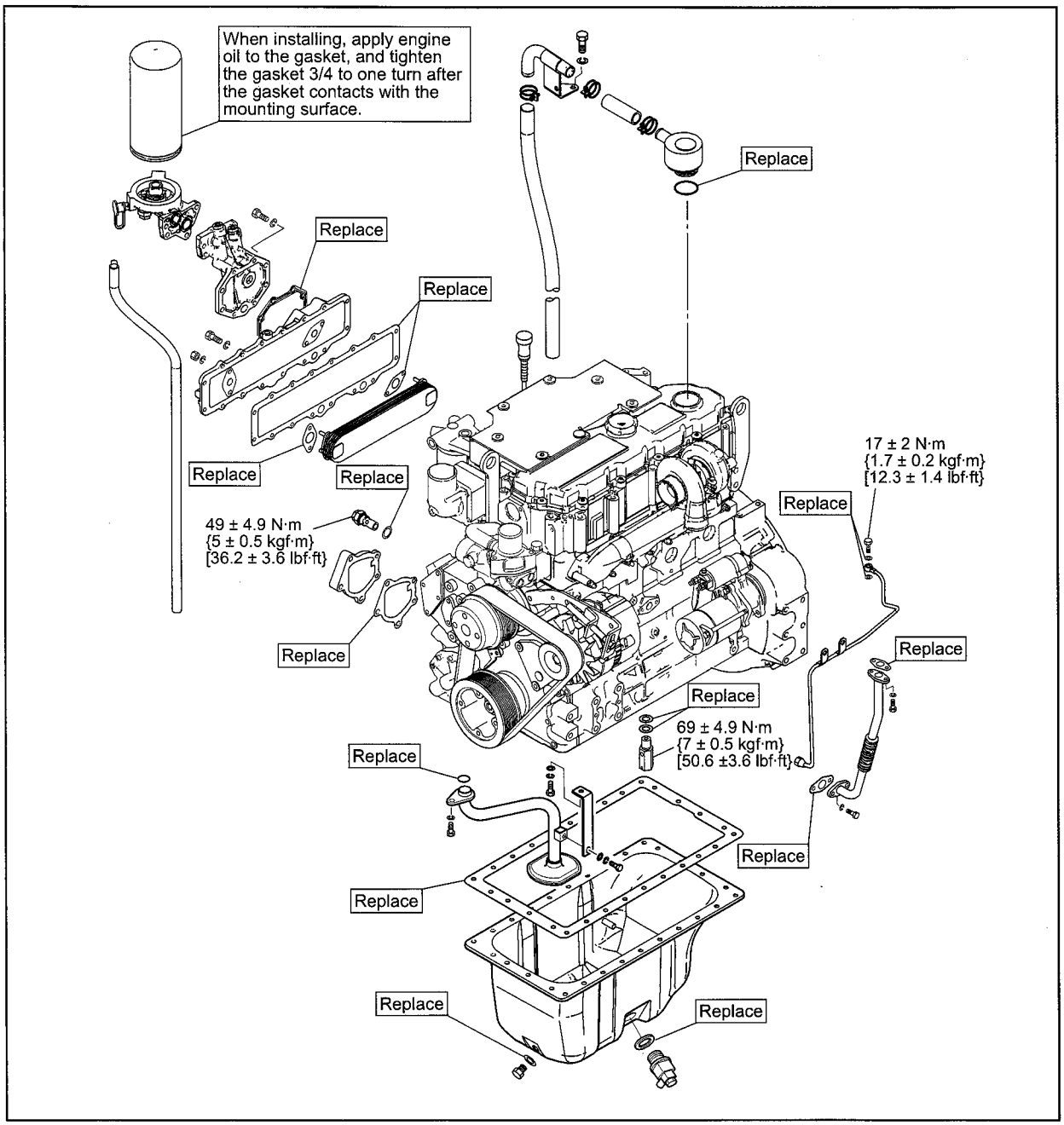
(2) Measure the safety valve opening pressure. If the pressure does not fall within the standard range, replace the safety valve with new one.

| Item | Standard |
|---|---|
| Safety valve opening pressure | 1.1 MPa {11 kgf/cm² } [157 psi] |




Inspecting oil pump safety valve

## 3. Installing lubrication system




Installing lubrication system

To install the lubrication system, follow the removal procedure in reverse order, observing the followings:

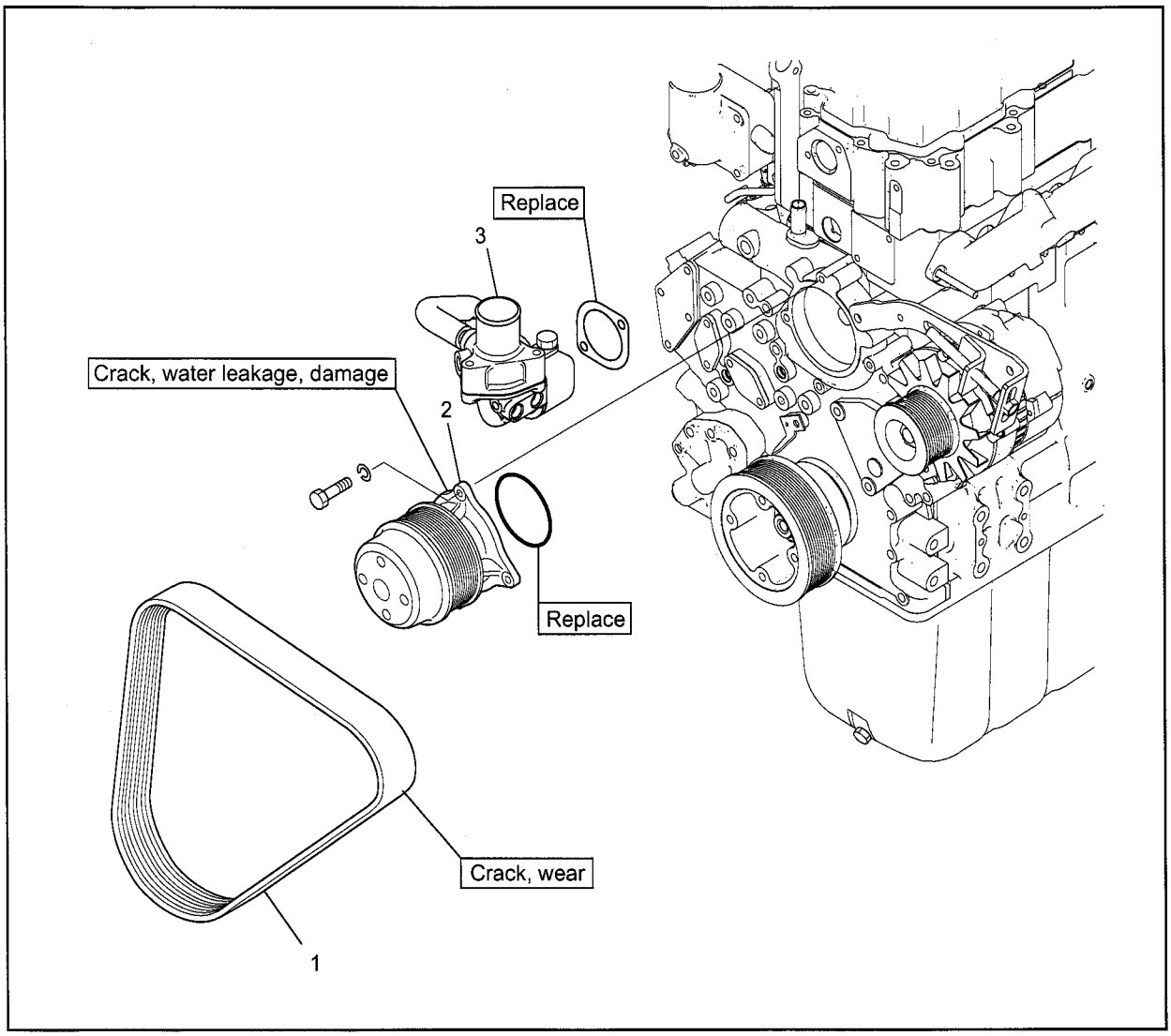
(1) Use new gaskets and O-rings when reinstalling.

(2) Clean oil passage of each part thoroughly in wash oil, and dry it completely using compressed air.

(3) Install the bracket first, then install the oil filter.

# COOLING SYSTEM

## 1. Removing cooling system



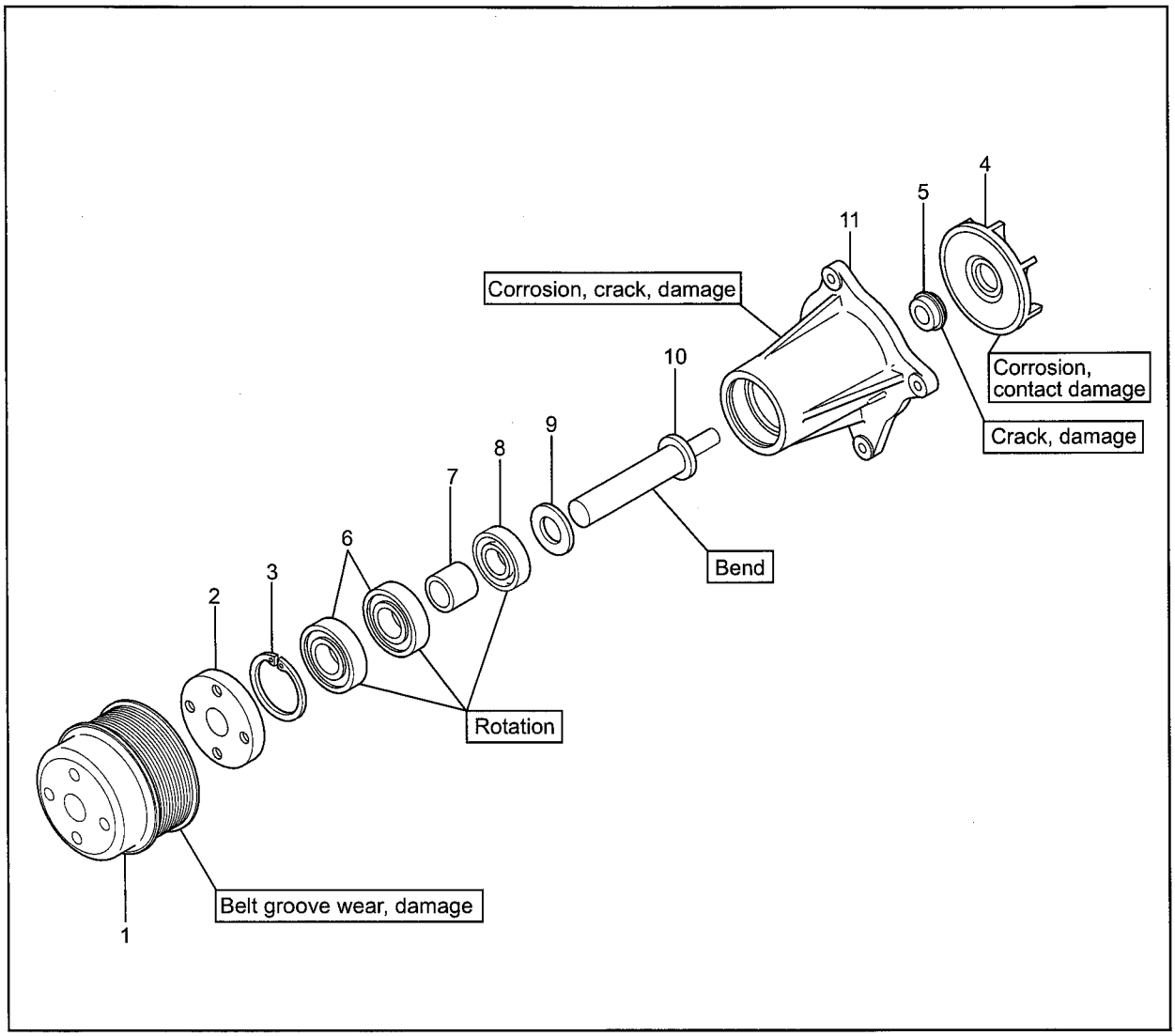

Removing cooling system

Removing sequence

1 Belt
2 Water pump assembly
3 Thermostat assembly

## 2. Disassembling, inspecting and reassembling cooling system

### 2.1 Disassembling and inspecting water pump



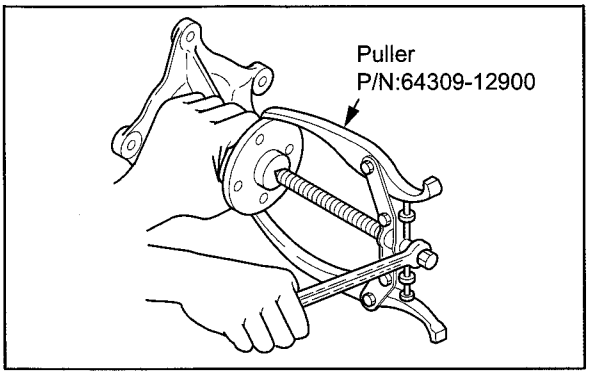

Disassembling and inspecting water pump

Disassembling sequence

1 Water pump pulley
2 Flange
3 Snap ring
4 Impeller
5 Unit seal
6 Bearing
7 Spacer
8 Bearing
9 Washer
10 Shaft
11 Case

### 2.2 Removing flange

Remove the flange with a puller.



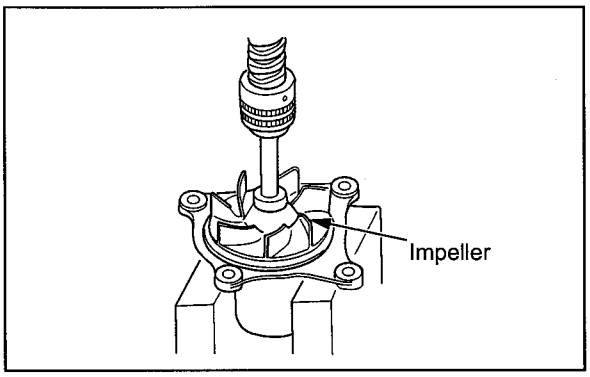

Removing flange

### 2.3 Removing impeller and shaft

(1) Remove the snap ring.

(2) Using a press, remove the shaft together with the ball bearing, and remove the impeller.

Note: To facilitate the removal work, heat the case to a tempeature of 80°C [176°F].

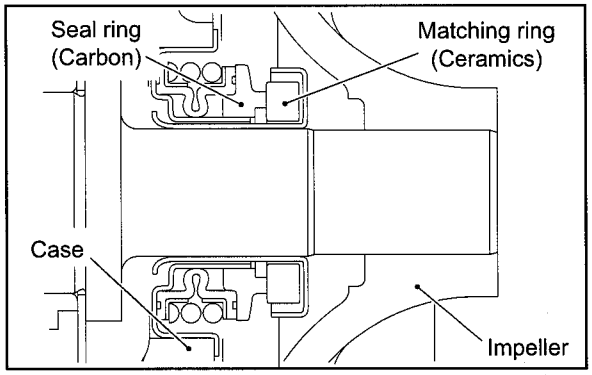



Removing impeller and shaft

### 2.4 Inspecting unit seal

If excessively worn unit seal or water leak during operation is observed, replace the unit seal with new one.

| Item | Standard | Limit |
|---|---|---|
| Carbon protrusion | 1.5 mm [0.059 in.] | 0 mm [ 0 in.] |
| Height (free) | 20.8 to 22.8 mm [0.819 to 0.898 in.] | - |

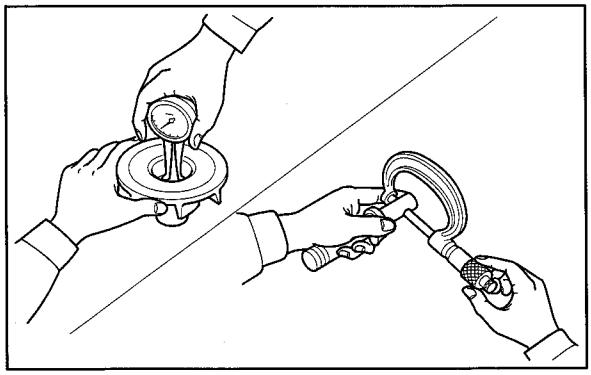



Inspecting unit seal

### 2.5 Inspecting water pump shaft

When the flange and the impeller are removed from the water pump shaft, the interference may be reduced and results in the loose fitting. Even if the reassembling is the second time or less, replace the part with new one when the interference is less than the standard value.

| Item | Standard |
|---|---|
| Interference between water pump shaft and flange | 0.035 to 0.065 mm [0.0014 to 0.0026 in.] |
| Interference between water pump and impeller | 0.022 to 0.062 mm [0.0009 to 0.0024 in.] |



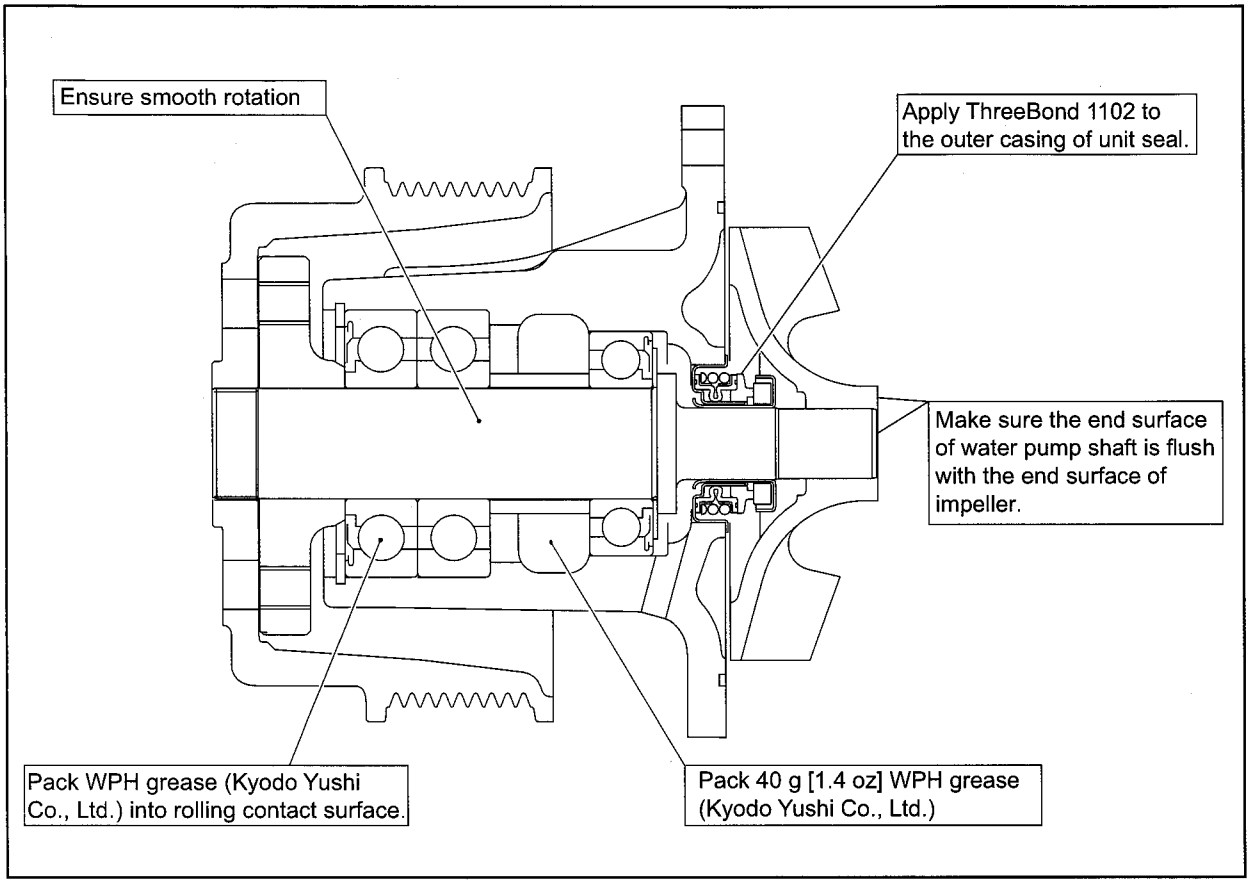
Inspecting water pump shaft

## 2.6 Inspecting water pump

Measure the water pump case bore and the shaft diameter at the bearing fitting portions as well as the inside and outside diameters of the bearings. If any of the measurements is out of the standard, replace the part with a new one.

| Item | | Nominal | Standard |
|---|---|---|---|
| Pump case bearing bore diameter | | ø 52 mm [2.05 in.] | 51.988 to 52.018 mm [2.0468 to 2.0479 in.] |
| | | ø 62 mm [2.44 in.] | 61.988 to 62.018 mm [2.4405 to 2.4416 in.] |
| Bearing | Inside diameter | ø 25 mm [0.98 in.] | 24.880 to 25.000 mm [0.9795 to 0.9843 in.] |
| | Outside diameter | ø 52 mm [2.05 in.] | 51.987 to 52.000 mm [2.0467 to 2.0472 in.] |
| | | ø 62 mm [2.44 in.] | 61.987 to 62.000 mm [2.4404 to 2.4409 in.] |
| Shaft bearing fitting section outer diameter | | ø 25 mm [0.98 in.] | 25.002 to 25.011 mm [0.9843 to 0.9847 in.] |

## 2.7 Reassembling water pump




Reassembling water pump

**CAUTION**

(a) After reassembling, install the water pump to the timing gear case, and make sure that the impeller does not contact with the timing gear case.

(b) Reassembling of the water pump shaft, the flange and the impeller is restricted to only twice.

(1) For reassembly, reverse the order of the disassembly procedure.

(2) Use a hydraulic press to press fit bearings.

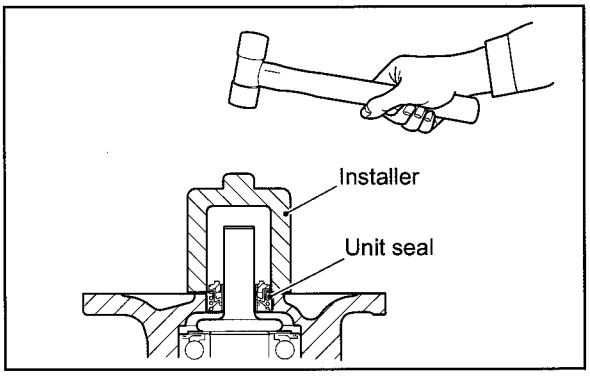
(3) After reassembling, make sure that the pulley rotates smoothly without any looseness, eccentricity, or abnormal noise.

### 2.7.1 Installing unit seal

(1) Apply sealant (ThreeBond 1102) to the circumference of the unit seal.

(2) Drive the unit seal into the case using a unit seal installer.

Note: Always replace the unit seal with a new one once it has been removed from the pump case.




Installing unit seal

## 2.8 Checking water pump for smooth rotation

Check to make sure that the impeller and shaft of water pump rotate smoothly without noise and irregularities. If faulty, replace the water pump assembly.

## 2.9 Inspecting thermostat

**⚠ CAUTION**

Be careful of burns or a fire when measuring temperature, as it involves a high-temperature and open flame.

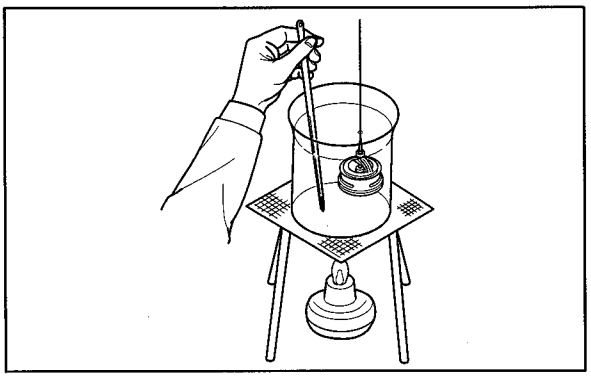
To test the thermostat operation, immerse the thermostat in a container filled with water. Heat the water, while measuring the water temperature. Record the temperature at the conditions shown in the table below. If the temperatures are not within the standard range, replace the thermostat.

Note: (a) Stir the water in the container with a stick to ensure uniform temperature distribution.

(b) Prior to installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve end face.

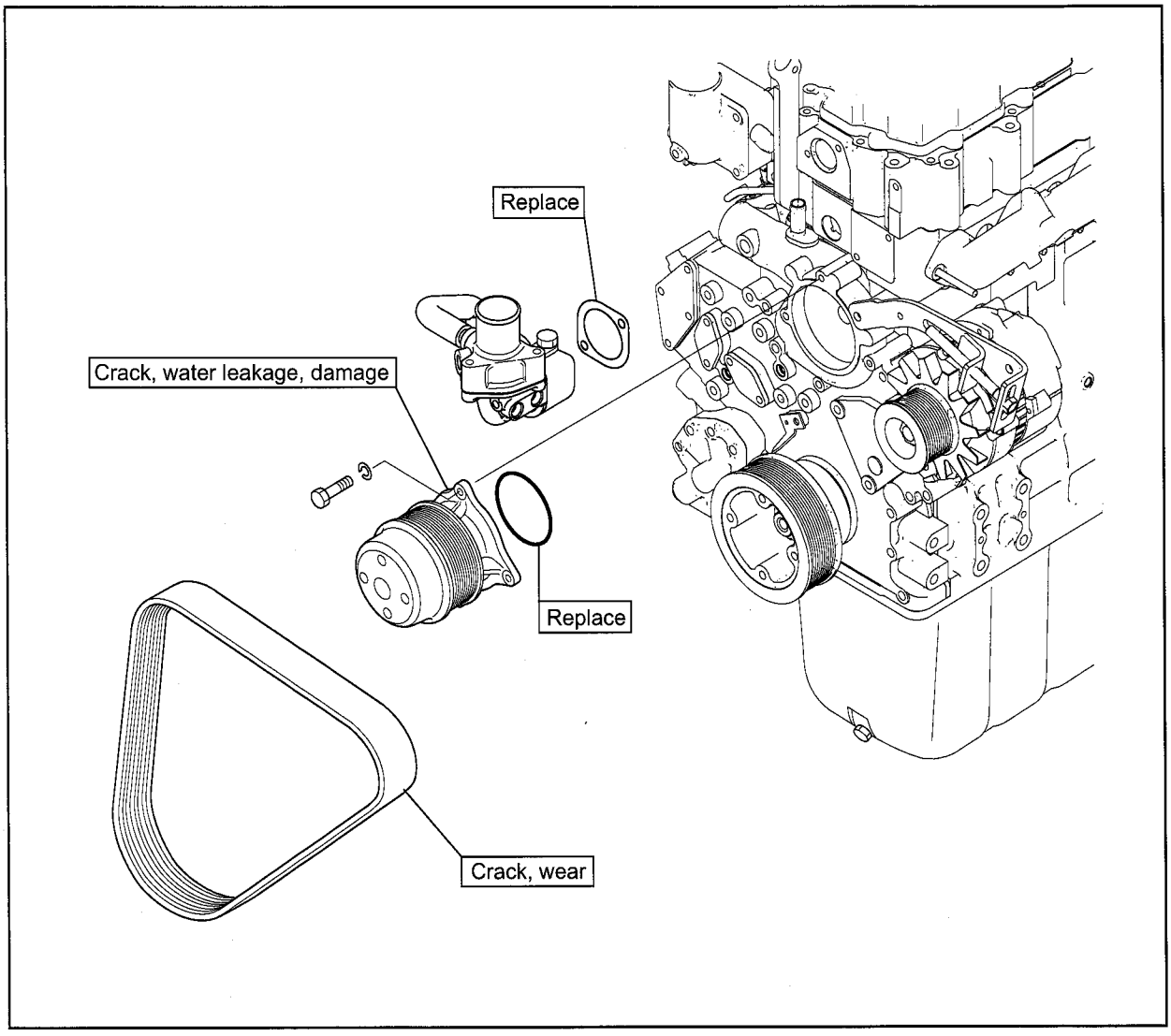
| Item | Standard |
|---|---|
| Temperature at which valve starts opening | 71 ± 2°C [160 ± 3.6°F] |
| Temperature at which valve lift becomes 10 mm [0.39 in.] or more. | 85°C [185°F] |

Note: When assembling, orient the thermostat with its air breed hole faced upward.



Inspecting thermostat

## 3. Installing cooling system

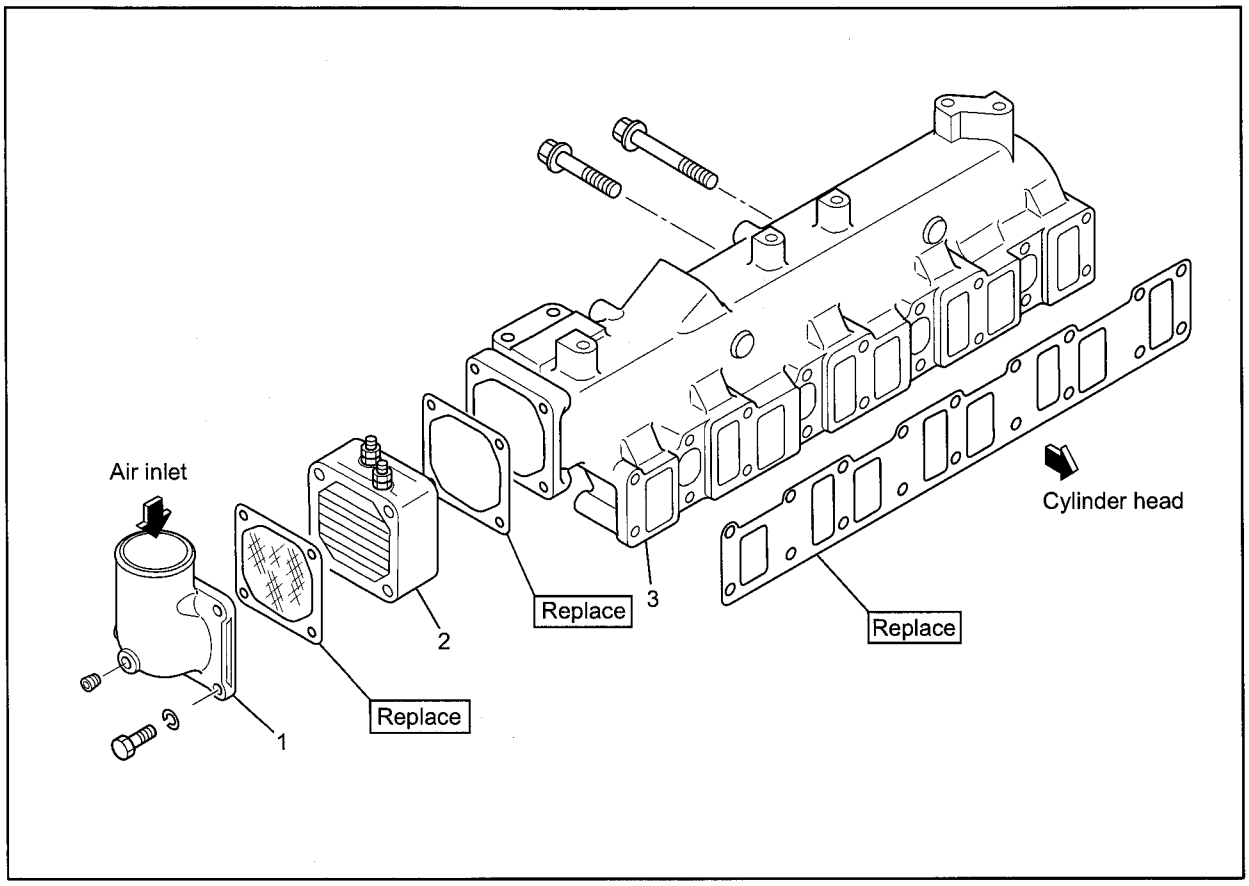



Installing cooling system

# INLET AND EXHAUST SYSTEM

# 1. Removing inlet and exhaust sysytem

## 1.1 Removing inlet system

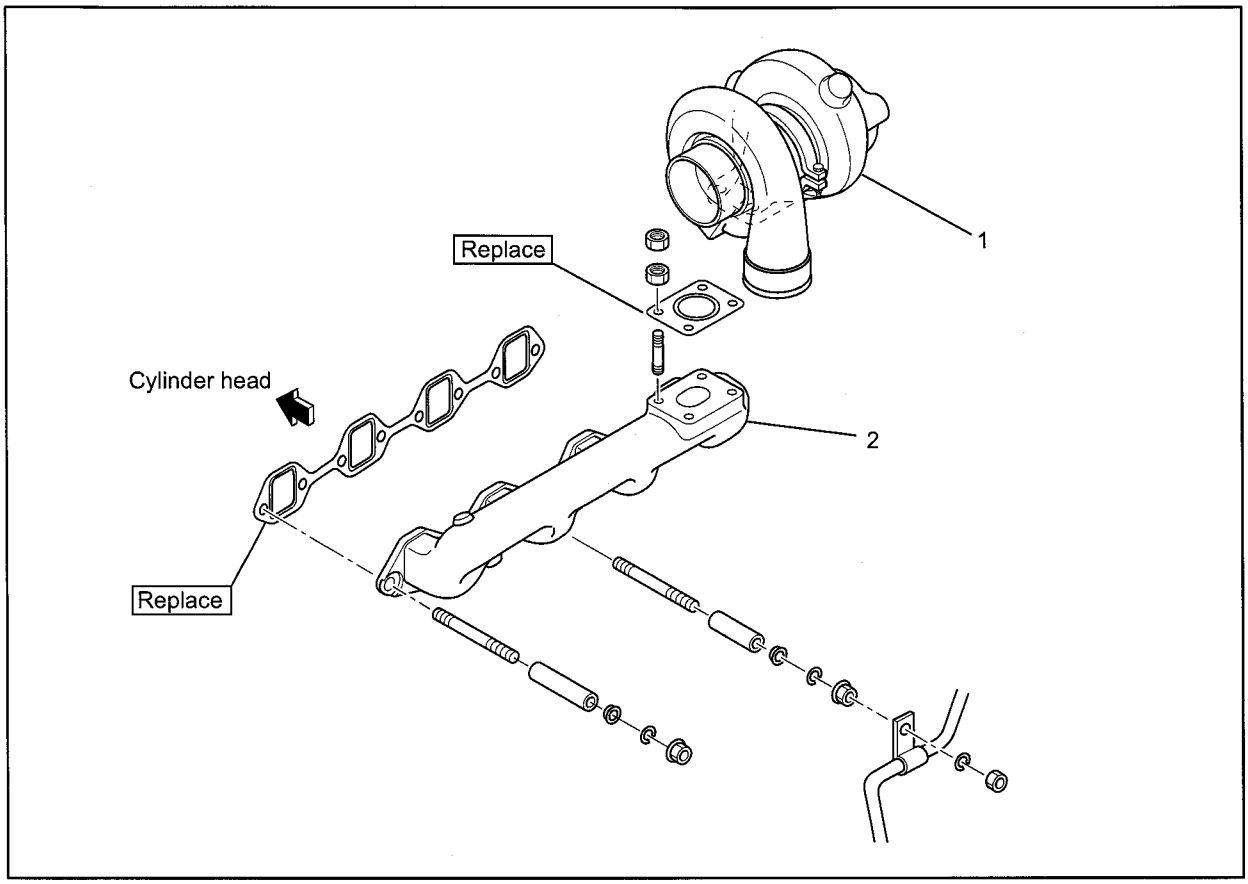



Removing inlet system

Removing sequence

1 Air inlet elbow
2 Air heater
3 Inlet manifold

## 1.2 Removing exhaust system




Removing exhaust system

Removing sequence

1 Turbocharger
2 Exhaust manifold

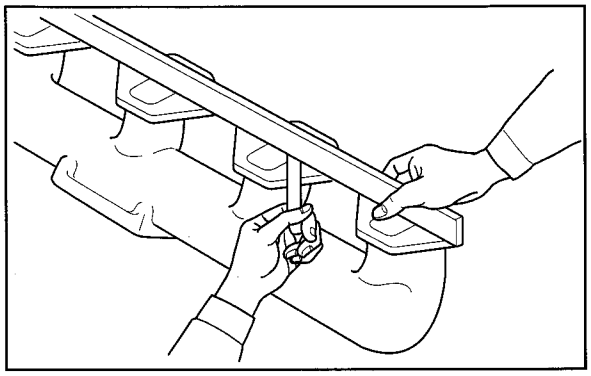
## 2. Disassembling, inspecting and reassembling inlet and exhaust system

### 2.1 Measuring exhaust manifold distortion

(1) Check the flange for crack.

(2) Check the flange suface for distortion. If the distortion exceeds the standard, retouch the surface.

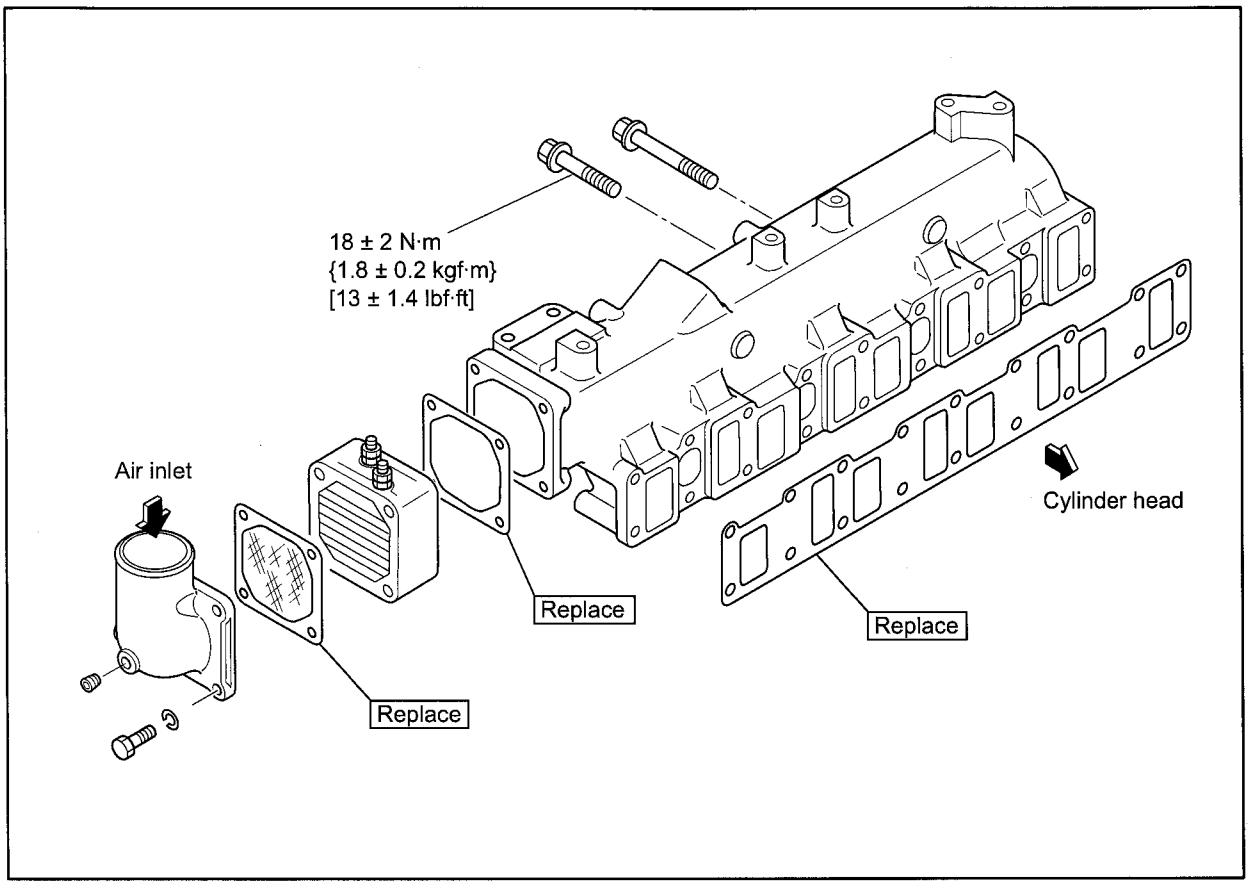
| Item | Standard |
|---|---|
| Exhaust manifold distortion | Less than 0.2 mm [0.008 in.] |



Measuring exhaust manifold distortion

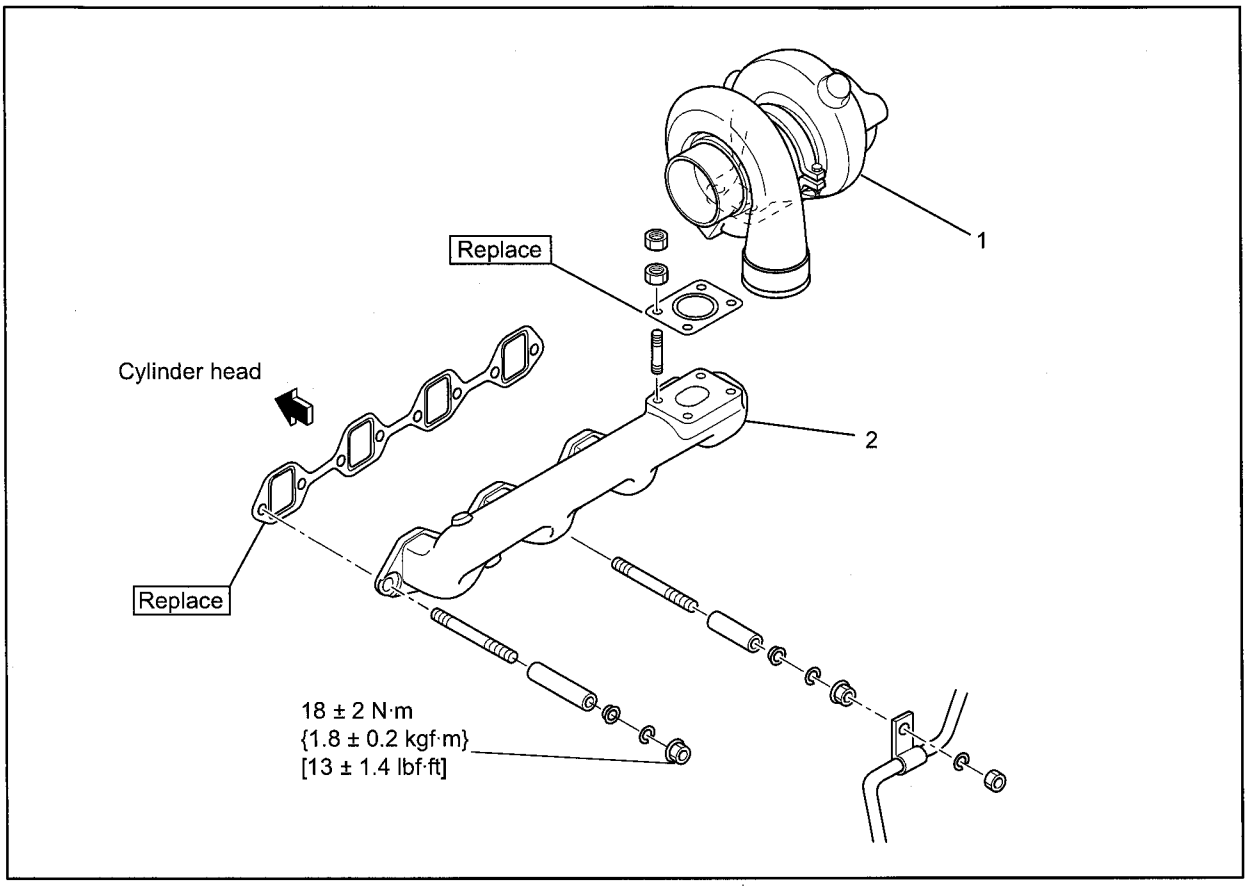
## 3. Installing inlet and exhaust system

### 3.1 Installing inlet system




Installing inlet system

### 3.2 Installing exhaust system

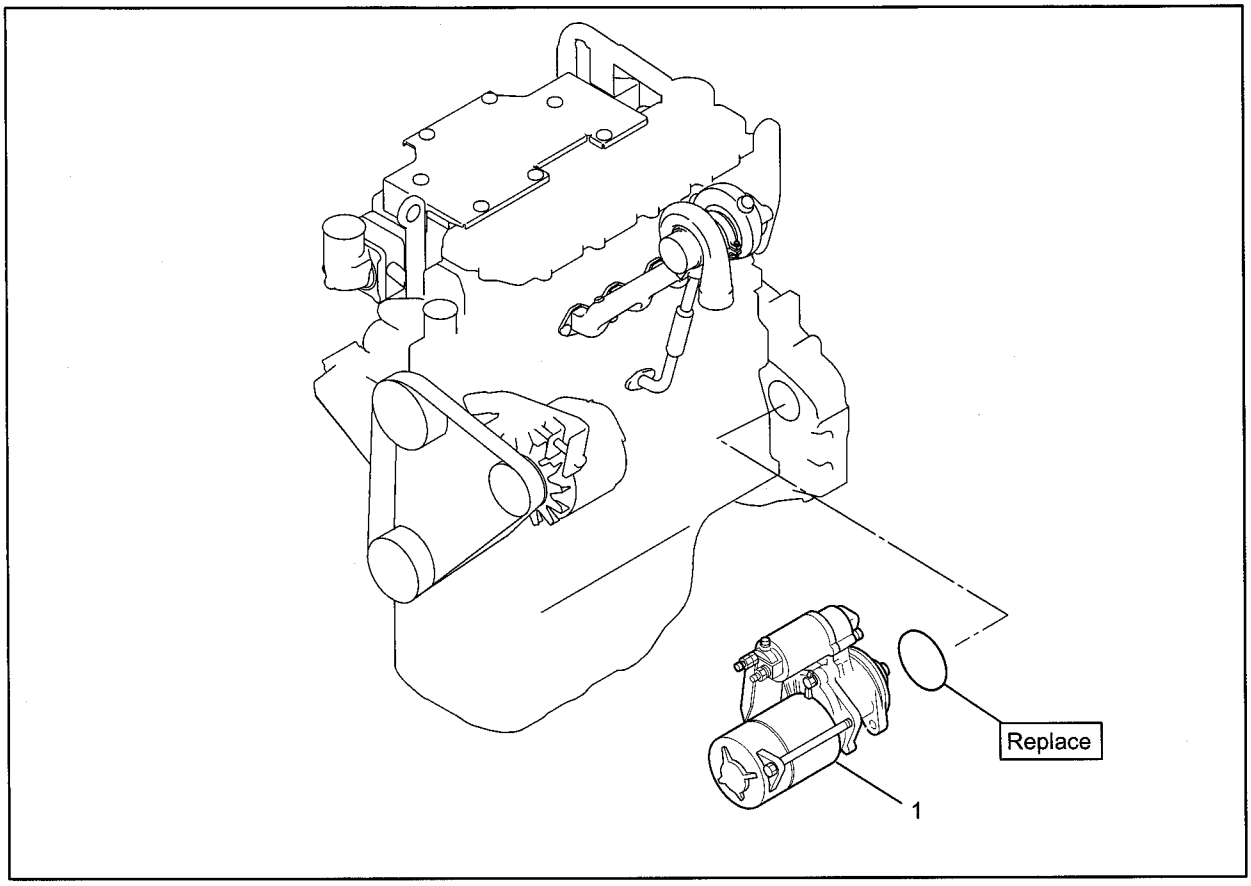



Installing exhaust system

# ELECTRICAL SYSTEM

# 1. Removing electrical system

## 1.1 Removing starter




Removing starter

Removing sequence

1 Starter, bolt, washer and O-ring

## 1.2 Inspection before removing alternator

### 1.2.1 Inspecting alternator operation

Locate the cause of faulty charging from malfunctions described below. Do not remove the alternator for inspection and repair unless inspection cannot be performed with the alternator installed on the engne.

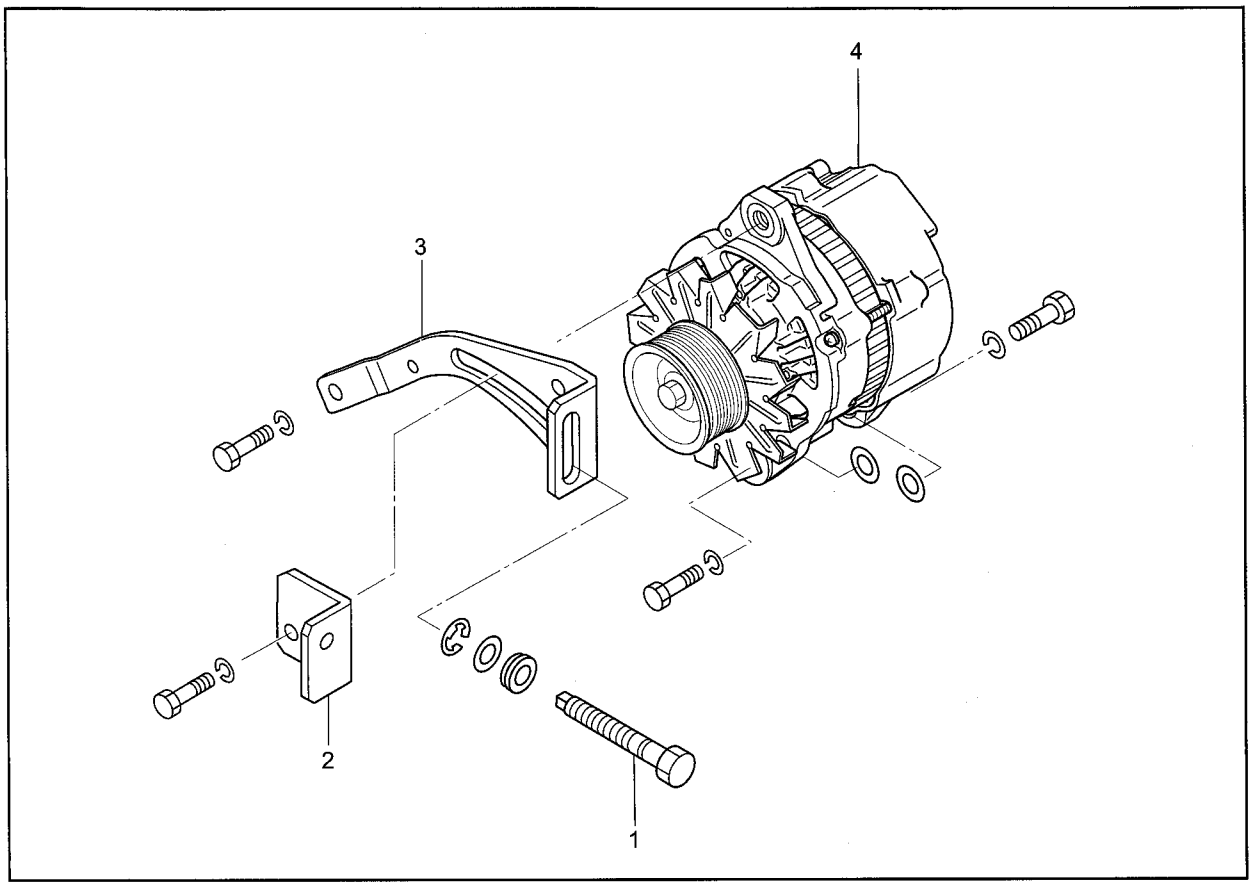
| | |
|---|---|
| Overcharge | Adjusted value of voltage regulator is high. |
| | Faulty battery. |
| Over discharge | Low adjusted value of voltage relay. |
| | Faulty alternator output. |
| | Electric power consumption is extremely high. |
| | Special load is used. |
| | Faulty wiring. |

### 1.2.2 Handling precaution

Improper handling could cause damage or failure to the alternator.

(1) Connect battery cables correctly. The (-) cable is for grounding.
(2) Do not use any high voltage tester such as megger.
(3) Disconnect battery cables before recharging.
(4) Do not disconnect lead wire from B terminal of the alternator while the engine is running.
(5) Battery voltage is constantly applied to B terminal of the alternator. Do not ground at this terminal.
(6) Do not short circuit or ground at L terminal. (For a built-in IC regulator type)
(7) When a steam cleaner is used, do not allow the steam directly contact the alternator.

### 1.3 Removing alternator




Removing alternator

Removing sequence

1 Set bolt
2 Puller
3 Adjusting plate
4 Alternator

# 2. Disassembling, inspecting and reassembling electrical system

## 2.1 Inspection before disassembling starter

### 2.1.1 Inspecting magnet switch

Perform the inspection as described below. If faulty, replace the magnet switch with a new one.

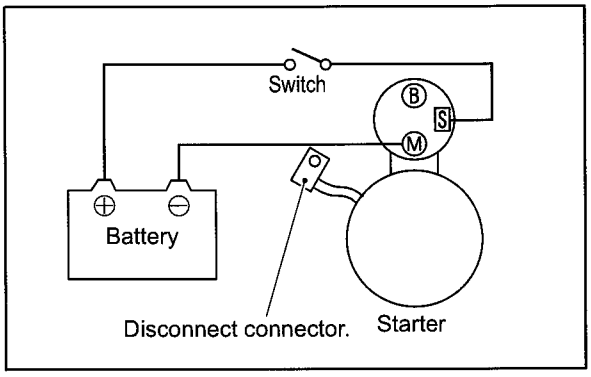
**CAUTION**

Do not apply current continuously for longer than 10 seconds.

(1) Disconnect the connector of M terminal.

(2) Pull-in test

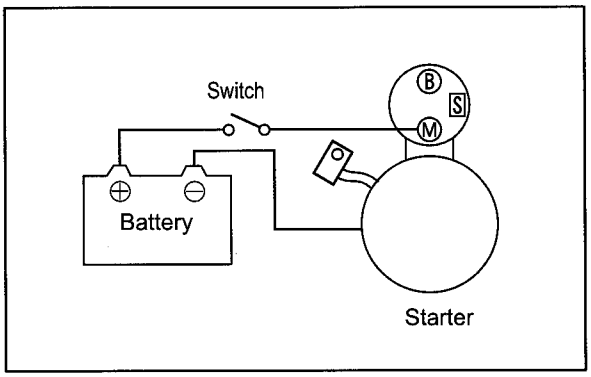
Connect the starter to the circuit as shown in the illustration. The magnet switch is normal if the pinion springs out when the switch is turned ON.




Pull-in test

(3) Holding test

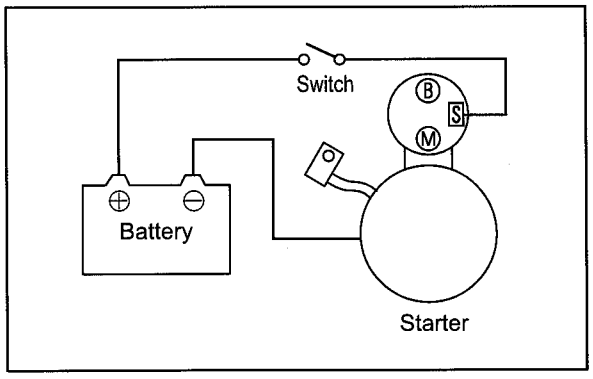
Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnet switch is normal if the pinion does not return when it is released.




Holding test

(4) Return test

Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnet switch is normal if the pinion returns immediately when it is released.




Return test

### 2.1.2 No load test

**CAUTION**

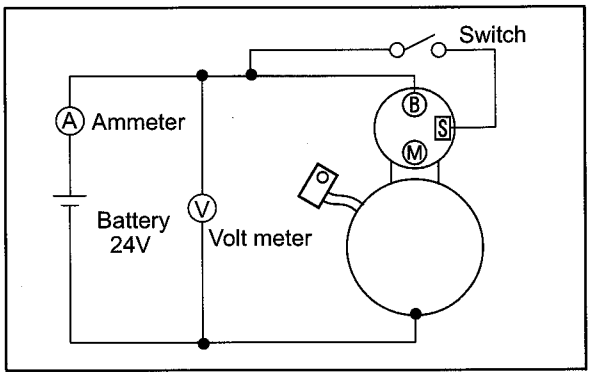
Use as thick a wire as possible and firmly tighten each terminal.

When detecting the rotation at the tip of the pinion, be careful, as the pinion pops out during operation.

(1) Connect the starter to the circuit as shown in the illustration.

(2) In normal condition, the pinion pops out when the switch is turned ON, and the starter rotates at or above the specified rotation speed.

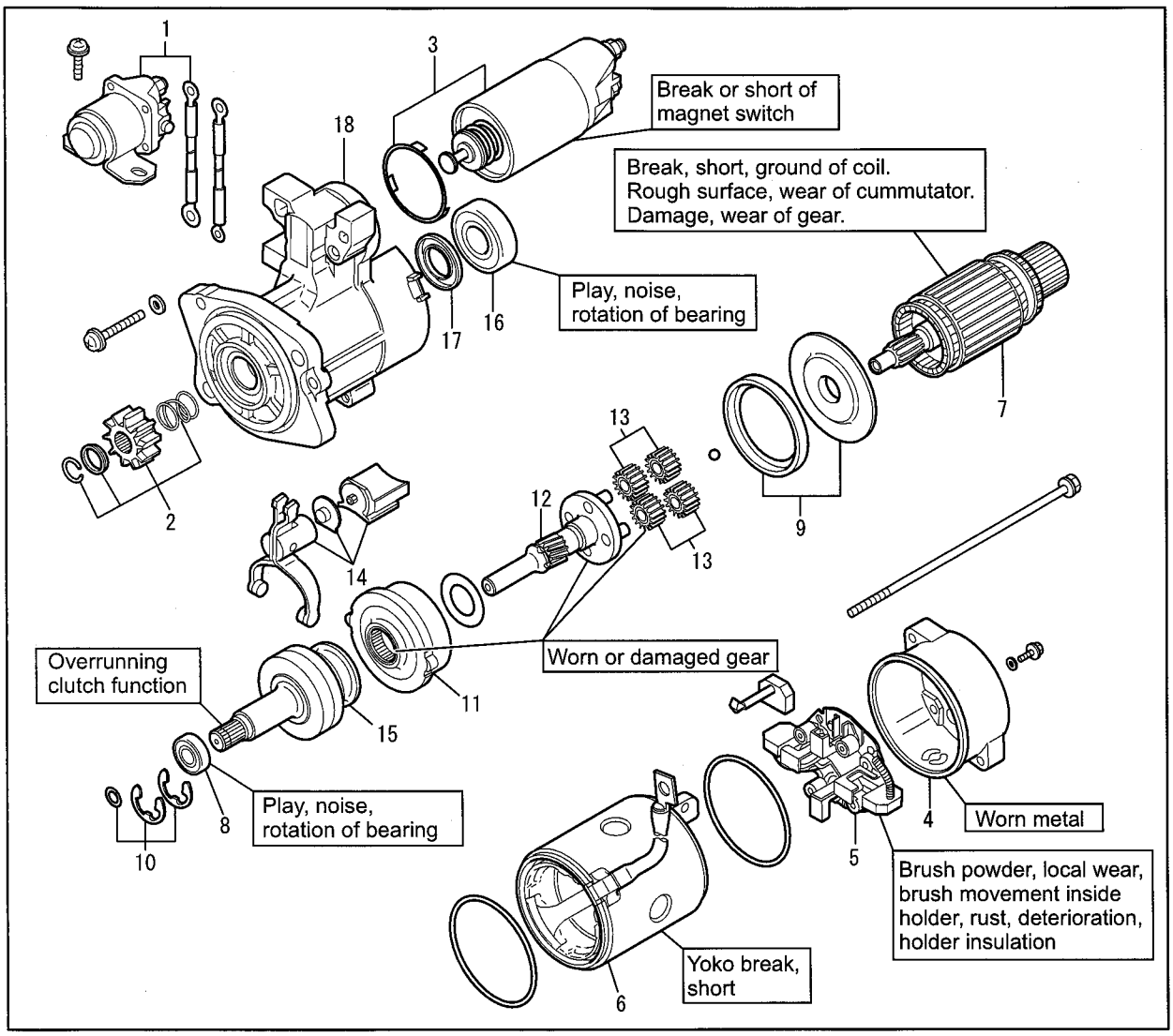
If the terminal voltage, current or rotation speed does not meet the standard, disassemble, inspect and repair the starter.




No-load test

| Item | | Standard |
|---|---|---|
| Starter mode type | | M008T60471 |
| Nominal output V-kW | | 24-5.0 |
| No-load characteristics | Terminal voltage V | 23 |
| | Current A | 85 or less |
| | Rotation speed $min^{-1}$ | 3300 |

## 2.2 Disassembling and inspecting starter




Disassembling and inspecting starter

Disassembling sequence

1 Auxiliary switch
2 Pinion set
3 Magnet switch assembly
4 Rear bracket
5 Brush holder
6 Yoke assembly
7 Armature
8 Ball bearing
9 Packing set
10 Washer set
11 Internal gear
12 Gear shaft
13 Planetary gear
14 Lever assembly
15 Overrunning clutch
16 Ball bearing
17 Oil seal
18 Front bracket

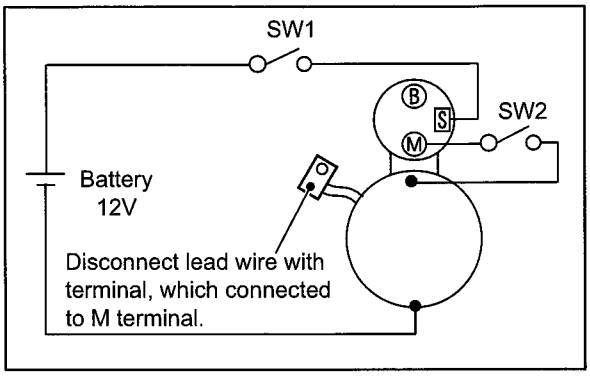
### 2.2.1 Removing pinion set

**CAUTION**

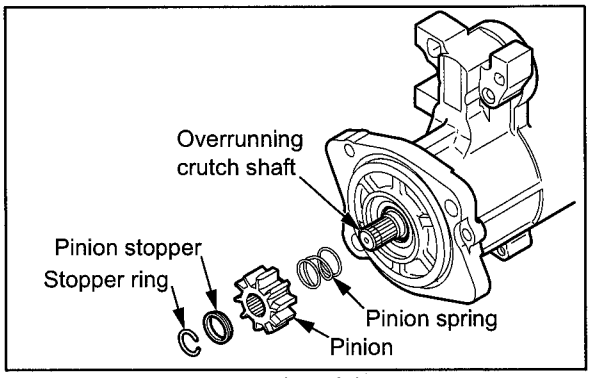
The starter generates heat if it is left with current being applied. Remove the pinion within 10 seconds.

(1) Connect the starter to the circuit as shown in the illustration.
(2) Turn the switches SW1 and SW2 ON to move the pinion out and then turn the SW2 OFF to stop the rotation of the armature and the pinion.
(3) Place an appropriate tube on the pinion stopper. Tap the tube with a hammer to drop the pinion stopper to the clutch side. This will expose the stopper ring.
(4) Remove the stopper ring with pliers and remove the pinion.

Note: Do not reuse the stopper ring for reassembly.



Connection to move the pinion forward



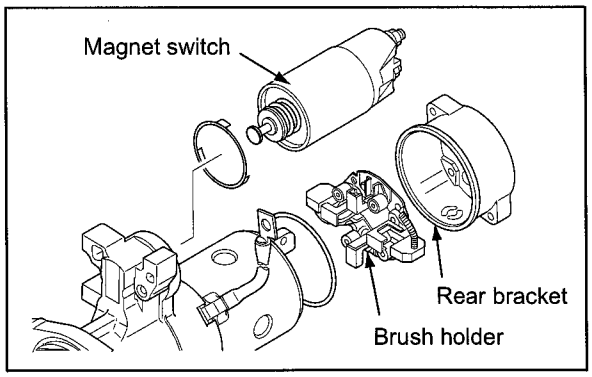
Removing pinion

### 2.2.2 Removing magnet switch

Disconnect the leads, and remove the magnet switch.

### 2.2.3 Removing brush holder and brush assembly

Apply a socket (of the same diameter as the commutator) to the commutator of the armature. Remove the brush holder and brush assembly by sliding on the socket.



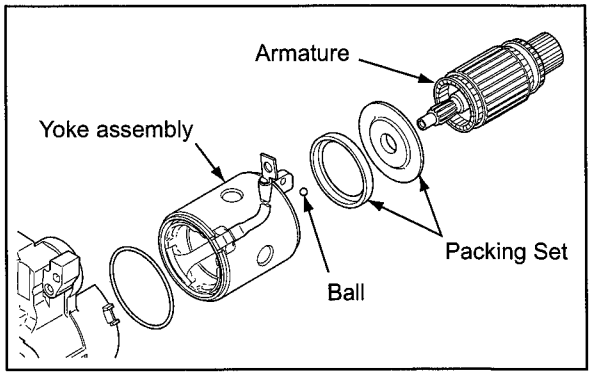
Disassembling starter 1

### 2.2.4 Removing rear bracket

Remove the through bolts and screws of the brush holder, and then remove the rear bracket.

### 2.2.5 Removing armature and yoke

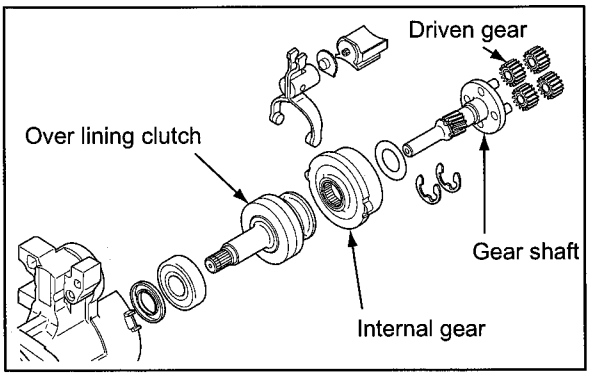
(1) Remove the armature and the yoke.
(2) Remove the packing from the internal gear.
(3) Remove the packing and plate on the lever support.
(4) Remove the ball from the internal gear.
(5) Remove the planetary gears.



Disassembling starter 2

### 2.2.6 Removing overrunning clutch

Pull out the internal gear, gear shaft, overrunning clutch and lever as an assembly from the front bracket, and remove the lever.



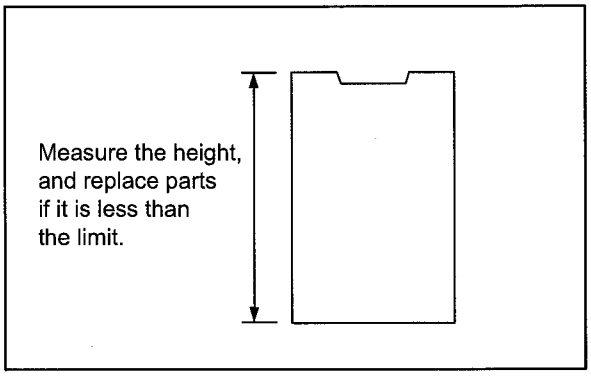

Disassembling starter 3

## 2.3 Inspecting and repairing starter

### 2.3.1 Inspecting brushes for wear

Measure the length of the brushes. If the measured value is less than the limit, replace both the brush holder assembly and the brush assembly.

| Item | Standard | Limit |
|---|---|---|
| Brush length | 18 mm [0.71 in.] | 11 mm [0.43 in.] |

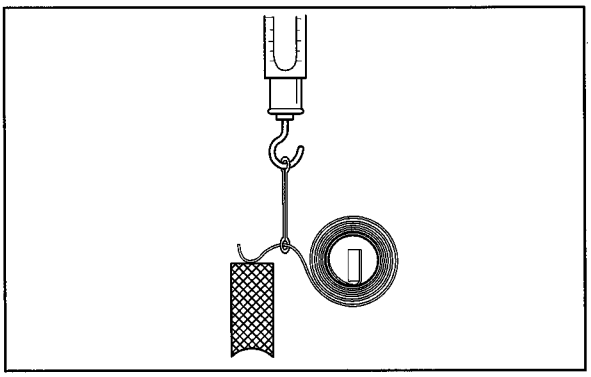



Inspecting brushes for wear

### 2.3.2 Measuring brush spring load

Using a new brush, measure the spring load at which the spring lifts from the brush. If the measured value is less than the limit, replace the spring.

| Item | Standard | Limit |
|---|---|---|
| Spring load | 29 to 39 N {3.0 to 4.0 kgf} [22 to 29 lbf] | 13.7 N {1.4 kgf} [30.2 lbf] |

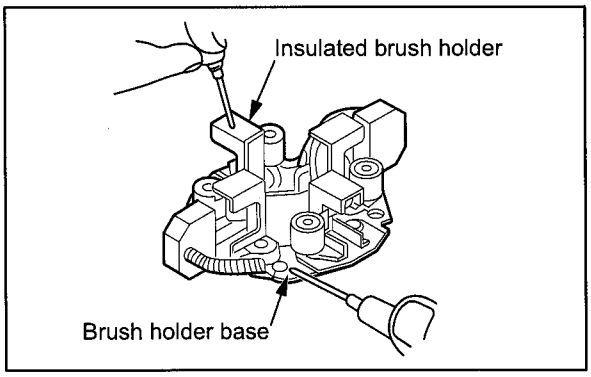


Measuring brush spring load

### 2.3.3 Inspecting brush holder for insulation

Check that there is no continuity between each brush holder and the brush holder base. If continuity is observed, replace the whole brush holder assembly.

Check the brush holders for looseness.



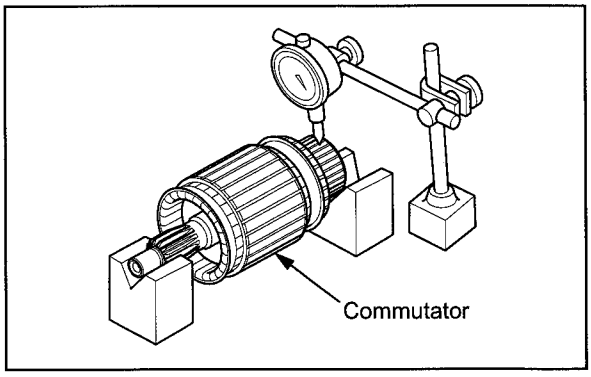

Checking brush holder for insulation

### 2.3.4 Inspecting commutator radial runout

(1) Inspect the commutator surface. If the surface is rough, polish it using a 400 to 600 grit sandpaper.

(2) Measure the radial runout using a dial gauge. If the measured value exceeds the limit, replace the commutator with a new one.

| Item | Standard | Limit |
|---|---|---|
| Commutator radial runout | 0.03 mm [0.0012 in.] | 0.10 mm [0.0039 in.] |



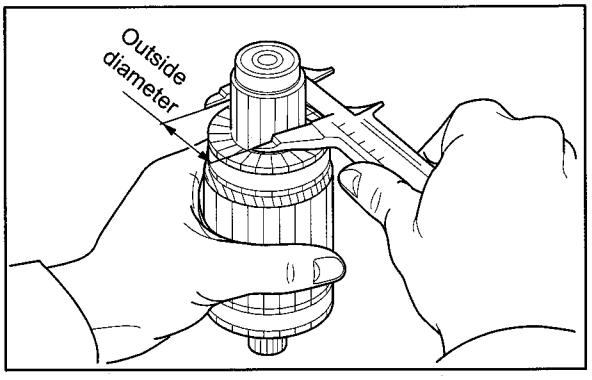

Inspecting commutator radial runout

### 2.3.5 Measuring commutator outside diameter

Measure the commutator outside diameter.

If the measured value is less than the limit, replace the armature with a new one.

| Item | Standard | Limit |
|---|---|---|
| Commutator outside diameter | 32.0 mm [1.259 in.] | 31.4 mm [1.236 in.] |



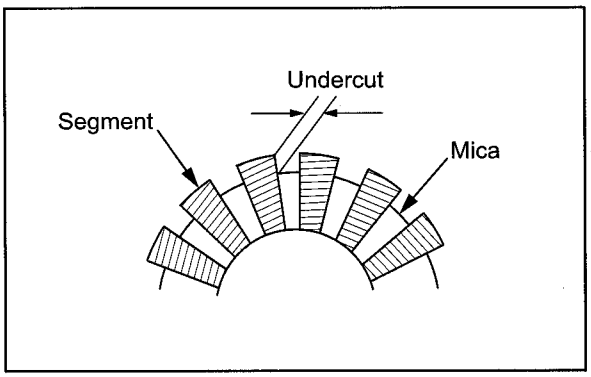

Measuring commutator outside diameter

### 2.3.6 Measuring undercut depth

Measure the depth of undercutting between the commutator segments.

If the measured value is less than the limit, repair or replace with a new part.

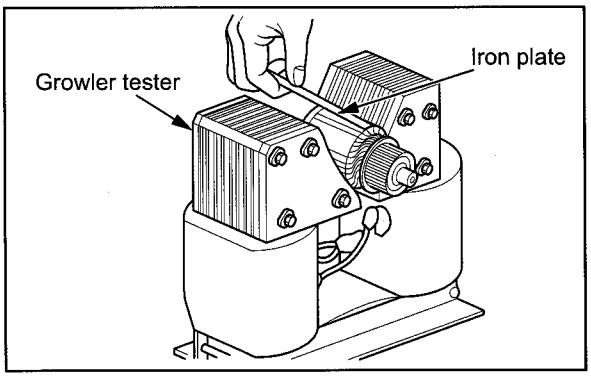
| Item | Limit |
|---|---|
| Undercut depth | 0.2 mm [0.008 in.] |




Measuring undercut depth

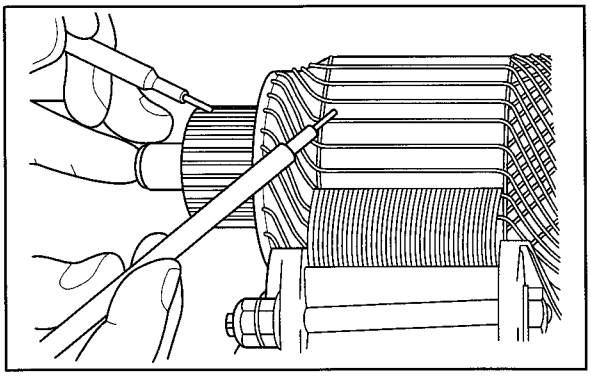
### 2.3.7 Checking armature coil

(1) Inspect the armature coil using a growler.
Hold a piece of iron plate against the armature core. If the iron plate vibrates, replace the armature with a new one.



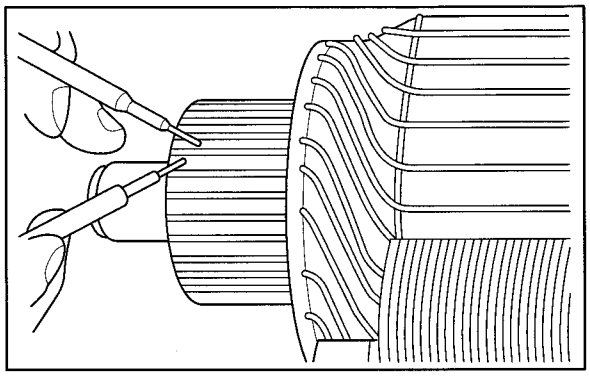

Inspecting armature coil short circuit

(2) Check that there is no continuity between the commutator and the shaft (core).
If any continuity is observed, replace the armature with a new one.



Inspecting insulation between commutator and shaft

(3) Check that there is continuity between segments in various combinations.
If poor or no continuity is observed, replace the armature with a new one.



Inspecting continuity between segment

### 2.3.8 Inspecting rear bracket

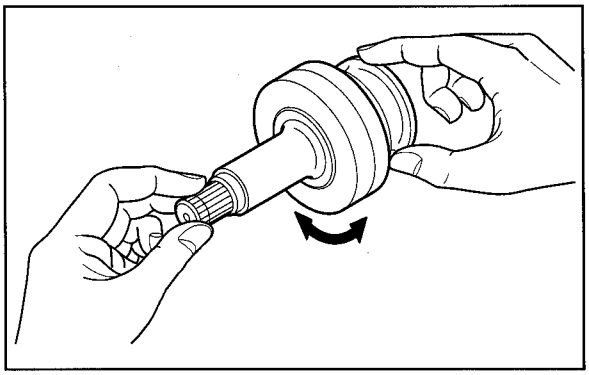
Replace the rear bracket if the bearing is worn.

### 2.3.9 Inspecting overrunning clutch

**CAUTION**

Do not wash the overrunning clutch in cleaning oil.

Check to ensure that, when attempting to turn the overrunning clutch, it locks in one direction and rotates smoothly in the opposite direction.



Inspecting overrunning clutch

### 2.3.10 Inspecting front bracket

The ball bearing should rotate smoothly without abnormal noise. If defective, replace the whole front bracket.

### 2.3.11 Inspecting gears of starter

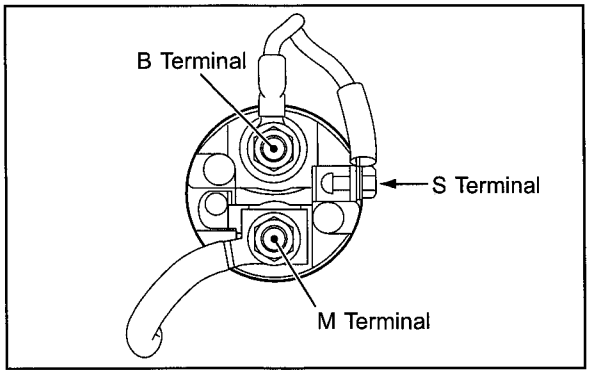
Check gears of the starter for wear or damage. If faulty, replace the starter.

### 2.3.12 Inspecting continuity of magnet switch (between M terminal and case)

Check that there is continuity between M terminal and case. If no continuity is observed, replace the magnet switch with a new one.

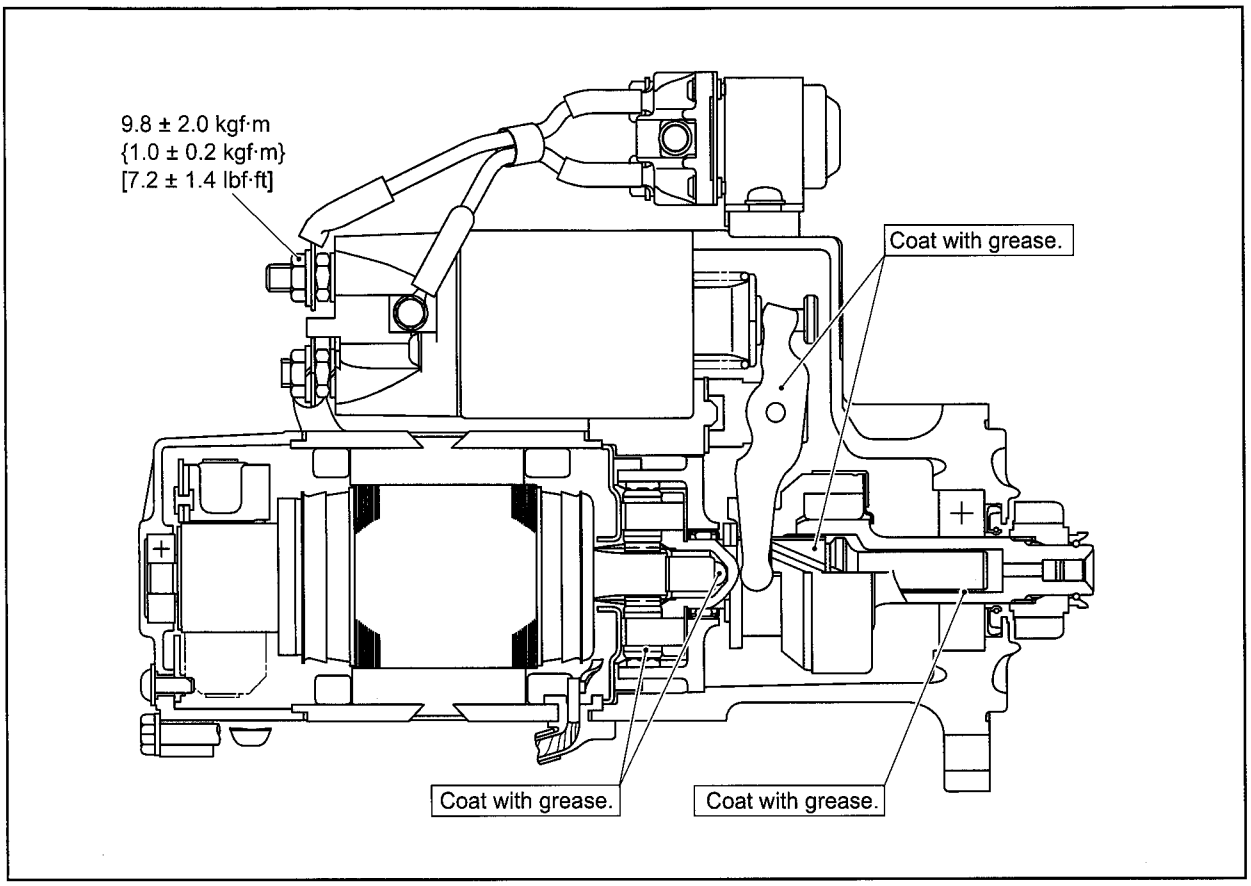
### 2.3.13 Inspecting insulation of magnet switch (between M terminal and B terminal)

Check that there is no continuity between M terminal and B terminal. If continuity is observed, replace the magnet switch with a new one.




Checking magnet switch for continuity

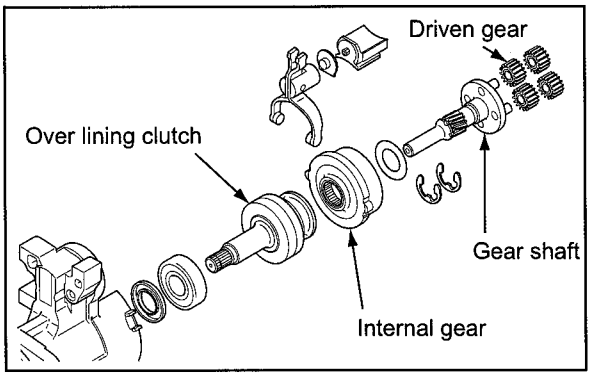
## 2.4 Reassembling starter




Reassembling starter

### 2.4.1 Installing gear shaft

(1) Install the lever to the overrunning clutch.
(2) Fit the internal gear into the gear shaft.
(3) Put the gear shaft into the overrunning clutch.




Installing gear shaft

### 2.4.2 Installing pinion

**CAUTION**

Before assembling, apply grease to the inner race groove of the front bracket bearing.

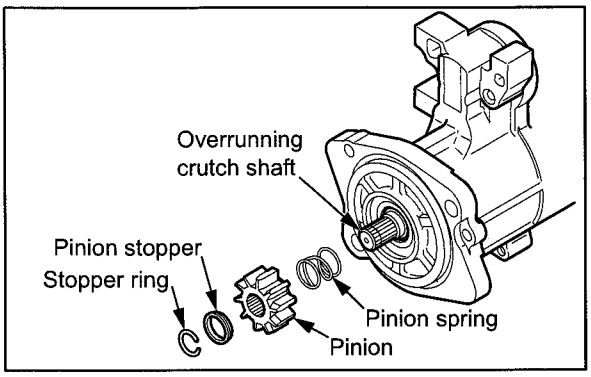
Be sure to use a new stopper ring. Do not reuse the stopper ring that has been removed.

(1) Put the overrunning clutch through the front bracket.

(2) Install the pinion spring first, then the pinion, and the pinion stopper to the shaft of the overrunning clutch.

(3) Install the stopper ring firmly to the shaft groove of overrunning clutch.

(4) Using a gear puller, firmly pull the pinion stopper closer to the stopper ring to fix.




Installing pinion

### 2.4.3 Installing yoke and armature

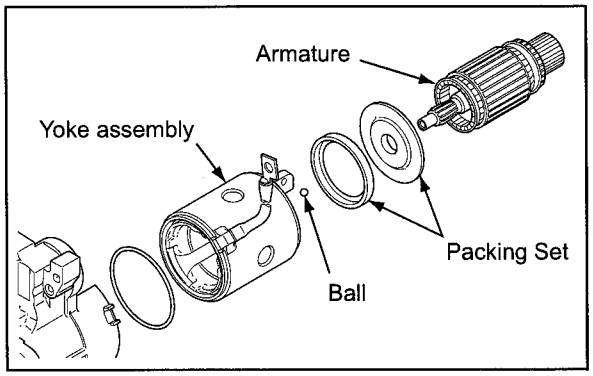
(1) Install the planetary gears on the gear shaft.

(2) Install the plate and packing.

(3) Install the yoke on the front bracket.

(4) Apply grease to the armature shaft end and install the ball on it.

(5) Install the armature.

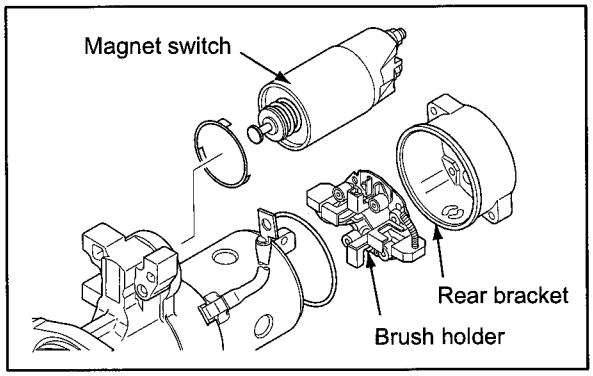



Installing yoke and armature

### 2.4.4 Installing brush holder and brush assembly

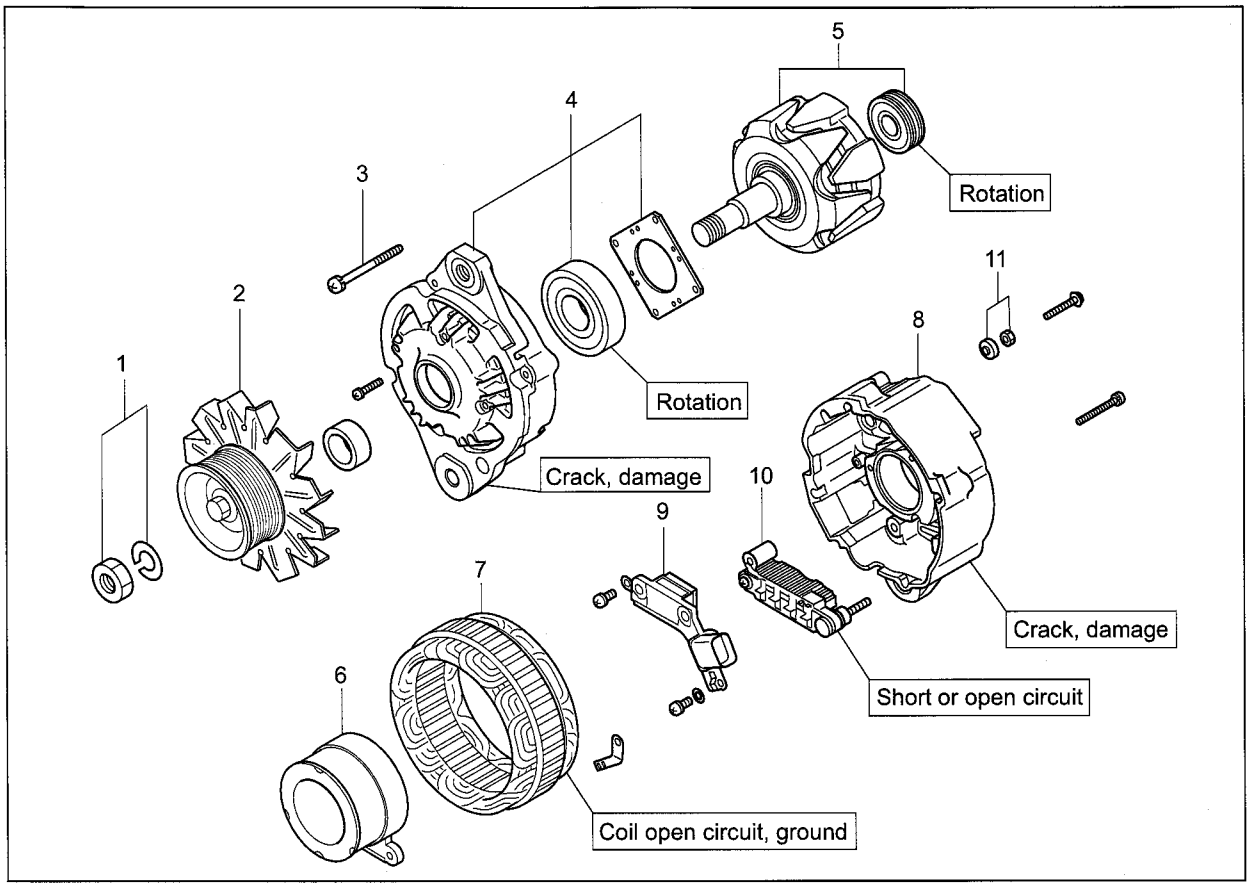
Attach the socket to the commutator of the armature.

While sliding the brushes on the socket, install the brush holder and brush assembly on the armature.




Installing brush holder and brush assembly

## 2.5 Disassembling and inspecting alternator




Disassembling and inspecting alternator

Disassembling sequence

1 Nut and washer
2 Pulley (with fan)
3 Screw
4 Front bracket assembly
5 Rotor assembly
6 Coil
7 Stator coil
8 Rear bracket
9 Regulator assembly
10 Rectifier assembly
11 Nut set

### 2.5.1 Separating front bracket from stator

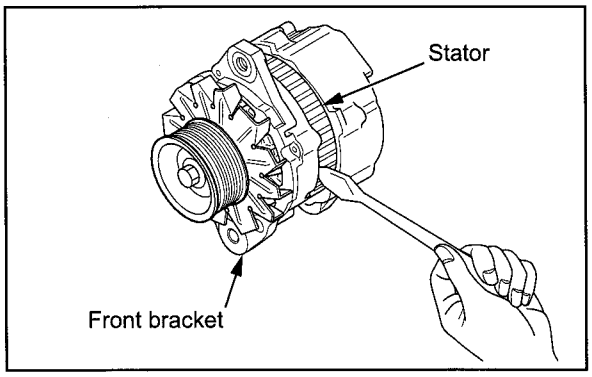
**CAUTION**

Do not disassemble the alternator unless the repair is necessary.

Do not insert the screwdrivers too deep, as it can damage the stator.

(1) Remove the through bolts.

(2) With two flat-head screwdrivers inserted between the front bracket and stator, pry them apart.



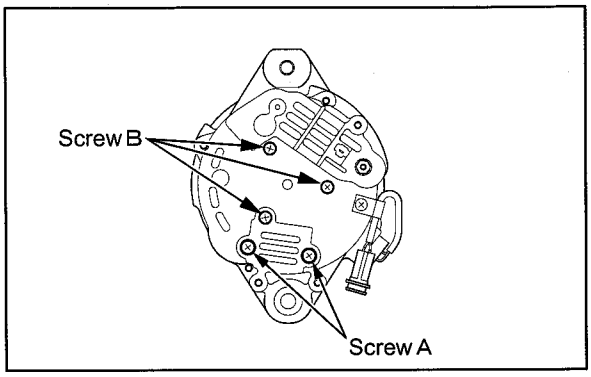

Separating front bracket from stator

### 2.5.2 Removing field coil

**CAUTION**

When removing the field coil, be sure to observe the removal order of screws.
Otherwise, the outlet lines of the field coil will be damaged.
If all the screws are removed, the coil will fall with its own weight. Be careful not to drop the coil.
When removing the field coil, the outlet side of the coil may be caught with the stator. Do not pull the coil forcibly.

(1) Unscrew the screw A.
(2) Unscrew the screw B.
(3) Remove the field coil.



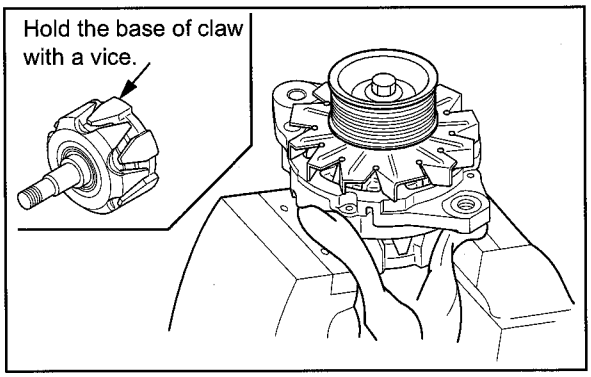
Removing field coil

### 2.5.3 Removing pulley

**CAUTION**

When setting the rotor in a vise, be sure to hold the base of the rotor claw. Do not hold the rotor claw, as it causes damage to the claw.

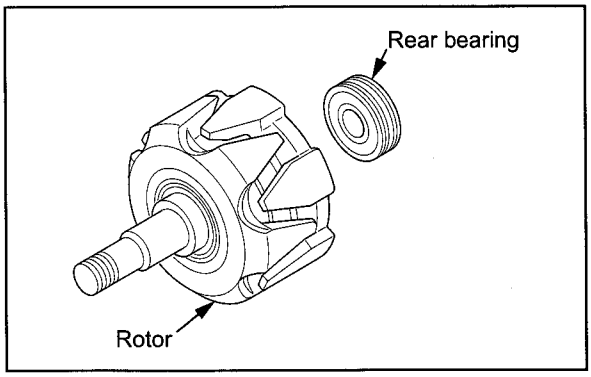
(1) Apply a cloth to the rotor and set it in a vise.
(2) Remove the pulley nut and then pull out the pulley.



Removing pulley

### 2.5.4 Removing rear bearing

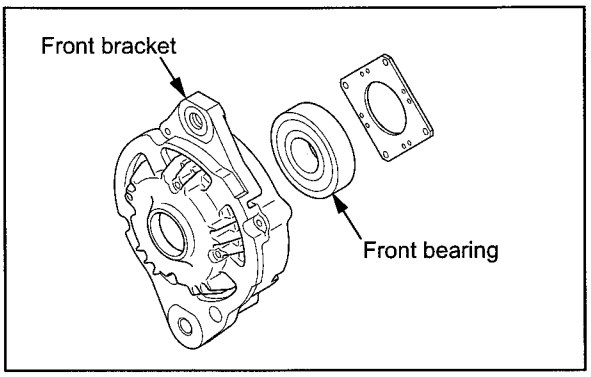
Remove the rear bearing from the rotor using a bearing puller.



Removing rear bearing

### 2.5.5 Removing front bearing

Remove the screw, and then remove the bearing retainer and front bearing from the front bracket.



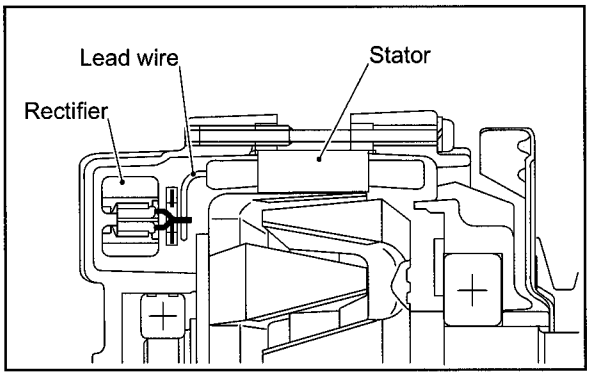

Removing front bearing

### 2.5.6 Removing stator

**CAUTION**

Unsoldering must be finished as quickly as possible. Extended heating will damage the diodes.

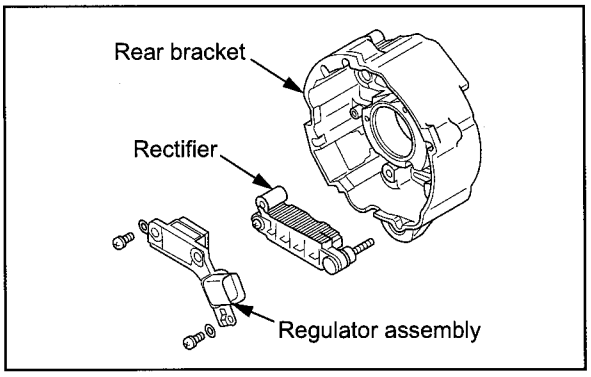
Cut off the joint of the stator and remove the stator from the rectifier.




Removing stator

### 2.5.7 Removing regulator assembly

Remove the screws of the regulator assembly and then remove the regulator assembly.




Removing regulator assembly and rectifier assembly

### 2.5.8 Removing rectifier assembly

(1) Remove the screw and nut from the rectifier.
(2) Remove the rectifier assembly.

## 2.6 Inspecting and repairing alternator

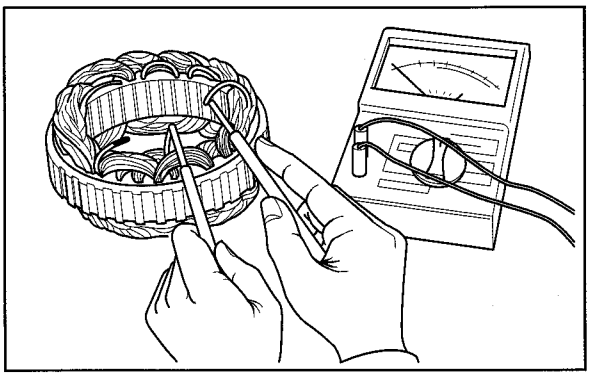
### 2.6.1 Inspecting stator

(1) Checking continuity between lead wires

Check that there is continuity between a pair of lead wires.

Also check that there is no continuity between a pair of lead wires and other pair of lead wires.

If defective, replace the stator.

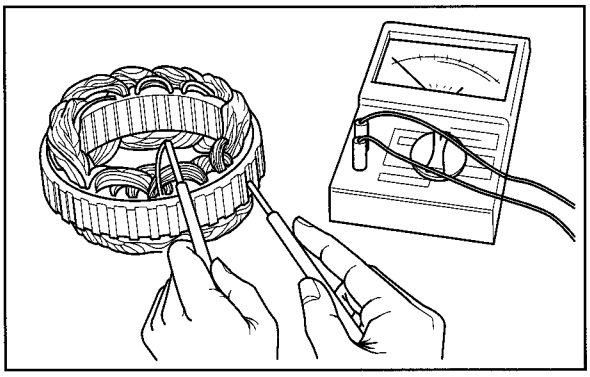


Inspecting continuity between lead wires

(2) Checking insulation between lead wire and core

Check that there is no continuity between each lead wire and the stator core. If continuity is observed, replace the stator.

Note: The core cannot be replaced as a single item.

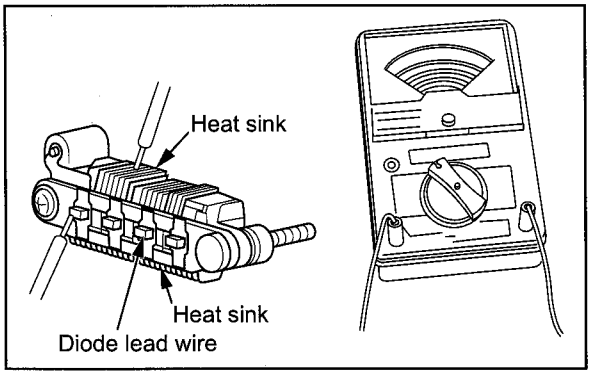


Inspecting continuity between lead wires and core

### 2.6.2 Inspecting rectifier

Check that diodes in a rectifier function properly. To check, measure both negative (-) and positive (+) resistance alternately twice. If both infinite negative and infinite positive resistances are observed, the diode is open-circuited. If measured value is close to 0 Ω, the diode is short-circuited. In either case, replace the rectifier with a new one.

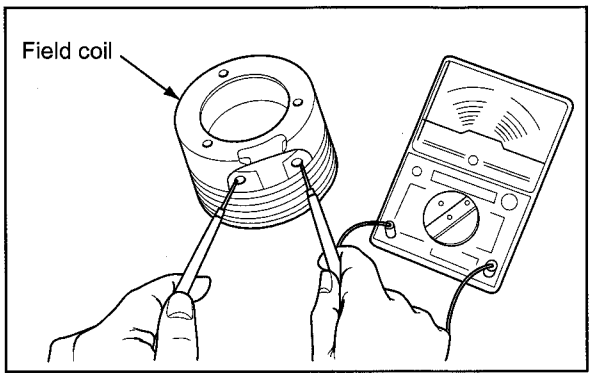
Note: Use a wide measuring range as much as possible. The current flow during test is significantly lower than the current that normally flows in the rectifier, by which the accurate resistance may not be measured using a tester, and this tendency is noticeable if the measuring range is small.




Checking rectifier

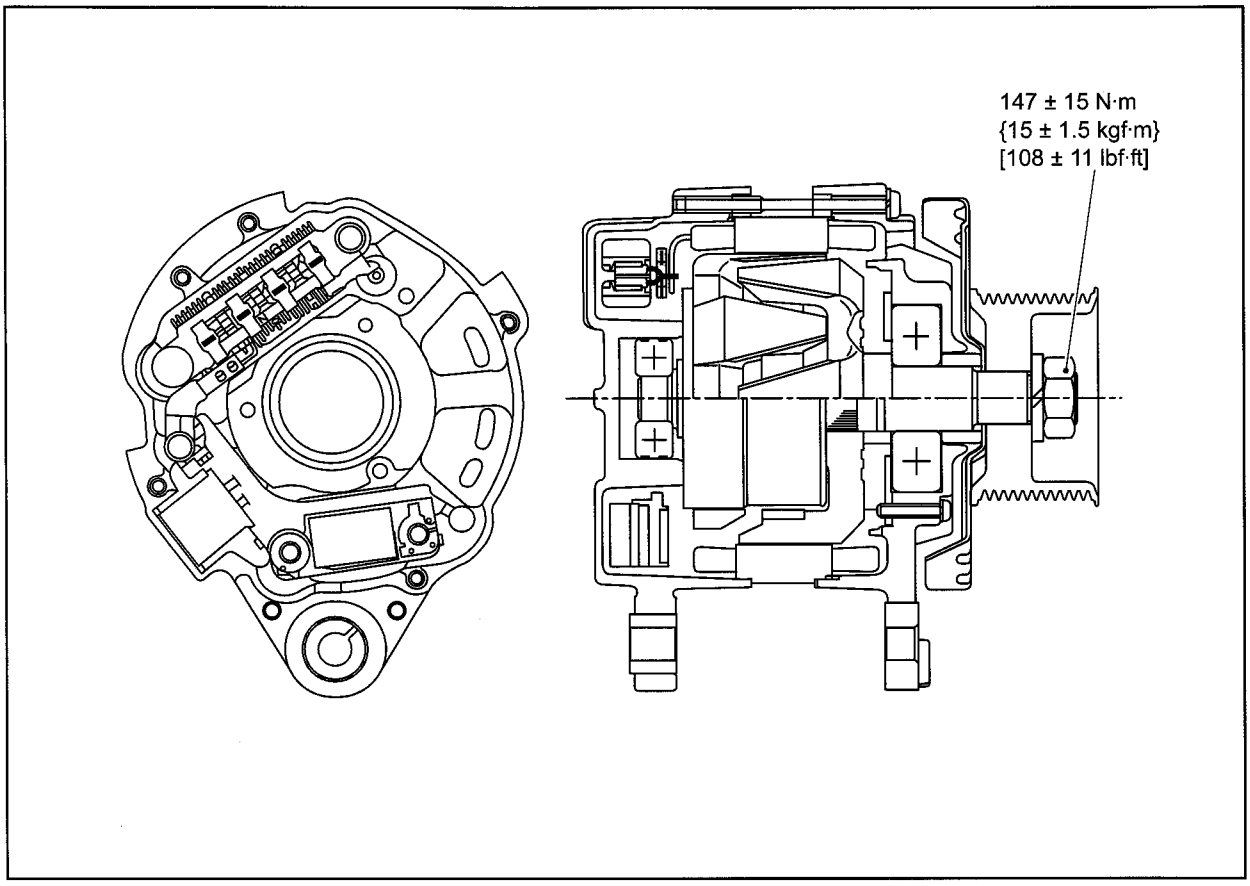
### 2.6.3 Measuring field coil

Measure resistance between the terminals of the field coil.
If the measured value deviates from the standard value, replace the field coil with a new one.




Measuring field coil

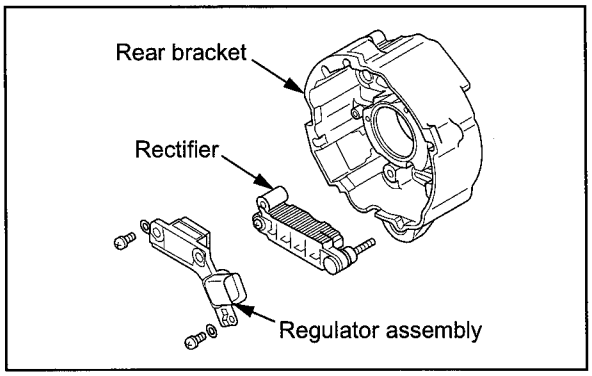
## 2.7 Reassembling alternator




Reassembling alternator

### 2.7.1 Installing rectifier assembly and regulator assembly

Install the rectifier assembly and regulator assembly on the rear bracket.



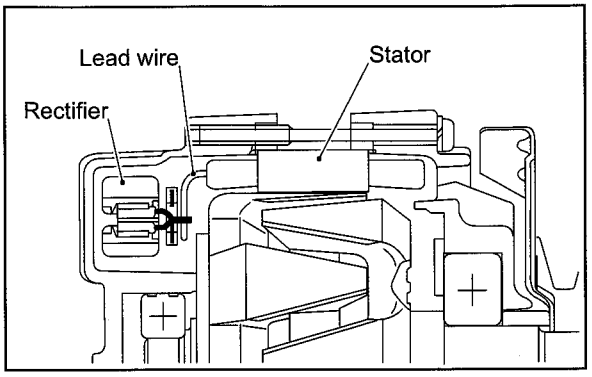

Installing rectifier assembly and regulator assembly

### 2.7.2 Installing stator

**CAUTION**

Soldering must be finished as quickly as possible.
Extended heating will damage the diodes.

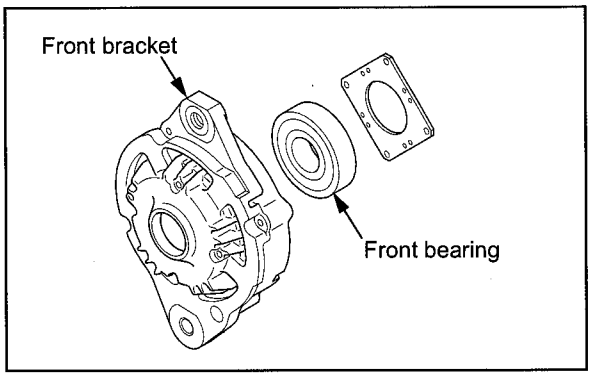
Install the stator and solder the leads of the stator to the rectifier.




Installing stator

### 2.7.3 Installing front bearing

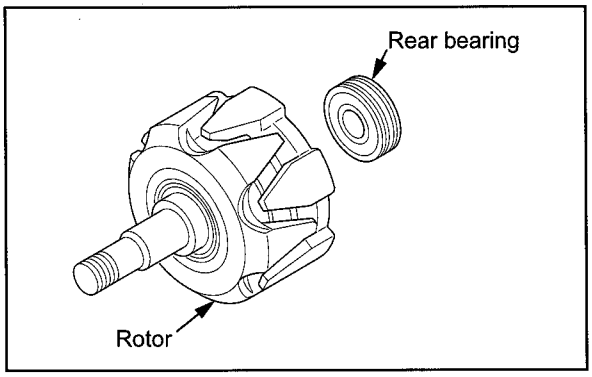
Drive the front bearing into the front bracket and secure the bearing retainer with a screw.




Installing front bearing

### 2.7.4 Installing rear bearing

Press-fit the rear bearing to the rotor.

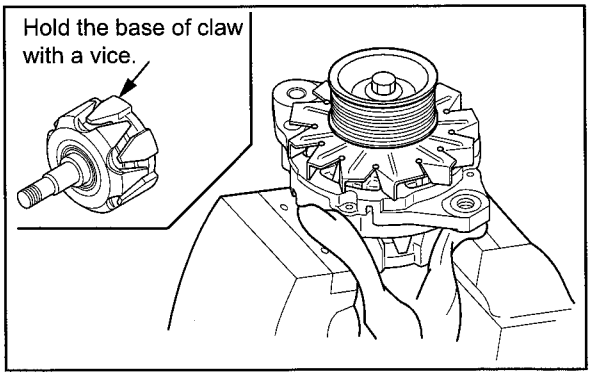



Installing rear bearing

### 2.7.5 Installing pulley

(1) Insert the rotor into the front bracket.
Apply a cloth to the rotor and set it in a vice.

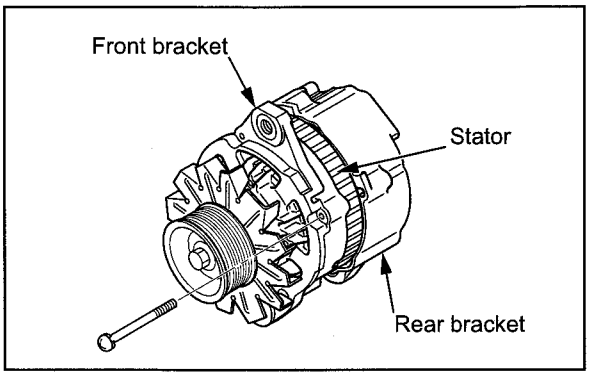
(2) Install the spacer and pulley, and secure the pulley with a nut.




Installing pulley

### 2.7.6 Assembling stator and front bracket

Assemble the front bracket, stator and rear bracket, and secure them with through bolts.



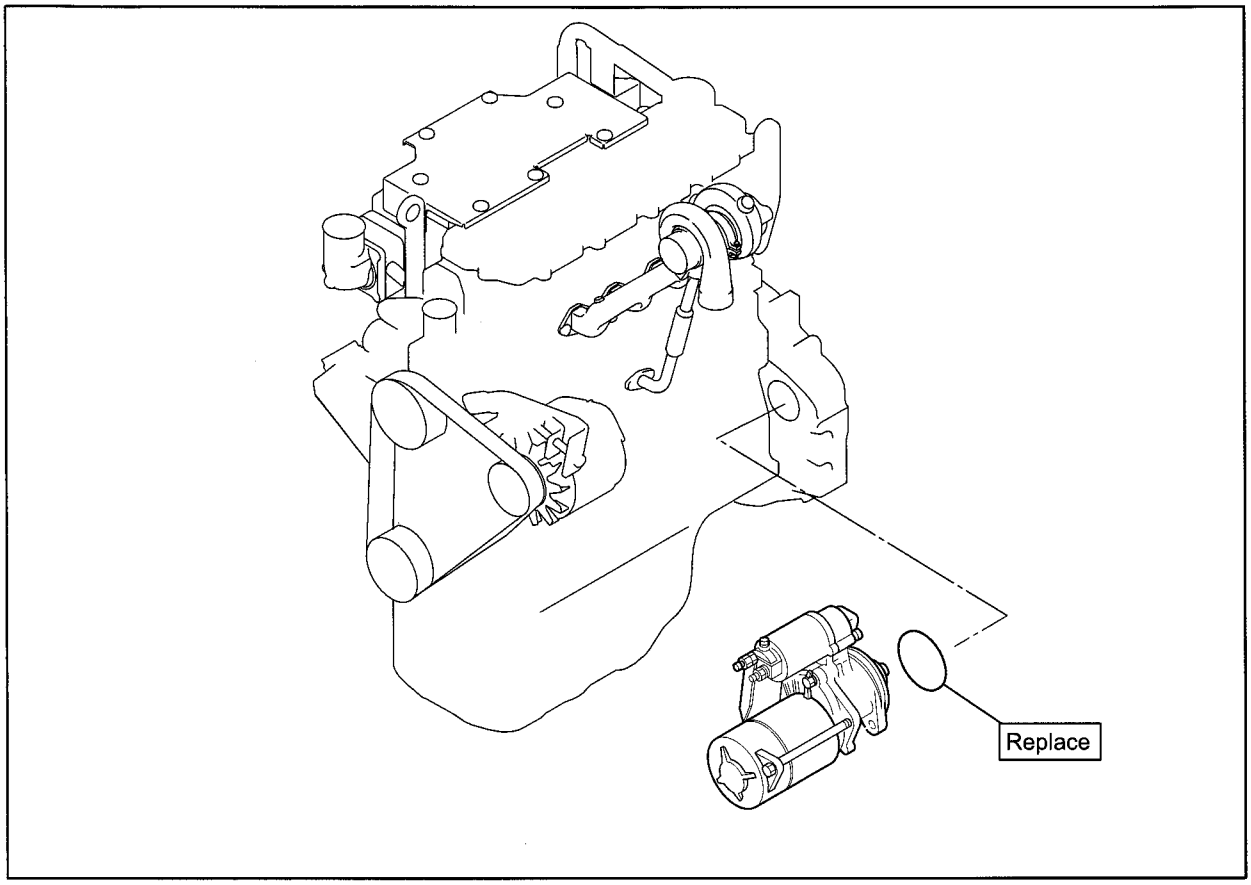

Installing stator and front bracket

### 2.7.7 Inspecting air heater

Check the air heater for loose terminals. Also check the heater element for damage or contact.

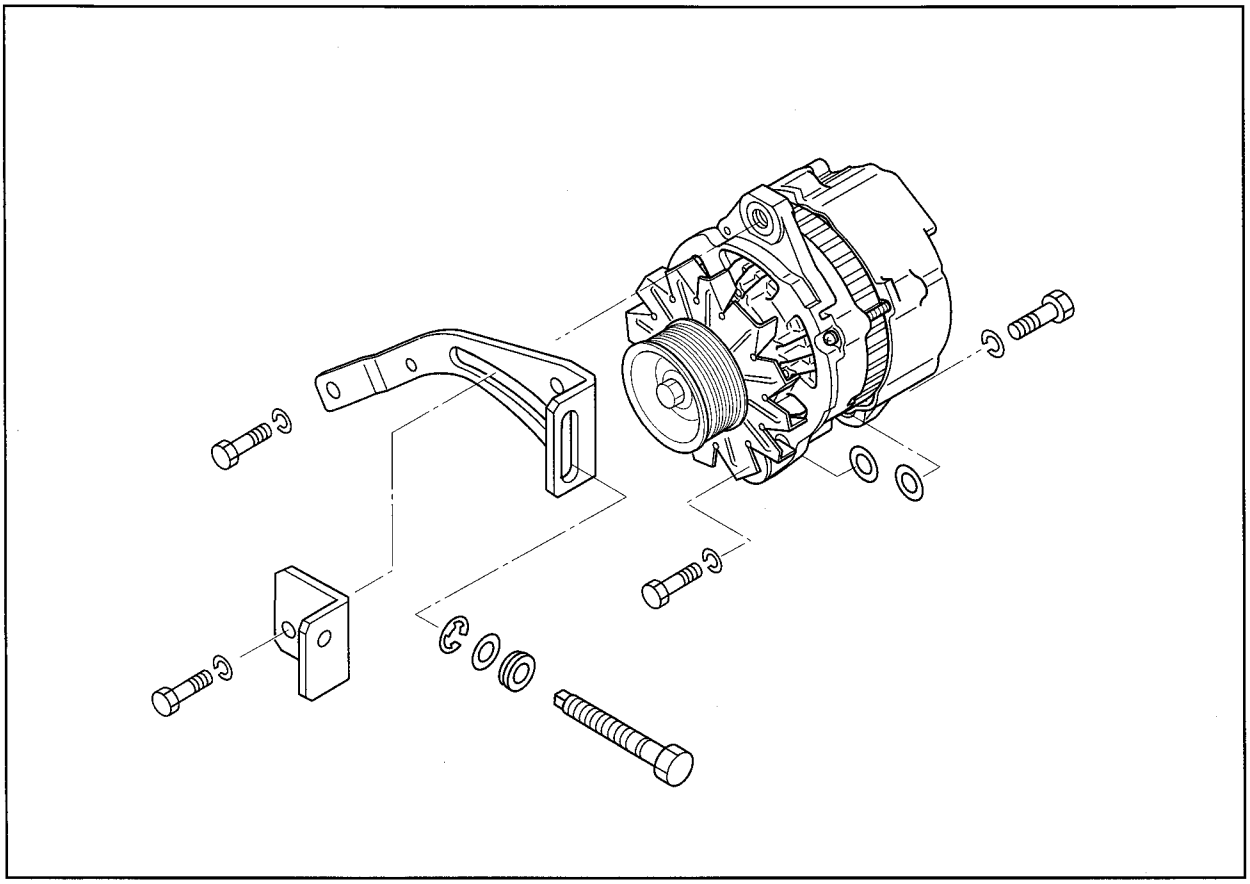
## 3. Installing electrical system

### 3.1 Installing starter



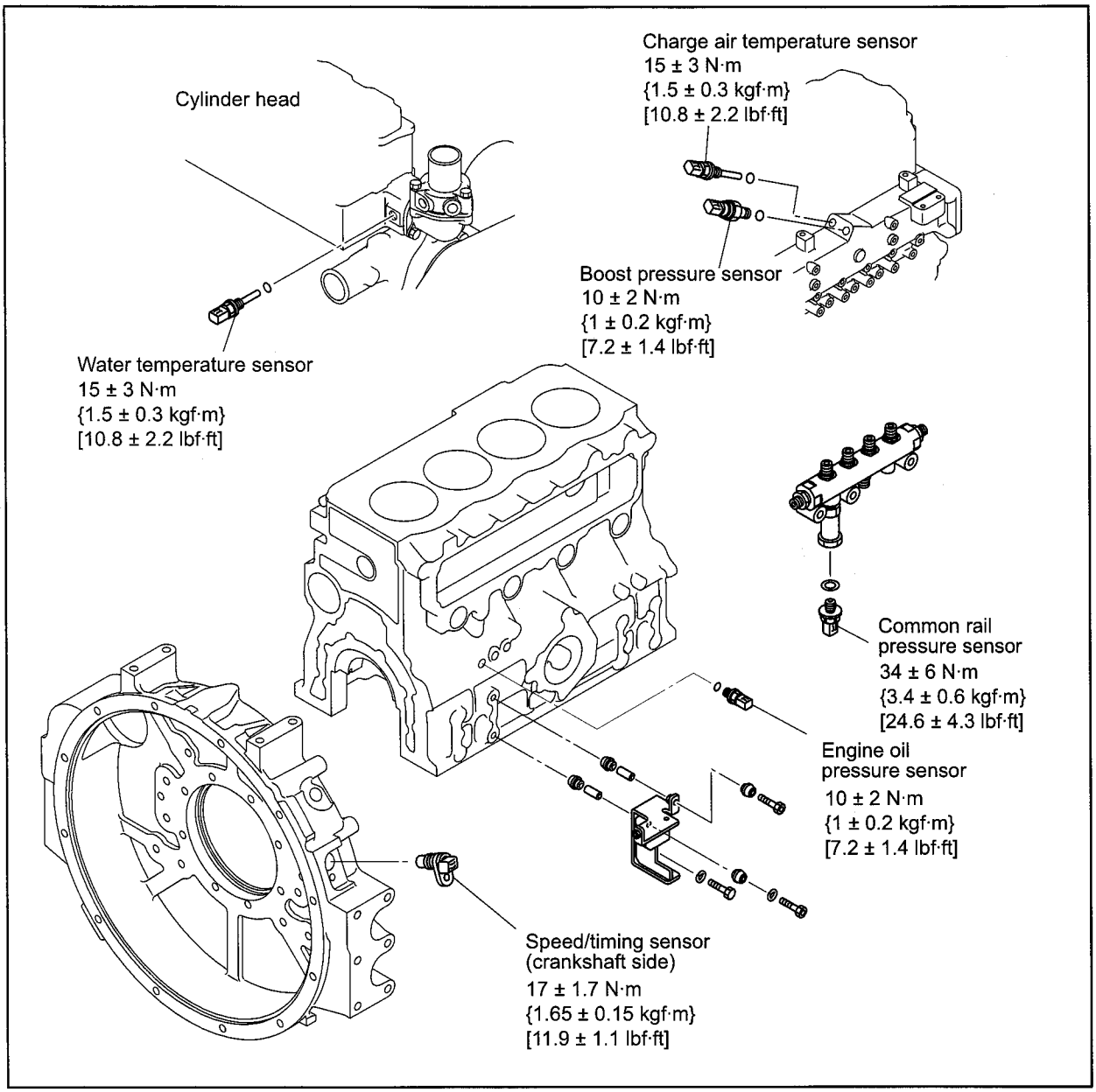

Installing starter

### 3.2 Installing alternator



Installing alternator

### 3.3 Installing various sensors




Installing various sensors

# ENGINE ADJUSTMENT, BREAK-IN OPERATION AND PERFORMANCE TEST

# 1. Adjusting engine

## 1.1 Inspecting and adjusting valve clearance

Inspect and adjust the valve clearance.

The valve clearance should be inspected and adjusted when the engine is cold.

Note: (a) The inlet valves are on the left side and the exhaust valves are on the right side as the cylinder head is viewed from the camshaft gear side.

(b) The valve clearance standard values are indicated on the caution plate on the No.1 cylinder rocker cover.

| Item | | Standard |
|---|---|---|
| Valve clearance (when engine is cold) | Inlet | 0.25 mm [0.0098 in.] |
| | Exhaust | 0.40 mm [0.0157 in.] |

### 1.1.1 Adjusting front and rear valve heights by valve bridge

**CAUTION**

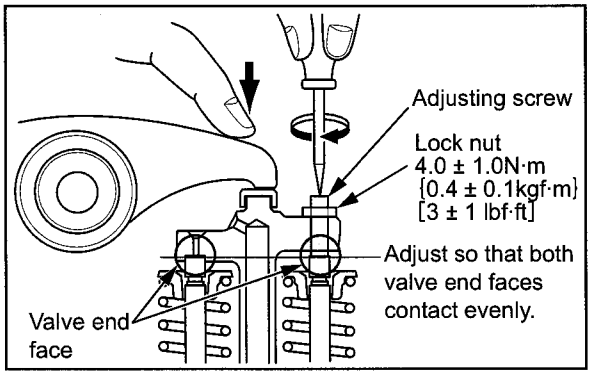
If there is no clearance between the bridge and valve rotator, the interference between them may cause the valve cotters to fall out. Be sure to provide the specified clearance.

When adjusting the front and rear valve heights with the valve bridge, bring the piston at the top dead center on the compression stroke.

(1) Prior to the valve clearance adjustment, it is necessary to adjust the front and rear valve heights with the valve bridge (bringing the bridge into contact with the front and rear valves). If the front and rear valve heights are not the same, which can occur due to such conditoins as valve seat wear, a clearance will be generated between the top of valve steam and the either side of bridge, resulting in the change of valve clearance.

(2) To adjust the valve height, loosen the rock nut and unscrew the adjusting screw.

(3) Hold the rocker arm with a finger, and slowly turn the adjusting screw until the screw contacts the top of valve stem. Then, turn the screw a further 10 degrees, and tighten the rock nut.




Adjusting front and rear valve heights by valve bridge

### 1.1.2 Inspecting valve clearance

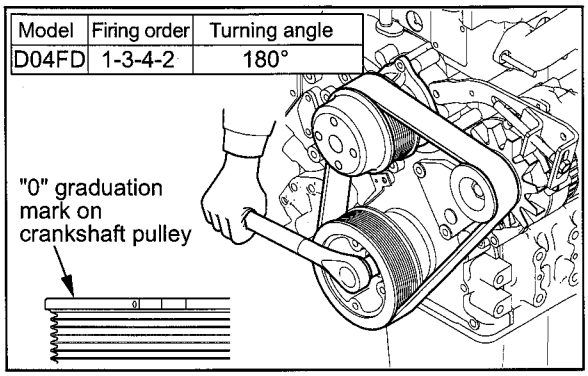
(1) Inspect the valve clearance for all cylinders in the firing order by turning the crankshaft to the specified degrees in the normal direction (clockwise when viewed from engine front side) to bring each piston to the top dead center on the compression stroke.

Note: To turn the crankshaft, fit a socket and ratchet handle on the crankshaft pulley nut.

(2) When the No. 1 piston is at the top dead center on the compression stroke, the "0" graduation mark on the periphery of the crankshaft pulley is aligned with the pointer on the timing gear case, and neither the inlet valve nor the exhaust valve is not lifted off its seat by the pushrod.

(3) Insert a thickness gauge between the rocker arm and valve cap to inspect the clearance.

| Model | Firing order | Turning angle |
|---|---|---|
| D04FD | 1-3-4-2 | 180° |

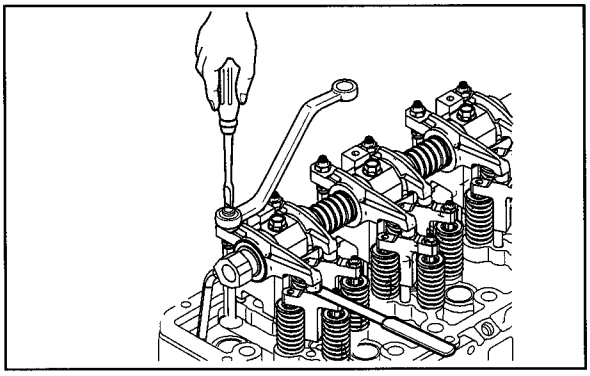



Inspecting valve clearance

### 1.1.3 Adjusting valve clearance

(1) Insert the feeler gauge of the specified thickness between the rocker arm and bridge cap, then adjust the clearance by turning the screw in either direction so that the gauge is gripped softly between the rocker arm and bridge cap.

(2) After adjusting the clearance, tighten the lock nut firmly, and inspect the clearance again.



Adjusting valve clearance

## 1.2 Bleeding Fuel System

**⚠ WARNING**

Completely wipe off any spilled fuel from the air vent plug with a cloth, and be sure to tighten the air vent plug after air bleeding. Failure to do so could cause a fire.

### 1.2.1 Bleeding fuel filter

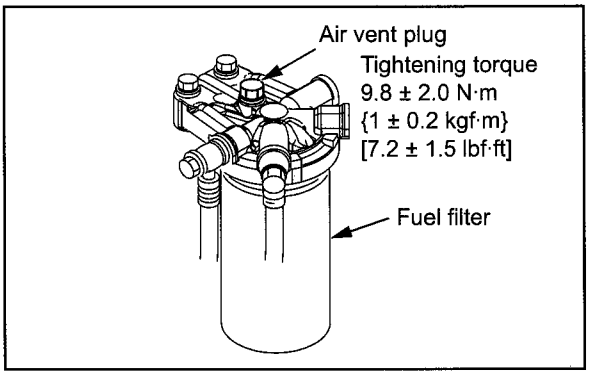
**CAUTION**

If the air vent plug or threads of bracket, or sealing washer is damaged, replace the defective part with a new one.

(1) Loosen the air vent plugs for the fuel filters. (approx. 1.5 turns)

(2) Unlock the priming pump cap by turning it counterclockwise, then move the cap up and down repeatedly.

(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs.




Bleeding fuel filter

## 2. Break-in operation

After the engine is overhauled, couple the engine to the dynamometer, and run the engine for break-in operation and inspection.

### 2.1 Starting up

(1) Before starting the engine, check the levels of coolant, engine oil and fuel.
Bleed the fuel and cooling systems.
(2) Stop the fuel supply, and crank the engine with the starter for about 10 seconds to lubricate the engine.
(3) Move the control lever slightly in the fuel increase direction (but not to the "full injection" position), and then turn the starter switch key to the [START] position to start the engine.
(4) After the engine is started, adjust the control lever to let the engine operate at a minimum no-load speed (low idle speed).
(5) Turn the starter switch key to the [OFF] position and make sure that the engine is stopped.

### 2.2 Inspecting engine condition after starting up

During the break-in operation, check the following.
If any abnormality is found, stop the engine, investigate the cause, and take appropriate measures.

(1) The oil pressure must be within the specified value.
(2) The coolant temperature must be within the specified value.
(3) The engine must be free from any leakages such as oil, coolant and fuel. Pay special attention to oil leakage from the fitting face of turbocharger lube oil pipe.
(4) Check for an abnormal noise.

Note: Knocking noise will disappear as the coolant temperature rises.

(5) Chech for the color of smoke and odors.

### 2.3 Break-in operation time

The relationship between the load in break-in operation and the operation time is as shown below.

| Break-in operation time | | | | |
|---|---|---|---|---|
| | Engine speed ($min^{-1}$) | | Load | Duration (min) |
| 1 | Low rotation speed | 600 to 900 | No-load | 5 |
| 2 | Medium rotation speed | 1000 to 1200 | No-load | 5 |
| 3 | High rotation speed | 1400 to rated rota-tion speed | No-load | 10 |
| 4 | Rotated speed | | 25 % | 10 |
| 5 | | | 50 % | 10 |
| 6 | | | 75 % | 30 |
| 7 | | | 100 % | 20 |

Note: The table above is provided solely for referece purpose. Run the engine at appropriate speed and load for the break-in operation of your engine. Be sure to perform break-in operation after overhaul or installation.

### 2.4 Inspection and adjustment after break-in operation

(1) Valve clearance adjustment
(2) Ignition timing inspection
(3) Exterior bolt and nut tightness check

## 3. Performance test (JIS standard)

The following describes the procedures specified in "Earth moving machinery - Engines - Part 1: Test code of net power (JIS D0006-1)" and "Earth moving machinery - Engines - Part 2: Standard format of specifications and testing methods of diesel engines (JIS D0006-2)."
Other test items may be required in some applications. All test results should be evaluated comprehensively in order to determine the engine performance.

### 3.1 Engine equipment condition

The engine must be equipped with standard auxiliary devices such as cooling fan, air cleaner and alternator.

### 3.2 Test items and purposes

#### 3.2.1 Operation load test

Conduct this test to evaluate the engine output, torque, fuel consumption rate and governor performance under various load conditions.

#### 3.2.2 Continuous load test

Operate the engine continuously for 10 hours at 90% load (continuous load application) of nominal net brake power while the engine speed is maintained at revolutions corresponding to the nominal brake power. In this test, evaluate the fuel consumption rate and operating condition, and confirm that the engine is capable of continuous operation.

#### 3.2.3 Low idle test

Conduct this test to confirm that the engine can operate stably at the specified low idle speed.

### 3.3 Other inspections

Check for leakage of gases, coolant and oil; abnormal odors; and hunting. Make adjustment as needed.

### 3.4 Engine output adjustment

Diesel engine output is affected by atmospheric pressure, temperature and humidity. Therefore, correction calculations must be performed to obtain the value of engine output under the standard atmospheric conditions.

#### 3.4.1 Standard atmospheric conditions:

Base temperature: 298 K (25°C) [77°F]
Total pressure: 100 kPa (750 mmHg)
Dry pressure: 99 kPa [743 mmHg]

### 3.4.2 Calculation of corrected power

Multiply the measured brake power or torque by the calculated diesel engine correction factor to obtain a corrected value.

If the applicable range of the correction formula is exceeded, indicate the corrected values and record the test conditions on the test record.

**Colculation output = Correction factor ( $\alpha_c$) × Measured brake power**

- Atmospheric conditions during test

  Temperature($T$):283K(10°C) [50°F] ≦ $T$ ≦313K(40°C) [104°F]

  Dry atmospheric pressure($P_d$):80kPa (600mmHg) ≦ $P_d$ ≦ 110kPa (825mmHg)

  $\alpha_c=(f_a)^{f_m}$ $f_a$:Atmospheric factor $f_m$: Engine factor

- Range of correction equation use

  The range of correction factor( $\alpha_c$)is as follows:

  $0.9 \leqq \alpha_c \leqq 1.1$.

**Calculation of correction factor($f_a$)**

- Natural aspiration engine and engine with mechanically driven air charger

  $$f_a=\left(\frac{99}{P_d}\right)\cdot\left(\frac{T}{298}\right)^{0.7}$$

- Turbocharged engine without air cooler or with air-to-air cooler

  $$f_a=\left(\frac{99}{P_d}\right)^{0.7}\cdot\left(\frac{T}{298}\right)^{1.2}$$

- Turbocharged engine with air-to-liquid cooler

  $$f_a=\left(\frac{99}{P_d}\right)^{0.7}\cdot\left(\frac{T}{298}\right)^{0.7}$$

**Calculation of engine factor ($f_m$)**

$f_m=0.036q_c-1.14$

$q_c$:Corrected fuel supply volume

$$q_c=\frac{q}{r}$$

$$q=\frac{(z)\times(\text{Fuel flow rate g/s})}{(\text{Stroke volume } l)\times(\text{Engine speed min}^{-1})}$$

$z$=120000(4-cycle engine)

$r$:Ratio between pressure at turbocharger or air cooler outlet and atmospheric pressure ($r$=1 for natural aspiration engine)

- Applicable range of engine factor ($f_m$)

  $37.2 \leqq q_c \leqq 65$mg/($l$-cycle)

  · $q_c \leqq 37.2$mg/($l$-cycle) : $f_m$=0.2(constant)

  · 65mg/($l$-cycle) ≦ $q_c$ : $f_m$=1.2(constant)

# TROUBLESHOOTING

# 1. Electronic troubleshooting

## 1.1 System overview

This engine was designed for electronic control. The engine has an Electronic control module (ECM), a fuel pump and electronic unit injectors. All of these items are electronically controlled. There are also a number of engine sensors. 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.

The ECM is the computer. The personality module is the software for the computer. The personality module defines the following characteristics of the engine:

- Engine power
- Torque curves
- Engine speed ($min^{-1}$)
- Engine noise
- Smoke and Emissions

### 1.1.1 Engine speed governor

The ECM determines the injection timing, the amount of fuel that is delivered to the cylinders and the inlet manifold pressure. 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 speed/timing (crankshaft side) sensor and the speed/timing (fuel pump side) sensor. If the desired engine speed is greater than the actual engine speed, the governor injects more fuel in order to increase engine speed.

### 1.1.2 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 inlet manifold air temperature
- The sensor for the inlet manifold pressure
- Speed/timing (crankshaft, camshaft) sensors
- Throttle position sensor

At start-up, the ECM determines the top center position of the number 1 cylinder from the speed/timing (fuel pump side) sensor in the fuel 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 common rail. The ECM also provides the signal to the solenoid in the fuel pump. The solenoid in the fuel pump controls a valve in the fuel pump. This valve controls the pressure in the common rail. Fuel that is not required for the engine is diverted away from the fuel 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 Mitsubishi electronic technician (Mitsubishi ET). Also, the desired timing can be viewed with an Mitsubishi ET.

### 1.1.3 Fuel injection

The personality module inside the ECM sets certain limits on the amount of fuel that can be injected.

The Fuel Ratio Control Limit (FRC) is a limit that is based on inlet manifold air pressure and engine speed. 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 inlet manifold air pressure, the ECM increases the FRC Limit. A higher inlet 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 speed. 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 by the operator.

### 1.1.4 Diagnostic

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 occurs, the diagnostic code may indicate the cause of the problem. Use Mitsubishi ET to access the diagnostic codes. The problem should then be corrected.

### 1.1.5 Event

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.

### 1.1.6 Programmable parameters

Certain parameters that affect the engine operation may be changed with Mitsubishi ET. The parameters are stored in the ECM, and the parameters are protected from unauthorized changes by passwords. These parameters are system configuration parameters.

System configuration parameters are set at the factory. System configuration parameters affect emissions or power ratings within the engine. Factory passwords must be obtained and factory passwords must be used to change the system configuration parameters.

### 1.1.7 Passwords

System configuration parameters are protected by factory passwords. Factory passwords are calculated on a computer system that is available only to MHI 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.

## 1.2 Replacing the ECM

**⚠ CAUTION**

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.

**CAUTION**

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

Follow the troubleshooting procedures in this manual in order to be sure that replacing the ECM will correct the problem. Verify that the suspect ECM is the cause of the problem.

Note: Ensure that the ECM is receiving power and that the ECM is properly grounded before replacement of the ECM is attempted. The ECM contains no moving parts.

A test ECM can be used in order to determine if the ECM on the engine is faulty.

(1) Install a test ECM in place of the suspect ECM.
(2) Flash the personality module 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 problem, reconnect the suspect ECM.
(3) Verify that the problem returns.
(4) If the problem returns, replace the ECM.
(5) Use Mitsubishi ET to read the parameters in the suspect ECM.
(6) Record the parameters in the suspect ECM. The personality module can be flashed into the new ECM.
(7) After the ECM is installed on the engine, the parameters must be programmed into the new ECM.

Note: When a new 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 personality module interlock code 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.

**CAUTION**

If the personality module and engine application are not matched, engine damage may result.

Perform the following procedure in order to replace the ECM.

(1) Connect Mitsubishi ET to the diagnostic connector.
(2) Use the "Copy configuration ECM replacement" function from the Mitsubishi ET. If the "Copy configuration" is successful, proceed to (4). If the "Copy configuration" failed, proceed to (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 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 specified web site or product support.

(4) Remove power from the ECM.

(5) Remove the ECM.

(6) Install the replacement ECM.

(7) Download the Flash file.
Connect the electronic service tool to the diagnostic connector.
Select "WinFlash" from the "Utilities" menu of the Mitsubishi ET.
Select the appropriate file.

(8) If necessary, use the Mitsubishi ET to clear the rating interlock in the Personality module. To clear the rating interlock, enter the factory password when the Mitsubishi ET is first connected. Activating the "Test ECM" mode will also clear the rating interlock.

(9) Use the Mitsubishi ET to program the parameters. Perform the following procedure.
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. 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. Clear logged events if they are unnecessary.

## 1.3 Self-diagnostics

The ECM has the ability to detect problems with the electronic system and with engine operation. When a problem is detected, a code is generated. An alarm may also be generated. There are two types of codes:

- Diagnostic
- Event

### 1.3.1 Diagnostic code

When a problem with the electronic system is detected, the ECM generates a diagnostic code. This indicates the specific problem with the circuitry.

Diagnostic codes can have two different states:

- Active
- Logged

Active diagnostic code

An active diagnostic code indicates that an active problem 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.

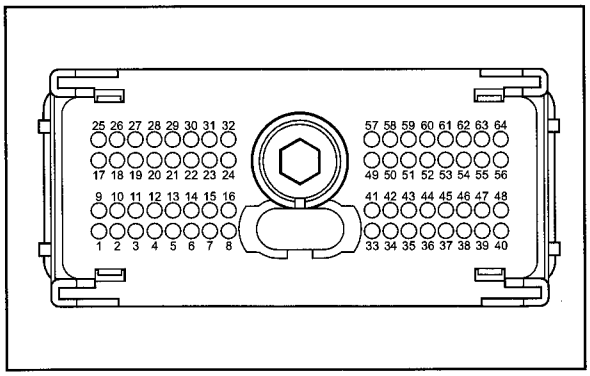
### 1.3.2 Event code

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 problem. Event code also have both "Active" and "Logged" states.

Logged codes may not indicate that a repair is needed. The problem may have been temporary. The problem 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 problems. Logged codes can also be used to review the performance of the engine and the electronic system.

## 1.4 ECM harness connector terminals

The ECM uses connectors that have 64 terminals to interface to the wiring harness.

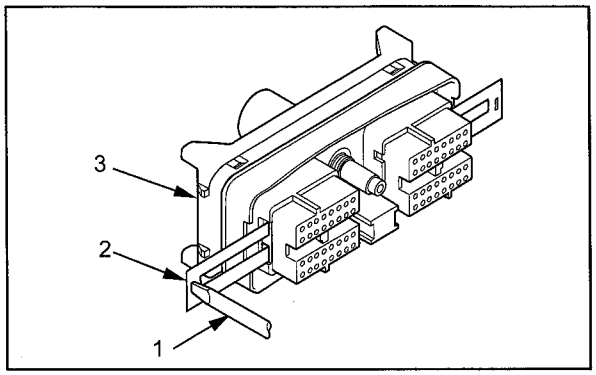



Layout of the connector pins (view from the rear)

### 1.4.1 Harness connector terminal removal

Table 14-1 Required tool

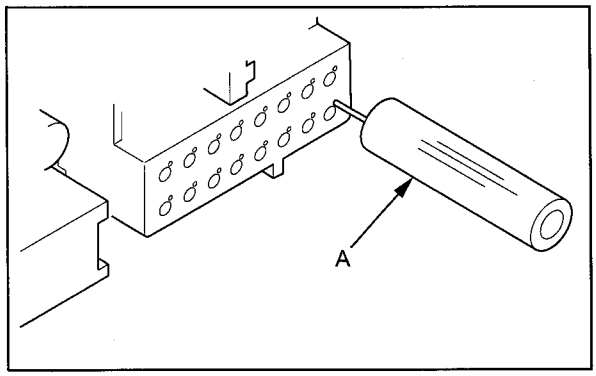
| Tool | Part number | Part description | Qty |
|---|---|---|---|
| A | 32E91-03100 | Extracting tool | 1 |




Removal of terminal position assurance components

(1) Remove the connector from the ECM.
(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 extracting tool (A) to remove the terminal position assurance components.




The extracting tool (A)

(3) Insert the extracting tool (A) 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 extracting tool (A) in position and gently pull the wire in order to remove the terminal from the rear of the connector.
(5) Remove the extracting tool (A) from the face of the connector.

### 1.4.2 Harness connector terminal insertion

(1) Push the terminal into the rear of the connector 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 into the sides of the connector.
(4) Connect the connector to the ECM.

# 2. Programming parameters

## 2.1 Programming parameters

Mitsubishi ET can be used to view certain parameters that can affect the operation of the engine. Mitsubishi ET can also be used to change certain parameters. The parameters are stored in the 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.

## 2.2 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 problem with the 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 fix the problem continue with this procedure.

(2) Use the "Copy configuration" feature on the Mitsubishi ET to copy the parameters from the suspect ECM.

Note: If the "ECM replacement" feature cannot be used, record the programmed values into the "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 Mitsubishi ET. Access the feature through the "Service" menu. Mitsubishi ET 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 Mitsubishi ET to program the test ECM.

Note: If the "ECM replacement" feature can not be used, program the test ECM with the values from the "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 fixes the problem.

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 key switch 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 fixes the problem, 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.

Table 14-2 Parameters worksheet

| | |
|---|---|
| Engine serial No. | |
| Full load setting | |
| Full torque setting | |
| No.1 Injector serial No. | |
| No.2 Injector serial No. | |
| No.3 Injector serial No. | |
| No.4 Injector serial No. | |

## 2.3 ECM snapshot

The ECM can record a snapshot of certain engine parameters. The snapshot records the parameters for a period of 13 seconds that surround an event. The following events trigger snapshots:

- Certain diagnostic codes
- Operator request

The ECM can store a maximum of two snapshots that are triggered by a diagnostic code. Two snapshots can be triggered manually. The snapshots are stored in a circular buffer. The newest snapshot will replace the oldest snapshot.

The ECM stores the snapshots in memory. Snapshots are maintained in the ECM until the snapshots are cleared. The following conditions will clear a snapshot:

- Operator request via the Mitsubishi ET.
- The snapshot has been stored for 100 hours of engine operation.

### 2.3.1 Snapshot that is triggered by a diagnostic code

When certain diagnostic codes occur, the ECM records many of the status parameters that are available on Mitsubishi ET. The ECM records this information for approximately nine seconds before the code occurs and approximately four seconds after the code occurs.

### 2.3.2 Snapshot that is triggered by the operator

A snapshot can be triggered by the operator by using the Mitsubishi ET.

On the Mitsubishi ET, the snapshot can be triggered from the "Snapshot recorder tool". Refer to the instructions on the screen or refer to the documentation for help on the system.

### 2.3.3 Use of snapshot data

Use snapshot data only to help determine engine operating conditions when an intermittent problem occurs. If an intermittent diagnostic code is causing problems, use the snapshot data. Snapshot data can be used to determine whether the problem occurs under specific circumstances. The following list contains examples of specific circumstances:

- Engine speed
- Range of coolant temperatures

Use the snapshot data in order to determine the operating conditions that were present during the event. Attempt to duplicate the conditions in order to get the code to recur.

Replacement of electronic components should not be based on snapshot data alone.

If too much emphasis is put on snapshot data, the result could be a misdiagnosed root cause. Also when snapshot data that is triggered by a diagnostic code is being viewed, the ECM sets a sensor value with an active diagnostic code to a default value when the code is active. This is the reason that the sensor value suddenly jumps to a specific value at the trigger point and the sensor value remains at the specific value for the rest of the snapshot frames.

## 2.4 Factory passwords

**CAUTION**

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 MHI dealer.

Factory passwords are required to perform each of the following functions:

- Program a new 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 the problem has been corrected. 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 Mitsubishi ET 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, Mitsubishi ET will request the factory passwords and Mitsubishi ET will display the information that is required to obtain the passwords. For the worksheet that is used for acquiring factory passwords, refer to "Factory passwords worksheet".

## 2.5 Factory passwords worksheet

Note: A mistake in recording these parameters will result in incorrect passwords.

Table 14-3 Factory passwords worksheet

| Factory passwords worksheet | |
|---|---|
| Dealer code | |
| Customer's name | |
| Address | |
| | |
| | |
| Telephone number | |
| Information from the engine information plate | |
| Engine serial number | |
| Full load setting | |
| Full torque setting | |
| Information from the diagnostic clock | |
| Miles, kilometers or hours (As applicable) | |
| Information from the "Factory password entry screen" on the caterpillar electronic technician (ET) | |
| Electronic service tool serial number | |
| Engine serial number | |
| ECM serial number | |
| Total tattletale | |
| Reason code | |
| From Interlock | |
| To interlock | |
| Factory passwords | |
| Factory password (No. 1) | |
| Factory password (No. 2) | |

Note: This parameter is required when the engine is being rerated.

This parameter is required when the engine is being rerated. This parameter is displayed only when the engine is being rerated.

## 2.6 Flash programming

Flash programming is a method of loading a flash file into the ECM.

The Mitsubishi ET 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.

### 2.6.1 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, download the new flash file from the specified website or contact product support. You must have the engine serial number in order to search for the flash file's part number.

(2) Connect Mitsubishi ET 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 Mitsubishi ET.

Note: If "Winflash" will not communicate with the ECM, refer to "Electronic service tool will not communicate with ECM".

(5) Flash program the flash file into the ECM.

Select the engine ECM under the "Detected ECMs".

Press the "Browse" button in order to select the part number of the flash file that will be programmed into the ECM.

When the correct flash file is selected, press the "Open" button.

Verify that the "File values" match the application. If the "File values" do not match the application, search for the correct flash file.

When the correct flash file is selected, press the "Begin flash" button.

Mitsubishi ET 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.

### 2.6.2 "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.

## 2.7 Injector trim file

The Mitsubishi ET is used to load the injector trim files into the ECM.

The injector trim files must be loaded into the ECM if any of the following conditions occur:

- An electronic unit injector is replaced.
- The ECM is replaced.
- Diagnostic code 0253-02 is active.
- Electronic unit injectors are exchanged between cylinders.

### Exchanging electronic unit injectors

Exchanging electronic unit injectors can help determine if a combustion problem 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 Mitsubishi ET. 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 for the electronic unit injector and the confirmation code number for the electronic unit injector for each electronic unit injector.
(2) Obtain the injector trim file by one of the following methods: Download from the specified wedsite. Contact product support.
(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 Mitsubishi ET to the service tool connector.
(6) Turn the keyswitch to the ON position.
(7) Select the menu options "Service", "Calibrations", "Injector code calibrations" on Mitsubishi ET.
(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 Mitsubishi ET 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.

# 3. System configuration parameters

## 3.1 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 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.

### 3.1.1 "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. The correct value for this parameter is stamped on the engine information ratings plate. If the ECM is replaced, the "full load setting" must be reprogrammed in order to prevent a diagnostic code "0253-02 Personality module mismatch" from becoming active.

### 3.1.2 "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 diagnostic code "0253-02 Personality module mismatch" from becoming active.

### 3.1.3 "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.
- The diagnostic code "0253-02 Personality module mismatch" 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.

### 3.1.4 "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 excluding first two digits"D0" and "-".

Example: D04FD-XXXXXX → 4FDXXXXXX

### 3.1.5 "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 (NOV05). NOV is the month (November). 05 is the year (2005).

# 4. Troubleshooting without diagnostic code

## 4.1 ECM will not accept factory passwords

### 4.1.1 Probable causes

One of the following items may not be recorded correctly on the Mitsubishi ET

- Passwords
- Serial numbers
- Total tattletale
- Reason code
- From interlock
- To interlock

### 4.1.2 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 Mitsubishi ET is on the "Factory password" screen.

(3) Use Mitsubishi ET to verify that the following information has been entered correctly.

- Engine serial number
- Serial number for the ECM
- Serial number for Mitsubishi ET
- Total tattletale
- Reason code
- From interlock
- To interlock

## 4.2 ECM will not communicate with other systems or display modules

### 4.2.1 Probable causes

- Electrical connectors
- Conventional data link
- ECM

### 4.2.2 Recommended actions

(1) Connect the Mitsubishi ET to the service tool connector. If the ECM does not communicate with Mitsubishi ET, refer to "Electronic service tool will not communicate with ECM".

(2) Ensure that the following items are correctly installed and undamaged. Refer to "Electrical connectors inspect".
P1/J1 and P2/J2 connectors on the ECM
Wiring to display modules
Wiring to other control modules

(3) Troubleshoot the Conventional data link for possible faults. Refer to Conventional data link circuit -test".

## 4.3 Electronic service tool will not communicate with ECM

### 4.3.1 Probable causes

- Configuration for the communications adapter
- Electrical connectors
- Communication adapter and/or cables
- Electrical power supply to the service tool connector
- Mitsubishi ET and related hardware
- Electrical power supply to the ECM
- Flash file
- Conventional Data Link

### 4.3.2 Recommended actions

Start the engine. If the engine starts, but the ECM will not communicate with Mitsubishi ET, continue with this procedure.

### 4.3.3 Configuration for the communications adapter

(1) Access "Preferences" under the "Utilities" menu on Mitsubishi ET.

(2) Verify that the correct "Communications interface device" is selected.

(3) Verify that the correct port is selected for use by the communication adapter.

(4) Check for any hardware that is utilizing the same port as the communication adapter. If any devices are configured to use the same port, exit or close the software programs for that device. But if you use USB-RS232 conversion cable between PC and communication adapter, both Mitsubishi ET and "Device driver" of Microsoft Windows must select same port number.

### 4.3.4 Electrical connectors

Check for correct installation of the P1/J1 and P2/J2 ECM connectors and of the service tool connector. Refer to "Electrical Connectors Inspect".

### 4.3.5 Communication adapter and/or cables

(1) If you are using a "Communication adapter II", ensure that the firmware and driver files for the communication adapter are the most current files that are available. If the firmware and driver files do not match, the communication adapter will not communicate with Mitsubishi ET.

(2) Disconnect the communication adapter and the cables from the service tool connector. Reconnect the communication adapter to the service tool connector.

(3) Verify that the correct cable is being used between the communication adapter and the service tool connector.

### 4.3.6 Electrical power supply to the service tool connector

Verify that battery voltage is present between terminals A and B of the service tool connector. If the communication adapter is not receiving power, the display on the communication adapter will be blank.

### 4.3.7 Mitsubishi ET and related hardware

In order to eliminate Mitsubishi ET and the related hardware as the problem, connect Mitsubishi ET to a different engine. If the same problem occurs on a different engine, check Mitsubishi ET and the related hardware in order to determine the cause of the problem.

### 4.3.8 Electrical power supply to the ECM

Check power to the ECM.

Note: If the ECM is not receiving battery voltage, the ECM will not communicate.

### 4.3.9 Flash file

Ensure that the correct flash file is properly installed in the ECM.

Note: The new ECM does not have a flash file. The engine will not start and the engine will not communicate with Mitsubishi ET until the flash file has been installed. Refer to "Flash programming".

### 4.3.10 Conventional data link

Troubleshoot the Conventional data link for possible problems. Refer to "Conventional data link circuit test".

# 5. Troubleshooting with a diagnostic code

## 5.1 Diagnostic code cross reference

Note: "Mitsubishi ET J1939 code" are codes which added "J" in the begginning of the J1939 code. These codes are indicated to the Mitsubishi ET screen.

Table 14-4 Diagnostic code cross reference (1 / 2)

| Mitsubishi ET J1939 code | Description | CDL code | 3rd party device J1939 code |
|---|---|---|---|
| N/A | No diagnostic code detected | N/A | N/A |
| J651-2 | Cylinder #1 Injector data incorrect | 0001-02 | 651-2 |
| J651-5 | Cylinder #1 Injector open circuit | 0001-05 | 651-5 |
| J651-6 | Cylinder #1 Injector short | 0001-06 | 651-6 |
| J651-7 | Cylinder #1 Injector not responding | 0001-07 | 651-7 |
| J652-2 | Cylinder #2 Injector data incorrect | 0002-02 | 652-2 |
| J652-5 | Cylinder #2 Injector open circuit | 0002-05 | 652-5 |
| J652-6 | Cylinder #2 Injector short | 0002-06 | 652-6 |
| J652-7 | Cylinder #2 Injector not responding | 0002-07 | 652-27 |
| J653-2 | Cylinder #3 Injector data incorrect | 0003-02 | 653-2 |
| J653-5 | Cylinder #3 Injector open circuit | 0003-05 | 653-5 |
| J653-6 | Cylinder #3 Injector short | 0003-06 | 653-6 |
| J653-7 | Cylinder #3 Injector not responding | 0003-07 | 653-7 |
| J654-2 | Cylinder #4 Injector data incorrect | 0004-02 | 654-2 |
| J654-5 | Cylinder #4 Injector open circuit | 0004-05 | 654-5 |
| J654-6 | Cylinder #4 Injector short | 0004-06 | 654-6 |
| J654-7 | Cylinder #4 Injector not responding | 0004-07 | 654-7 |
| J678-03 | 8 volt DC supply short to +batt | 0041-03 | 678-03 |
| J678-04 | 8 volt DC supply short to ground | 0041-04 | 678-04 |
| J91-03 | Accelerator pedal -voltage above normal | 0091-03 | 91-03 |
| J91-04 | Accelerator pedal -voltage below normal | 0091-04 | 91-04 |
| J91-08 | Throttle position signal abnormal | 0091-08 | 91-08 |
| J100-03 | Engine oil pressure open/short to +batt | 0100-03 | 100-03 |
| J100-04 | Engine oil pressure short to ground | 0100-04 | 100-04 |
| J100-10 | Engine oil pressure sensor abmormal rate of change | 0100-10 | 100-10 |
| J110-03 | Engine coolant temperature open/short to +batt | 0110-03 | 110-03 |
| J110-04 | Engine coolant temperature short to ground | 0110-04 | 110-04 |
| J168-00 | System voltage high | 0168-00 | 168-00 |
| J168-01 | System voltage low | 0168-01 | 168-01 |
| J168-02 | System voltage intermittent/erratic | 0168-02 | 168-02 |
| J105-03 | Intake manifold air temp open/short to +batt | 0172-03 | 105-03 |
| J105-04 | Intake manifold air temp short to ground | 0172-04 | 105-04 |
| J190-08 | Engine speed signal abnormal | 0190-08 | 190-08 |
| J639-9 | J1939 data link communications | 0247-09 | 639-9 |
| J631-02 | Personality module mismatch | 0253-02 | 631-02 |
| J637-11 | Speed/timing sensor offset fault | 0261-11 | 637-11 |

Table 14-4 Diagnostic code cross reference (2 / 2)

| Mitsubishi ET J1939 code | Description | CDL code | 3rd party device J1939 code |
|---|---|---|---|
| J1079-03 | 5 Volt sensor DC power supply short to +batt | 0262-03 | 1079-03 |
| J1079-04 | 5 Volt sensor DC power supply short to ground | 0262-04 | 1079-04 |
| J630-02 | Check programmable parameters | 0268-02 | 630-02 |
| J723-08 | Secondary engine speed signal abnormal | 0342-08 | 723-08 |
| J729-05 | IAH relay current low | 0617-05 | 729-05 |
| J729-06 | IAH relay current high | 0617-06 | 729-06 |
| J29-02 | Secondary throttle position sensor data erratic | 0774-02 | 29-02 |
| J29-03 | Secondary throttle position sensor open/short to +batt | 0774-03 | 29-03 |
| J29-04 | Secondary throttle position sensor short to ground | 0774-04 | 29-04 |
| J29-08 | Secondary throttle position sensor signal abnormal | 0774-08 | 29-08 |
| J2882-02 | Engine mode selection switch state incorrect | 1743-02 | 2882-02 |
| J1347-05 | Fuel pump solenoid open circuit | 1779-05 | 1347-05 |
| J1347-06 | Fuel pump solenoid short to ground | 1779-06 | 1347-06 |
| J1347-07 | Fuel pump solenoid not responding | 1779-07 | 1347-07 |
| J102-03 | Intake manifold pressure sensor voltage high | 1785-03 | 102-03 |
| J102-04 | Intake manifold pressure sensor voltage low | 1785-04 | 102-04 |
| J157-03 | Common rail pressure sensor open/short to +batt | 1797-03 | 157-03 |
| J157-04 | Common rail pressure sensor short to ground | 1797-04 | 157-04 |
| J158-02 | Ignition key switch loss of signal | 1834-02 | 158-02 |
| | Event codes | | |
| J94-15 | High fuel pressure filtered | E96 | 94-15 |
| J94-18 | Low fuel pressure filtered | E198 | 94-18 |
| J100-17 | Low oil pressure -warning | E360-1 | 100-17 |
| J100-01 | Low oil pressure -shutdown | E360-3 | 100-01 |
| J110-15 | High engine coolant temperature -warning | E361-1 | 110-15 |
| J110-16 | High engine coolant temperature -derate | E361-2 | 110-16 |
| J110-00 | High engine coolant temperature -shutdown | E361-3 | 110-00 |
| J190-15 | Engine overspeed | E362-1 | 190-15 |
| J95-15 | Fuel filter restriction -warning | E390-1 | 95-15 |
| J95-16 | Fuel filter restriction -derate | E390-2 | 95-16 |
| J157-00 | High fuel rail pressure | E396-1 | 157-00 |
| J157-01 | Low fuel rail pressure | E398-1 | 157-01 |
| J105-15 | High intake manifold air temperature -warning | E539-1 | 105-15 |
| J105-16 | High intake manifold air temperature -derate | E539-2 | 105-16 |

### 5.2 Injector data incorrect (code J65X-2)

The ECM detects the following condition:

- Data from the electronic unit injector is out of limits.
- Diagnostic code J168-01 is not active.
- Diagnostic codes J65X-5 and J65X-6 are not active for this injector.
- Diagnostic codes J678 are active.
- Diagnostic codes J1079 are active.
- Diagnostic code J190-08 is not active.
- Diagnostic codes J110 are active.

System response

An active diagnostic code will be generated. The ECM will log the diagnostic code. The ECM will trigger a snapshot.

Possible performance effect

The engine will be derated while this diagnostic code is active.

Troubleshooting

Perform the following diagnostic procedure "Injector data incorrect -test".

### 5.3 Injector open circuit (code J65X-5)

This diagnostic code is designed to indicate an open circuit (low current) in either the solenoid or the wiring for the electronic unit injector.

The 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 for 2 seconds.

System response

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. An open circuit in common wiring within the ECM can prevent the 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".

### 5.4 Injector short (code J65X-6)

This diagnostic code is designed to indicate a short circuit (high current) in either the solenoid or the wiring for the electronic unit injector.

The ECM detects the following conditions:

- A high current condition (short circuit) for each of five consecutive attempts to operate.
- Battery voltage above 9 volts for 2 seconds.

System response

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. A short circuit in common wiring within the ECM can prevent the 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".

### 5.5 Injector not responding (code J65X-7)

The electronic unit injector is no longer capable of delivering the correct amount of fuel.

System response

ECM will log the diagnostic code.

Possible performance effect

The engine will be derated.

Troubleshooting

Replace the suspect electronic unit injector.

Perform the "Fuel system verification test" on Mitsubishi ET.

### 5.6 8 volt DC supply short to +batt (code J678-03)

The ECM detects the following conditions:

- The 8 volt supply is more than 8.8 VDC for more than one second.
- The ECM has been powered for more than three seconds.
- Diagnostic code J168-01 is not active.

System response

The ECM will log the diagnostic code and the ECM will trigger a snapshot. An active diagnostic code may not cause any noticeable effect on engine response unless the voltage is above 12 or 13 VDC.

Possible performance effect

Note: The 8 volt supply provides power to the two speed/ timing sensors.

Troubleshooting

Perform the following diagnostic procedure "8 volt sensor supply circuit -test".

### 5.7 8 volt DC supply short to ground (code J678-04)

The ECM detects the following conditions:

- The 8 volt supply is less than 7.2 VDC for more than one second.
- The ECM has been powered for more than three seconds.
- Diagnostic code J168-01 is not active at the same time.

System response

The ECM will log the diagnostic code and the ECM will trigger a snapshot. An active diagnostic code may not cause any noticeable effect on engine response unless the voltage drops below 6.5 VDC.

Possible performance effect

Note: The 8 volt supply provides power to the two speed/ timing sensors.

Troubleshooting

Perform the following diagnostic procedure "8 volt sensor supply circuit -test".

### 5.8 Accelerator pedal -voltage above normal (code J91-03)

The ECM detects the following conditions:

- ECM has been powered for at least 3 seconds.
- A signal voltage for the throttle position is greater than 4.5 VDC.
- The power supply for the throttle sensor is within the expected range.
- Diagnostic code J168-01 is not active at the same time.

System response

The ECM will trigger a snapshot. The ECM logs the diagnostic code if the engine is running. The diagnostic codes can be viewed on Mitsubishi ET. The ECM will return the engine to 1500 $min^{-1}$.

Possible performance effect

- Low power
- Reduced engine speed

Troubleshooting

Perform the following diagnostic procedure "Analog throttle position sensor circuit -test".

### 5.9 Accelerator pedal -voltage below normal (code J91-04)

The 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 less than 0.5 VDC.
- The power supply for the throttle sensor is within the expected range.
- Diagnostic code J168-01 is not active.

System response

The ECM will trigger a snapshot. The ECM logs the diagnostic code if the engine is running. The diagnostic codes can be viewed on Mitsubishi ET. The ECM will return the engine to 1500 $min^{-1}$.

Possible performance effect

- Low power
- Reduced engine speed

Troubleshooting

Perform the following diagnostic procedure "Analog throttle position sensor circuit -test".

### 5.10 Throttle position signal abnormal (code J91-08)

The 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 J91-03 is not active.
- Diagnostic code J91-04 is not active.
- Diagnostic codes for the 8 volt sensor supplies are not active.

System response

The ECM sets the "Throttle position" to "0%". "DIAG" will be displayed next to the status for "Throttle position" on the Mitsubishi ET.

The ECM will trigger a snapshot. 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

The engine will remain at 1500 $min^{-1}$ while the diagnostic code is active.

Troubleshooting

This diagnostic code indicates that the frequency of a digital throttle signal is out of the normal range.

Perform the following diagnostic procedure "Analog throttle position sensor circuit -test".

### 5.11 Engine oil pressure open/short to +batt (code J100-03)

The ECM detects the following conditions:

- The signal voltage from the engine oil pressure sensor is greater than 4.95 VDC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code J168-01 is not active.
- Diagnostic code J1079-03 is not active.
- Diagnostic code J1079-04 is not active.

System response

The ECM will log the diagnostic code and the ECM will trigger a snapshot. The ECM will set data for engine oil pressure to the default value.

Note: The engine oil pressure that is displayed on the Mitsubishi ET is the default value for engine oil pressure. The default engine oil pressure is 600 kPa {6.1 kgf/cm²} [86.7 psi]. The Mitsubishi ET will display "Voltoltage above normal" on the status screens.

Possible performance effect

None

Troubleshooting

This 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".

### 5.12 Engine oil pressure short to ground (code J100-04)

The ECM detects the following conditions:

- The signal voltage from the engine oil pressure sensor is less than 0.1 VDC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code J168-01 is not active.
- Diagnostic code J1079-03 is not active.
- Diagnostic code J1079-04 is not active.

System response

The ECM will log the diagnostic code and the ECM will trigger a snapshot. The ECM will set data for engine oil pressure to the default value. The Mitsubishi ET 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".

### 5.13 Engine oil pressure sensor abnormal rate of change (code J100-10)

The ECM detects the following conditions:

- No other codes for the oil pressure sensor are active.
- No J1079 diagnostic codes are active for the 5 volt supply.
- Diagnostic code J168-01 is not active.
- The engine oil pressure signal is within the expected range for this failure mode.
- The engine oil pressure signal remains constant for 30 seconds.

System response

The ECM will log the diagnostic code. The diagnostic code can be viewed on the Mitsubishi ET.

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 {6.0 kgf/cm²} [72.5 psi].

The Mitsubishi ET will display "Conditions not met" on the status screen.

Possible performance effect:

None

Troubleshooting:

This diagnostic code is designed to detect the loss of the 5 volt supply to the sensor. This fault can be caused by a disconnected plug or a harness that has an open circuit.

Perform the following diagnostic procedure: "Engine pressure sensor open or short circuit -test".

### 5.14 Engine coolant temperature open/short to +batt (code J110-03)

The ECM detects the following conditions:

- The signal voltage from the engine coolant temperature sensor is greater than 4.95 VDC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code J168-01 is not active.

System response:

An active diagnostic code will be generated after 8 seconds. The diagnostic code will be logged if the engine has been operating for more than 7 minutes. The ECM will trigger a snapshot when the code is logged.

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 Mitsubishi ET.

Possible performance effect:

None

Troubleshooting:

Perform the following diagnostic procedure: "Engine temperature sensor open or short circuit -test".

### 5.15 Engine coolant temperature short to ground (code J110-04)

The ECM detects the following conditions:

- The signal voltage from the engine coolant temperature sensor is less than 0.2 VDC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code J168-01 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 Mitsubishi ET.

If equipped, the warning light will come on after 10 hours. An active diagnostic code will be generated after 8 seconds. The diagnostic code will be logged if the engine has been operating for more than 7 minutes. When the diagnostic code is logged, the ECM will trigger a snapshot.

Possible performance effect:

None

Troubleshooting:

Perform the following diagnostic procedure: "Engine temperature sensor open or short circuit -test".

### 5.16 System voltage high (code J168-00)

This condition indicates that the battery circuit to the ECM has excessive voltage while the engine is running.

The ECM detects the following conditions:

- The battery voltage to the ECM exceeds 32 V 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.

Possible performance effect:

None

Troubleshooting:

Perform the following diagnostic procedure: "Ignition keyswitch circuit and battery supply circuit -test".

### 5.17 System voltage low (code J168-01)

This code indicates that the battery circuit for the ECM has low voltage while the engine is running. If battery voltage disappears without returning, the ECM will not log this diagnostic code and the engine will shut down.

The ECM detects the following conditions:

- The keyswitch is in the ON mode.
- The engine is not cranking.
- The engine is running for more than three seconds.
- Battery voltage to the ECM is below 9 V for more than 0.5 seconds.

System response:

The ECM will log the diagnostic code and the ECM will trigger a snapshot. The engine will derate 100 percent.

Possible performance effect:

The engine may experience changes in the engine speed, and intermittent engine shutdowns or complete engine shutdowns while the conditions that cause this diagnostic code are present.

Troubleshooting:

Perform the following diagnostic procedure: "Ignition keyswitch circuit and battery supply circuit -test".

### 5.18 System voltage intermittent/erratic (code J168-02)

This condition indicates that the battery circuit for the ECM is intermittent while the engine is running. If battery voltage disappears without returning, the ECM will not log this diagnostic code and the engine will shut down.

The ECM detects the following conditions:

- Three voltage readings that are below 6 VDC in a period of 7 seconds will be detected by the ECM. The voltage must subsequently increase to more than 9 VDC.
- The keyswitch is in the ON position.
- The engine is running.
- The engine is not cranking.

System response:

The ECM may stop injecting fuel. This may be dependent on the length of time of the occurrence of the fault.

Possible performance effect:

The engine may experience changes in the engine speed, and intermittent engine shutdowns or complete engine shutdowns while the conditions that cause this diagnostic code are present.

Troubleshooting:

Perform the following diagnostic procedure: "Ignition keyswitch circuit and battery supply circuit -test".

### 5.19 Inlet manifold air temp open/short to +batt (code J105-03)

The ECM detects the following conditions:

- The signal voltage from the inlet manifold air temperature sensor is greater than 4.95 VDC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code J168-01 is not active.

System response:

The ECM will use the default value of 70 °C(158°F) for the inlet manifold air temperature. "Voltage high" will be displayed next to the status for "Inlet manifold air temperature" on Mitsubishi ET.
The ECM will log the diagnostic code and the ECM will trigger a snapshot.
Possible performance effect:
None
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".

### 5.20 Inlet manifold air temp short to ground (code J105-04)

The ECM detects the following conditions:
- The signal voltage from the inlet manifold air temperature sensor is less than 0.2 VDC for more than eight seconds.
- The ECM has been powered for at least two seconds.
- Diagnostic code J168-01 is not active.

System response:
The ECM will use the default value of 70 °C (158°F) for the inlet manifold air temperature. "Voltage low" will be displayed next to the status for "Inlet manifold air temperature" on Mitsubishi ET.
The ECM will log the diagnostic code and the ECM will trigger a snapshot.
Possible performance effect:
None
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".

### 5.21 Engine speed signal abnormal (code J190-08)

The ECM detects the following conditions:
- The ECM detected an intermittent loss of signal or a complete loss of signal from the speed/timing (crankshaft side) sensor for 2 seconds.
- The engine has been running for more than three seconds.
- Diagnostic code J168-01 is not active.
- Diagnostic code J678-03 or J678-04 is not active.

System response:
The ECM will trigger a snapshot and the diagnostic code will be logged.
The ECM will use the signal from the speed/timing (fuel pump side) sensor.
Possible performance effect:
The engine will be derated. If the signal from the speed/timing (fuel pump side) sensor is also lost, the engine will shut down.
Troubleshooting:
Perform the following diagnostic procedure: "Engine speed/timing sensor circuit -test".

### 5.22 J1939 data link communications (code J639-09)

The ECM detects the following condition:
- Another controller has stopped transmitting a J1939 speed request (TSC1) incorrectly.

System response:
Some system functions may not operate correctly.
Troubleshooting:
Perform the following diagnostic procedure: "CAN data link circuit -test".

### 5.23 Personality module mismatch (code J631-02)

The ECM detects incorrect engine software.
System response:
This diagnostic code is not logged. Factory passwords are required to clear this diagnostic code.
Possible performance effect:
The engine may not start.
Troubleshooting:
The flash file in the ECM is from the wrong engine family.
Perform the following diagnostic procedure: "ECM memory -test".

### 5.24 Speed/timing sensor offset fault (code J637-11)

The ECM detects the following conditions:
- The speed/timing (crankshaft side) sensor and the speed/timing (fuel pump side) sensor are off by more than 8 degrees.
- The engine has been running for more than five seconds.
- Diagnostic code J190-08 is not active.
- Diagnostic codes J678 are active.

System response:
Default timing is used. This code will not be logged.
Possible performance effect:
The engine may not run smoothly when this code is active.
Troubleshooting:
Perform the following diagnostic procedure: "Engine speed/timing sensor circuit -test".

### 5.25 5 volt sensor DC power supply short to +batt (code J1079-03)

The ECM detects the following conditions:

- The 5 volt supply is greater than 5.16 VDC for more than one second.
- The ECM has been powered for at least three seconds.
- Diagnostic code J168-01 is not active.

System response:

The ECM sets all of the pressure sensors and temperature sensors to the default values.

The ECM will use the default torque map.

Possible performance effect:

The engine may experience low power when this diagnostic code is active.

Troubleshooting:

Perform the following diagnostic procedure: "5 volt sensor supply circuit -test".

### 5.26 5 volt sensor DC power supply short to ground (code J1079-04)

The ECM detects the following conditions:

- The 5 volt supply is less than 4.84 VDC for more than one second.
- The ECM has been powered for at least three seconds.
- Diagnostic code J168-01 is not active.

System response:

The ECM sets all of the pressure sensors and temperature sensors to the default values.

The ECM will use the default torque map. "Sensor power supply unavailable" will be displayed next to the status for all of the pressure sensors on the Mitsubishi ET.

Possible performance effect:

The engine may experience low power when this diagnostic code is active.

Troubleshooting:

Perform the following diagnostic procedure: "5 volt sensor supply circuit -test".

### 5.27 Check programmable parameters (code J630-02)

The ECM detects one or more of the following conditions:

- One or more of the configuration parameters are not programmed. The effect on the ECM depends on the parameter.
- The rating interlock code of the current flash file does not match the rating interlock code that is stored in the ECM memory. Engine speed is limited to low idle.
- At least two programmable inputs are programmed to the same input terminal or at least two programmable outputs are programmed to the same output terminal. Engine speed is limited to low idle.
- All of the injector trim files are not loaded into the ECM. Engine performance and emissions are affected.

System response:

Note: The fault is not logged.

The Mitsubishi ET will display a list of the condition(s) 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 Mitsubishi ET to correct parameters that have not been programmed or parameters that have been incorrectly programmed.

If the diagnostic code was caused by a mismatch in the rating interlock code, a factory password must be obtained. Alternatively, the correct flash file must be flashed into the ECM in order to clear the diagnostic code.

### 5.28 Fuel pump side engine speed signal abnormal (code J723-08)

The ECM detects the following conditions:

- The signal from the speed/timing (fuel pump side) sensor is lost and/or intermittent.
- The signal from the speed/timing (fuel pump side) sensor was lost for at least 2 seconds while the signal from the speed/timing (crankshaft side) sensor remained valid and the engine was running.
- Diagnostic code J168-01 is not active.
- The engine has been running for more than 3 seconds.
- Diagnostic codes J678 are active.

System response:

The code is logged and the ECM triggers a snapshot.

Possible performance effect:

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. The engine will not restart if the signal from the speed/timing (fuel pump side) sensor is lost.

Troubleshooting:

Perform the following diagnostic procedure: "Engine speed/timing sensor circuit -test".

### 5.29 Engine mode selection switch state incorrect (code J2882-02)

The 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.
Possible performance effect:
The engine will start but the engine will run at reduced speed.

### 5.30 Fuel pump solenoid open circuit (code J1347-05)

This diagnostic code indicates that the ECM has detected an open circuit or low current condition in the solenoid for the common rail.
System response:
The ECM will trigger a snapshot. The ECM will log the diagnostic code.
Possible performance effect:
An electrical fault may prevent the provision of pressure to the common rail. This may result in the loss of fuel injection. If the solenoid for the fuel pump fails, it is likely that fuel will not be pumped into the common rail. The engine will stop or the engine will not start.
Troubleshooting:
Perform the following diagnostic procedure: "Fuel pump solenoid -test".

### 5.31 Fuel pump solenoid short to ground (code J1347-06)

This diagnostic code indicates that the ECM has detected a short circuit or high current condition in the solenoid for the common rail.
System response:
The ECM will trigger a snapshot. The ECM will log the diagnostic code.
Possible performance effect:
An electrical fault may prevent the provision of pressure to the common rail. This may result in the loss of fuel injection. If the solenoid for the fuel pump fails, it is likely that fuel will not be pumped into the common rail. The engine will stop or the engine will not start.
Troubleshooting:
Perform the following diagnostic procedure: "Fuel pump solenoid -test".

### 5.32 Inlet manifold pressure sensor voltage high (code J102-03)

The ECM detects the following conditions:
- The ECM has been powered for two seconds.
- The signal voltage from the inlet manifold pressure sensor is above 4.95 VDC for at least two seconds.
- Diagnostic code J168-01 is not active.
- Diagnostic codes J1079 for the 5 volt supply are not active.

System response:
The ECM will log the diagnostic code. The ECM will trigger a snapshot. The data for the inlet manifold pressure will be set to a default value 100 kPa {1.0 kgf/cm²} [14.2 psi] .
Possible performance effect:
- Low power.
- Reduced engine speed.

Troubleshooting:
This 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".

### 5.33 Inlet manifold pressure sensor voltage low (code J102-04)

The ECM detects the following conditions:
- The signal voltage from the inlet manifold pressure sensor is less then 0.2 VDC for at least two seconds.
- The ECM has been powered for two seconds.
- Diagnostic code J168-01 is not active.
- Diagnostic codes J1079 for the 5 volt supply are not active.
- The keyswitch is in the ON position so that the ECM is energized.

System response:
The ECM will log the diagnostic code. The ECM will trigger a snapshot. The data for the inlet manifold pressure will be set to a maximum valid pressure for two seconds. The ECM will then flag the inlet manifold pressure as being invalid. A default value is then used for the inlet manifold pressure.
Possible performance effect:
- Low power.
- Reduced engine speed.

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".

### 5.34 Common rail pressure sensor open/short to +batt (code J157-03)

The ECM detects the following conditions:
- Diagnostic codes J1079 for the 5 volt supply are not active.
- Diagnostic code J168-01 is not active.

- The signal voltage for the pressure in the common rail is more than 4.8 V for 0.6 seconds.

System response:

The ECM will log the diagnostic code. The ECM will trigger a snapshot. The Mitsubishi ET will display "Voltage above normal" next to "Desired common rail pressure" and "Actual common rail pressure" on the status screens. A default value 70 MPa (980 psi) is used for the pressure in the common rail.

Possible performance effect:

The engine will be derated.

Troubleshooting:

This code can be caused by a loss of reference ground, an open signal wire or a short to a voltage source.

Perform the following diagnostic procedure: "Engine pressure sensor open or short circuit -test".

### 5.35 Common rail pressure sensor short to ground (code J157-04)

The ECM detects the following conditions:

- Diagnostic codes J1079 for the 5 volt supply are not active.
- Diagnostic code J168-01 is not active.
- The signal voltage for the pressure in the common rail is less than 0.2 V for 0.6 seconds.

System response:

The ECM will log the diagnostic code. The ECM will trigger a snapshot. The Mitsubishi ET will display "Voltage below normal" next to "Desired common rail pressure" and "Actual common rail pressure" on the status screens. A default value is used for the pressure in the common rail.

Possible performance effect:

The engine will be derated.

Troubleshooting:

This code can be caused by a loss of the 5 V supply or a short to ground on the signal wire.

Perform the following diagnostic procedure: "Engine pressure sensor open or short circuit -test".

### 5.36 Ignition key switch loss of signal (code J158-02)

The ECM detects the following condition:

- The signal from the keyswitch was rapidly cycled at least three times within the last second.
- Diagnostic code J168-01 is not active.

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:

The ECM will log the diagnostic code and the ECM will trigger a snapshot. The ECM will stop energizing the injector solenoids and the engine will shut down.

Possible performance effect:

Engine shutdown.

Troubleshooting:

Perform the following diagnostic procedure: "Ignition keyswitch circuit and battery supply circuit -test".

# 6. Troubleshooting with an event code

## 6.1 Outline of 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 fault 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.

## 6.2 Low engine oil pressure (code J100-01, 17)

The ECM detects a fault with the engine's oil pressure. The ECM detects the following faults:

- The engine has been running for more than ten seconds.
- The low oil pressure trip is below the trip levels for the event code. Refer to table for a list of low oil pressure trip levels.
- Diagnostic code J100-03 Engine oil pressure open/short to +batt is not active.
- Diagnostic code J100-04 Engine oil pressure short to ground is not active.

Note: This event code represents an event. This does not represent an electronic system fault.

Table 14-5 Low oil pressure trip level

| | J100-17 | | J100-01 | |
|---|---|---|---|---|
| | $min^{-1}$ | kPa Gauge | $min^{-1}$ | kPa Gauge |
| Trip level | 0 | 0 | 0 | 0 |
| | 500 | 0 | 500 | 0 |
| | 1600 | 154 kPa {1.6 kgf/cm²} [22 psi] | 1600 | 104 kPa {1.1 kgf/cm²} [15 psi] |
| | 2400 | 154 kPa {1.6 kgf/cm²} [22 psi] | 2400 | 104 kPa {1.1 kgf/cm²} [15 psi] |
| Power derating rate | N/A | | 100% (Reduced 50% of rated power) | |
| Delay to activation | 8 seconds | | | |
| Delay after engine start | 10 seconds | | | |

System response:

The event code will be logged.

Possible performance effect:

J100-17

None

J100-01

A snapshot will be triggered. The ECM will derate the power.

## 6.3 High engine coolant temperature (code J110-00, 15, 16)

The ECM detects a fault with the engine's coolant temperature. The ECM detects the following faults:

- The engine has been running for more than 185 seconds.
- The engine coolant temperature trip level for the event code is reached.
- Diagnostic code J110-03 Engine coolant temperature open/short to +batt is not active.
- Diagnostic code J110-04 Engine coolant temperature short to ground is not active.

Table 14-6 Engine coolant trip level table

| | Engine coolant trip level | |
|---|---|---|
| - | J110-15 | J110-16 |
| Trip level | 107 °C [225 °F] | 108°C [226°F] |
| Power deratinbg rate | N/A | 25% (Reduced 12.5% of rated power) |
| Delay to activation | 10 seconds | |
| Delay after engine start | 185 seconds | |

System response:

The event code will be logged.

A snapshot will be triggered.

Possible performance effect:

J110-15

None

J110-16

The ECM will derate the power. The power will be derated at one percent per second. Refer to table for a list of derates.

### 6.4 Engine overspeed (code J190-15)

The engine speed is above 2600 $min^{-1}$ for more than 0.6 seconds.

Note: This event code represents an event. This does not represent an electronic system fault.

System response:

The event code will be logged. A snapshot will be triggered.

The event may be viewed by using a display module.

The ECM will reset the engine speed when the engine speed is lower than 2400 $min^{-1}$ for 0.6 seconds.

The fuel injection will be switched OFF.

Possible performance effect:

J190-15

None

### 6.5 High common rail pressure (code J157-00)

The ECM detects excessive common rail pressure. The ECM detects the following faults:

- The ECM detects common rail pressure that is more than normal operating conditions.
- Diagnostic code J168-01 System voltage low is not active.
- Diagnostic codes J1079 for the 5 volt supply are not active.
- Diagnostic codes J651 to J654 for the injector are not active.
- Diagnostic codes J1347 for the fuel pump solenoid are not active.
- Diagnostic codes J157 for the common rail pressure sensor are not active.

System response:

The event code will be logged. A snapshot will be triggered.

Possible performance effect:

J157-00

The ECM will derate the power 100%.

### 6.6 Low common rail pressure (code J157-01)

The ECM detects a fault with low common rail pressure. The ECM detects the following faults:

- The ECM determines that the expected common rail pressure cannot be achieved by the electronic control system.
- Diagnostic code J168-01 System voltage Low is not active.
- Diagnostic codes J1079 for the 5 volt supply are not active.
- Diagnostic codes J651 to J654 for the injector are not active.
- Diagnostic codes J1347 for the Fuel pump solenoid are not active.
- Diagnostic codes J157 for the Common rail pressure sensor are not active.

System response:

The event code will be logged. A snapshot will be triggered.

Possible performance effect:

J157-01

The ECM will derate the power 100%.

### 6.7 High inlet manifold air temperature (code J105-15, 16)

The ECM detects a fault with the inlet manifold air temperature. The ECM detects the following faults:

- The engine has been running for more than 3 minutes.
- The coolant temperature must be greater than 99C.
- The inlet manifold air temperature trip level for the event code is reached.
- Diagnostic codes J105 for the Inlet manifold air temperature sensor are not active.

Table 14-7 Inlet manifold air temp. trip level table

| Inlet manifold air temperature trip level | | |
|---|---|---|
| | J105-15 | J105-16 |
| Trip level | 83°C [181 °F] | 87°C [189°F] |
| Power deratinbg rate | N/A | 50% (Reduced 25% of rated power) |
| Delay to activation | 8 seconds | |
| Delay after engine start | 180 seconds | |

System response:

The event code will be logged.

A snapshot will be triggered.

Possible performance effect:

J105-15

None

J105-16

The ECM will derate the power. The power will be derated at one percent per second.

# 7. Diagnostic functional tests

## 7.1 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:

- J1079-03 5 volt sensor DC power supply, short to +battery
- J1079-04 5 volt sensor DC power supply, short to ground

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 ECM supplies regulated +5 VDC to the following sensors:

- Common rail pressure sensor
- Inlet manifold pressure sensor
- Engine oil pressure sensor
- Analog throttle position sensors

The supply for the +5 V engine pressure sensor is routed from the ECM through the P2 connector to terminal 1 of each pressure sensor connector. The supply voltage is 5.0 ± 0.16 VDC. The +5 V supply to the analog throttle position sensor is routed from the ECM through the P1 connector to the sensor pins "A".

The +5 V 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 or an open circuit in the harness
- A suspect sensor
- A suspect ECM

Table 14-8 P2 pin connections

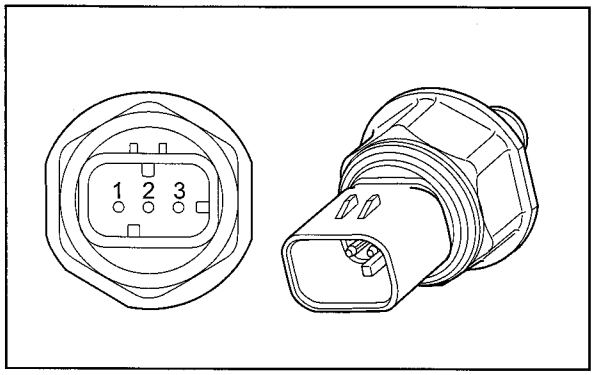
| Sensor pin | Function | Common rail pressure sensor | Inlet manifold pressure sensor | Oil pressure sensor |
|---|---|---|---|---|
| 1 | Volts (5 V) | 48 | 46 | 47 |
| 2 | Common | 40 | 38 | 39 |
| 3 | Signal | 51 | 55 | 56 |

Table 14-9 Extension harness connector pin connections

| Sensor pin | Function | Common rail pressure sensor | Inlet manifold pressure sensor | Oil pressure sensor |
|---|---|---|---|---|
| 1 | Volts (5 V) | 27 | 25 | 26 |
| 2 | Common | 19 | 17 | 18 |
| 3 | Signal | 30 | 35 | 36 |

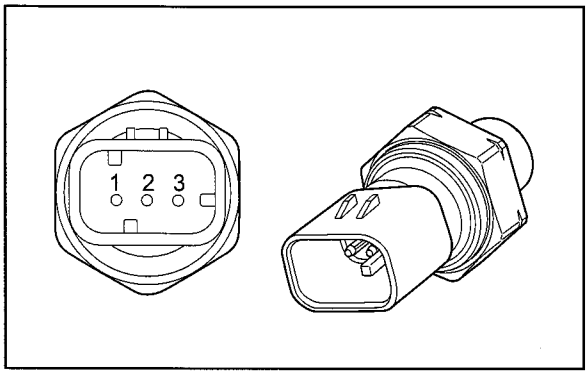
Table 14-10 P1 connector

| Sensor pin | Function | Throttle 1 |
|---|---|---|
| A | + 5V | 42 |
| B | Ground | 34 |
| C | Signal | 54 |




Typical example of the common rail pressure sensor

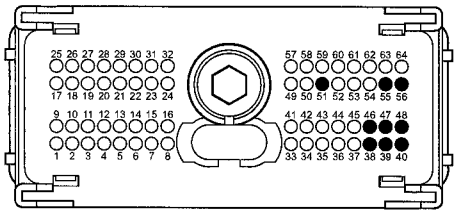
1 Voltage supply (Vs) 2 Ground (GND) 3 Signal (SIG)




Typical example of the inlet manifold and oil pressure sensors

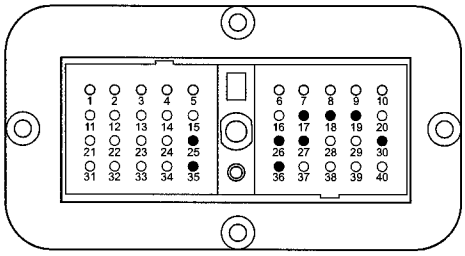
1 Voltage supply (Vs) 2 Ground (GND) 3 Signal (SIG)

P2 ECM connector



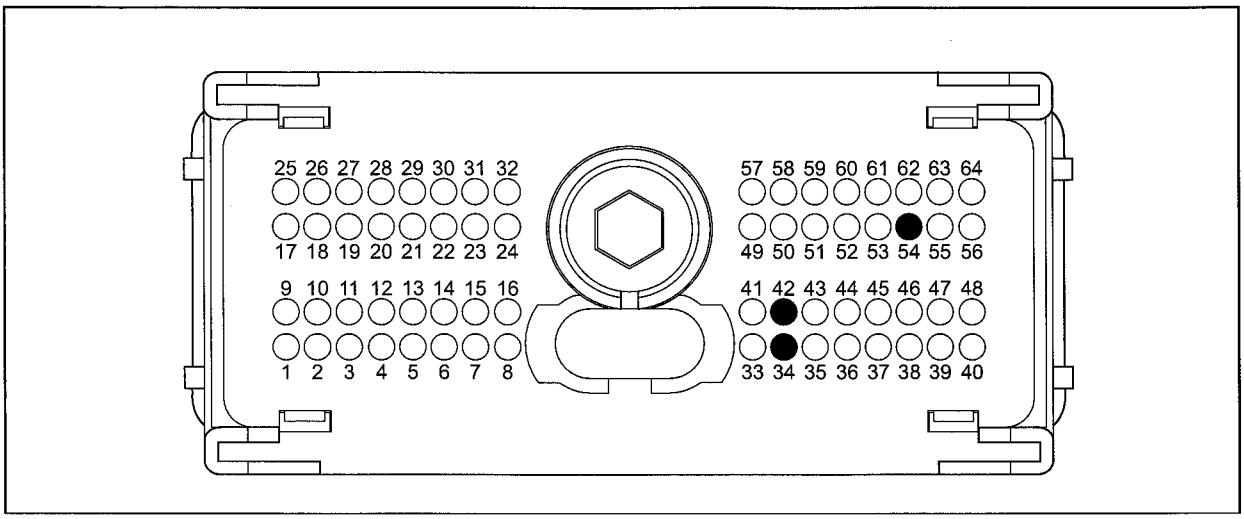

| | |
|---|---|
| 38 | Ground (GND) inlet manifold pressure sensor |
| 39 | Ground (GND) oil pressure sensor |
| 40 | Ground (GND) common rail pressure sensor |
| 46 | Voltage supply (5V) inlet manifold pressure sensor |
| 47 | Voltage supply (5V) oil pressure sensor |
| 48 | Voltage supply (5V) common rail pressure sensor |
| 51 | Signal (SIG) common rail pressure sensor |
| 55 | Signal (SIG) inlet manifold pressure sensor |
| 56 | Signal (SIG) oil pressure sensor |

Extension harness connector



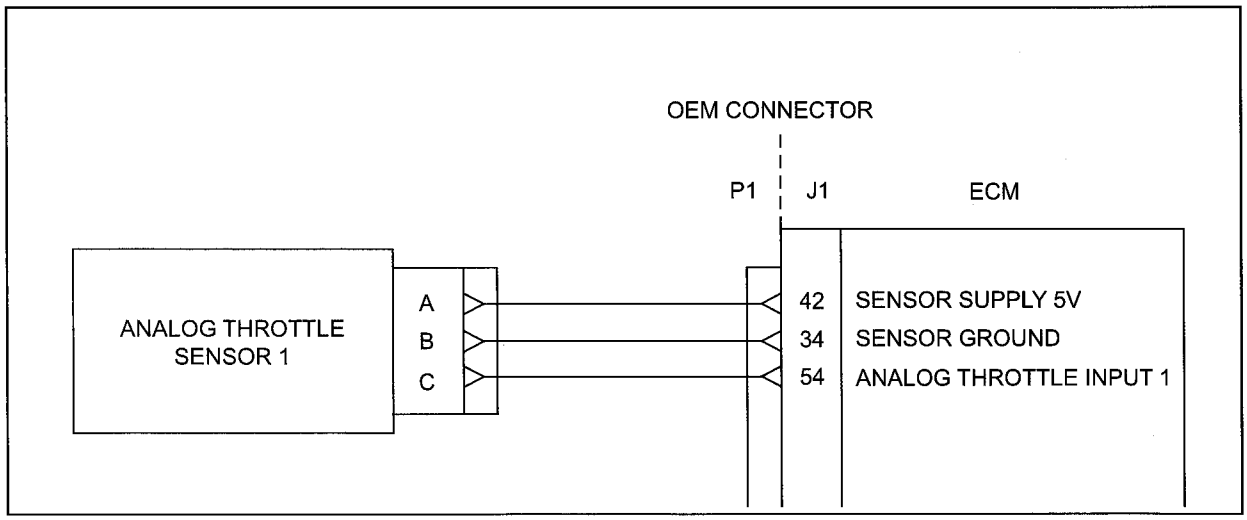

| | |
|---|---|
| 17 | Ground (GND) inlet manifold pressure sensor |
| 18 | Ground (GND) oil pressure sensor |
| 19 | Ground (GND) common rail pressure sensor |
| 25 | Voltage supply (5V) inlet manifold pressure sensor |
| 26 | Voltage supply (5V) oil pressure sensor |
| 27 | Voltage supply (5V) common rail pressure sensor |
| 30 | Signal (SIG) common rail pressure sensor |
| 35 | Signal (SIG) inlet manifold pressure sensor |
| 36 | Signal (SIG) oil pressure sensor |

Pressure sensor pin locations




Typical example of the P1 pin locations for the analog throttle position sensor

34 Analog throttle ground (GND) 42 Analog throttle voltage supply 54 Analog throttle throttle position




Typical example of the schematic for the P1 connector for the analog throttle position sensor

### 7.1.1 Test step 1. Check for connector damage

(1) Turn the keyswitch to the OFF position.

(2) Check the connectors and the harness for the following problems:
Damage
Abrasion
Corrosion
Incorrect attachment

(3) Refer to "Electrical connectors -inspect".

(4) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the harness. Check the wire connectors at the following positions:
ECM
Extension harness connector
Pressure sensors
Throttle pedal
The wire connectors are shown in tables.

(5) Check the screws for the ECM connectors for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].

Expected result:

The connectors and the harness should be free of the following faults:

- Damage
- Abrasion
- Corrosion
- 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.

Verify that the repair eliminates the fault.

### 7.1.2 Test step 2. Check for active diagnostic codes

(1) Connect the Mitsubishi ET to the diagnostic connector.

(2) Turn the keyswitch to the ON position.

(3) Use the Mitsubishi ET 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:

- J1079-03 5 volt sensor DC power supply short to +batt
- J1079-04 5 volt sensor DC power supply short to ground

Results:

- OK – Diagnostic code J1079-04 is active. Proceed to Test step 3.
- OK – Diagnostic code J1079-03 is active. Proceed to Test step 7.
- Not OK – Diagnostic codes J1079-04 and J1079-03 are not active. Proceed to Test step 4.

### 7.1.3 Test step 3. Disconnect the sensors

(1) Turn the keyswitch to the ON position.

(2) Use the Mitsubishi ET in order to monitor the diagnostic codes.

(3) Disconnect the pressure sensors and throttle position sensor one at a time. Wait for 30 seconds after each of the sensors is disconnected.

Note: The 5 volt diagnostic code will become in active when the sensor that caused the 5 volt diagnostic code is disconnected.

(4) Ensure that all the pressure sensors and the throttle position sensors 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 – The 5 volt diagnostic code is still active.

Repair: Leave all of the sensors disconnected. Proceed to Test step 5.

### 7.1.4 Test step 4. Install a new sensor

(1) Remove the suspect sensor and connect a replacement sensor. Do not install the replacement sensor to the engine.

(2) Use the Mitsubishi ET in order to monitor the diagnostic codes.

Expected result:

The 5 volt diagnostic code is not active.

Results:

- OK – The 5 volt diagnostic code is not active.

Repair: Use the Mitsubishi ET in order to clear all logged diagnostic codes. Replace all wires to the original configuration. Verify that the repair eliminates the fault.

- Not OK – The 5 volt diagnostic code is still active.

Repair: Do not use the new sensor. Repair the connectors or the wiring and/or replace the connectors or the wiring. Refer to "Electrical connectors -inspect".

Verify that the repair eliminates the fault.

### 7.1.5 Test step 5. Disconnect the ECM connector and check for active diagnostic codes

(1) Turn the keyswitch to the OFF position.

(2) Connect the Mitsubishi ET to the diagnostic connector.

(3) Check the ECM connectors for corrosion and moisture.

(4) Disconnect the P2 ECM connector from the ECM.

(5) If a P1:41 is installed, then temporarily disconnect the pin. If a P1:42 is installed, then temporarily disconnect the pin.

(6) Reconnect the P1 connector to the ECM.

(7) Turn the keyswitch to the ON position.

(8) Check for active diagnostic codes on the Mitsubishi ET.

Note: A "voltage high" diagnostic code (open circuit) should be active for all of the following sensors:

- Engine pressure sensors
- Engine temperature sensors
- Analog throttle position sensors

Expected result:

The 5 volt diagnostic codes are not active. A "voltage high" diagnostic code (open circuit) is active for all of the engine pressure sensors, temperature sensors and throttle position sensors.

Results:

- OK – The 5 volt diagnostic code is not active.

Repair: Use the Mitsubishi ET in order to clear all diagnostic codes.

Replace all wires to the original configuration.

Verify that the repair eliminates the fault.

• Not OK – The 5 volt diagnostic codes are still active.
Repair: Connect a test ECM.
If the test ECM fixes the fault, reconnect the suspect ECM.
If the problem returns, permanently install the new ECM.
Verify that the repair eliminates the fault.

### 7.1.6 Test step 6. Check the +5 volt supply wire for a short to engine ground or a short to other wires in the harness

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the J2/P2 ECM connector.
(3) Ensure that the analog sensors are disconnected at the sensor connectors.
Note: Wiggle the harness during the following test procedures in order to identify any intermittent short connectors.
(4) Measure the resistance from P2:46 +5 V supply to all terminals on the P2 ECM connector. Measure the resistance from the P2:46 to the ECM ground strap. Measure the resistance from the P2:47 +5 V supply to all terminals on the P2 ECM connector. Measure the resistance from the P2:47 to the ECM ground strap. Measure the resistance from P2:48 +5 V supply to all terminals on the P2 ECM connector. Measure the resistance from the P2:48 to the ECM ground strap.
(5) Repeat above procedure (1) to (4) for the extension harness connector. +5 V supply is pin 25, 26, 27.

Expected result:
Each resistance measurement is more than 20,000 Ω.
Results:
• OK – The resistance check does not indicate a short in the engine harness to engine ground.
Repair: Repeat this process for J1:42 and J1:54 if a throttle sensor is installed. If the throttle sensors are OK then the fault is intermittent.
Refer to "Electrical connectors -inspect".
Use the Mitsubishi ET in order to clear all logged diagnostic codes.
Replace all wires to the original configuration.
Restart the Test step.
• Not OK – A resistance measurement is less than 20,000 Ω. The +5 V supply wire is shorted in the engine harness or the +5 V supply wire is shorted to the engine ground.
Repair: Repair the faulty wire or replace the faulty wire.
Use the Mitsubishi ET in order to clear all logged diagnostic codes.
Verify that the repair eliminates the fault.

### 7.1.7 Test step 7. Measure the +5 volt supply to the sensor

(1) Turn the keyswitch to the ON position.
Note: All the pressure sensors and the analog throttle position sensors should be disconnected.
(2) Measure the voltage between terminal 1(Pressure sensor +5 V) and the engine ground for each of the pressure sensors.
(3) Measure the voltage between terminal A (analog throttle position sensors +5 V) and the engine ground for each of the analog throttle position sensors.

Expected result:
The voltage is 5.0 ± 0.16 VDC.
Results:
• OK – The +5 volt supply is within the expected range. Proceed to Test step 8.
• Not OK – The voltage is greater than 5.16 volts.
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.

### 7.1.8 Test step 8. Check the ground wire

(1) Turn the keyswitch to the ON position.
(2) Measure the voltage between terminal 1 (position sensor +5 V) and terminal 2 (position sensor ground) on all of the position sensors.
(3) Measure the voltage between terminal A (analog throttle position sensor +5 V) and terminal B (analog throttle position sensor ground) on each of the throttle position sensors.
(4) While the voltage is monitored, perform a 45 N {4.6 kgf} [10 lbf] pull test on the ground wires for the +5 volt supply.

Expected result:
The voltage is 5.0 ± 0.16 VDC.
Results:
• OK – The voltage is within the range.
Repair: If the fault is intermittent, refer to "Electrical connectors -inspect".
• Not OK – The voltage is not within the range.
Repair: Inspect the common wire for an open circuit.
Repair the common wire and/or replace the common wire.
Verify that the repair eliminates the fault.

### 7.2 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:

- J91-03 Accelerator pedal -voltage above normal
- J91-04 Accelerator pedal -voltage below normal
- J29-03 Throttle position sensor open/short to +batt
- J29-04 Throttle position sensor short to ground

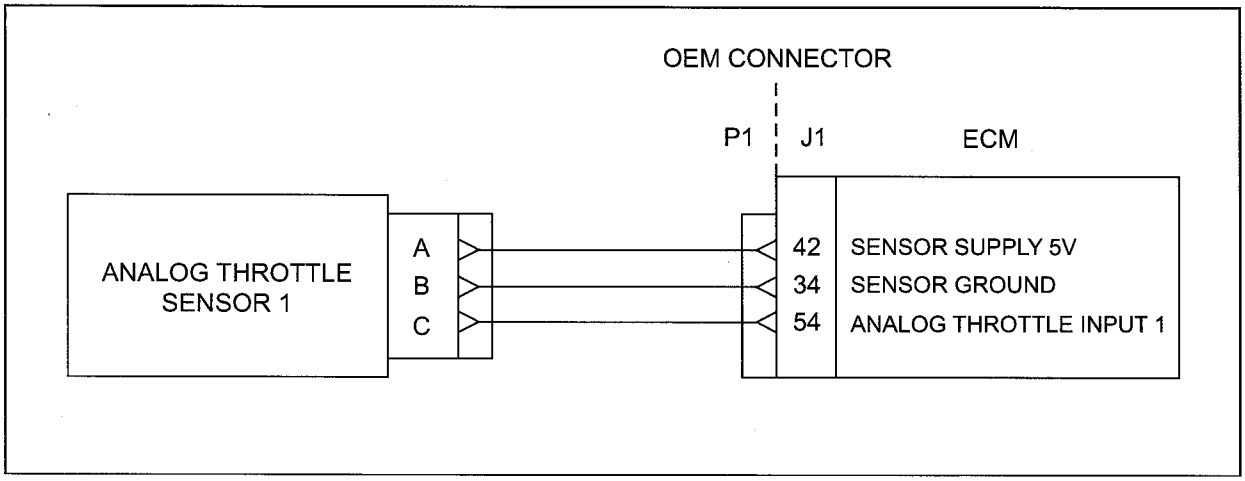
The diagnostic codes above relate to an analog sensor. Use this procedure only if the analog sensor is a variable resistance potentiometer sensor.

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 ECM. The sensor output voltage will vary with the position of the throttle. Foot operated or hand operated throttle assemblies are available.

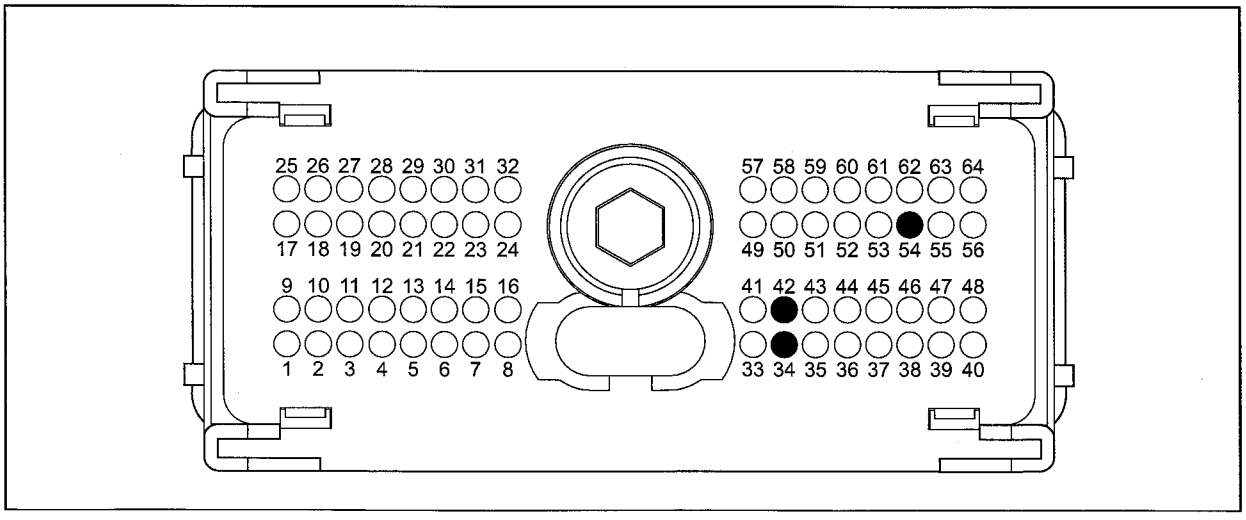
The sensor receives +5 volt power from the ECM. The sensor will produce a raw signal voltage that will alter between low idle and high idle. The voltage is changed into a throttle position within the range 0% to 100% by the ECM.

Table 14-11 Table 57

| P1 pin connections | |
|---|---|
| Function | Throttle |
| + 5 volt supply | 42 |
| Sensor ground | 34 |
| Throttle position input | 54 |
| Idle Validation | 45 |




Schematic of the analog throttle demand sensors




Typical view of the P1 connector pin locations

33 Sensor ground (GND)
34 Seonsor ground (GND)
41 Sensor supply (5v)
42 Sensor supply (5v)
54 Analog throttle input 1
55 Analog throttle input 2

### 7.2.1 Test step 1. Check for connectordamage.

(1) Turn the keyswitch to the OFF position.
(2) Check the connectors and the harness for the following faults: damage, abrasion, corrosion, and incorrect attachment.
(3) Refer to "Electrical Connectors -Inspect".
(4) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the harness that are associated with the throttle position sensor. Check the wire connectors at the ECM and at the throttle pedal. The wire connectors are shown in table.
(5) Check the screw for the ECM connector for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].

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.

Verify that the repair eliminates the fault.

### 7.2.2 Test step 2. Check for active diagnostic codes.

(1) Turn the keyswitch to the ON position.
(2) Use the Mitsubishi ET to check for diagnostic codes.

Expected result:

Result 1 The Mitsubishi ET displays the following active diagnostic codes or recently logged diagnostic codes:

- J91-03
- J91-04
- J29-03
- J29-04

Result 2 The Mitsubishi ET displays no active diagnostic codes:

Results:

- Result 1 – Proceed to Test step 3.
- Result 2 – Proceed to Test step 5.

### 7.2.3 Test step 3. Check the throttle position with the Mitsubishi ET.

(1) Connect the Mitsubishi ET to the diagnostic connector.
(2) Turn the keyswitch to the ON position. The engine should be off.
(3) Observe the throttle position reading on the Mitsubishi ET.
(4) Depress the throttle and release the throttle.

Expected result:

The output should increase when the throttle pedal is depressed.

The output should be between "10 percent" and "20 percent" at the low idle position. The output should be between "80 percent" and "90 percent" at the high idle position.

Results:

- OK – The sensor is operating correctly.
- Not OK – The ECM is not receiving a correct signal from thesensor. Proceed to Test step 4.

### 7.2.4 Test step 4. Check the voltage at the sensor

(1) Turn the keyswitch to the OFF position.
(2) Install a breakout "T" with 3 terminals to the sensor.
(3) Turn the keyswitch to the ON position.
(4) Measure the voltage between terminal "A" and terminal "B".

Expected result:

The supply voltage should be between 4.84 VDC and 5.16 VDC.

Results:

- OK – The supply voltage is reaching the sensor. Proceed to Test step 5.
- Not OK – The supply voltage is not reaching the sensor.

Repair: Refer to "5 Volt Sensor Supply Circuit -Test".

### 7.2.5 Test step 5. Check the position of sensor.

(1) Turn the keyswitch to the OFF position.
(2) Install a breakout "T" with 3 terminals to the sensor.
(3) Turn the keyswitch to the ON position.
(4) Measure the voltage between terminal "C" and terminal "B" of the breakout "T".
(5) Observe the voltage while the engine speed control is moved from the minimum to the maximum position.

Expected result:

The voltage should vary between 1.0V and 4.0V when the speed control is moved from the minimum to the maximum position.

Results:

- OK – The throttle position sensor is operating correctly. Proceed to Test step 6.
- Not OK – The throttle position sensor is faulty. Proceed to Test step 7.

### 7.2.6 Test step 6. Check the sensor at the ECM.

(1) Turn the keyswitch to the OFF position.
(2) Remove the P1 connector.
(3) Temporarily remove the pins from P1:54.

(4) Reconnect P1 connector.
(5) Connect the red probe of a multimeter to the removed pin and the black probe of a multimeter to P1:34.
(6) Turn the keyswitch to the ON position.
(7) Use the multimeter to display the output voltage of the sensor while the engine speed control is moved from the minimum position tothe maximum position.
(8) Turn the keyswitch to the OFF position.
(9) Reconnect P1:54 to the P1 connector.
(10)Remove P1 connector and reinstall P1:54 to the P1 connector.
(11)Reconnect P1 connector.

Expected result:

The output from the throttle position sensor is 0.5 volts or less with the sensor slot in the released position.
The output from the throttle position 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 the ECM is suspect.
1. Temporarily connect a test ECM.
Note: The test ECM should be programmed with the correct software. All parameters should be set to the same value as the suspected ECM.
2. If the fault is eliminated with the test ECM, install the suspect ECM and verify that the fault returns.
3. If the fault returns replace the ECM.
• 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. Check that the repairs have eliminated the fault.

### 7.2.7 Test step 7. Remove the sensor from the engine speed control assembly.

(1) Turn the keyswitch to the OFF position.
(2) Record the position of the sensor before removing the sensor.
(3) Remove the sensor from the housing and inspect the cables for signs of wear.
(4) Connect a multimeter to terminal "C" and terminal "B" of the breakout "T".
(5) Turn the keyswitch to the ON position.
(6) Record the signal voltage of the sensor with the sensor slot in the released position.
(7) 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 or less with the sensor slot in the released position.
The output from the sensor is 4.5 volts or more with the sensor slot in the advanced position.

Results:

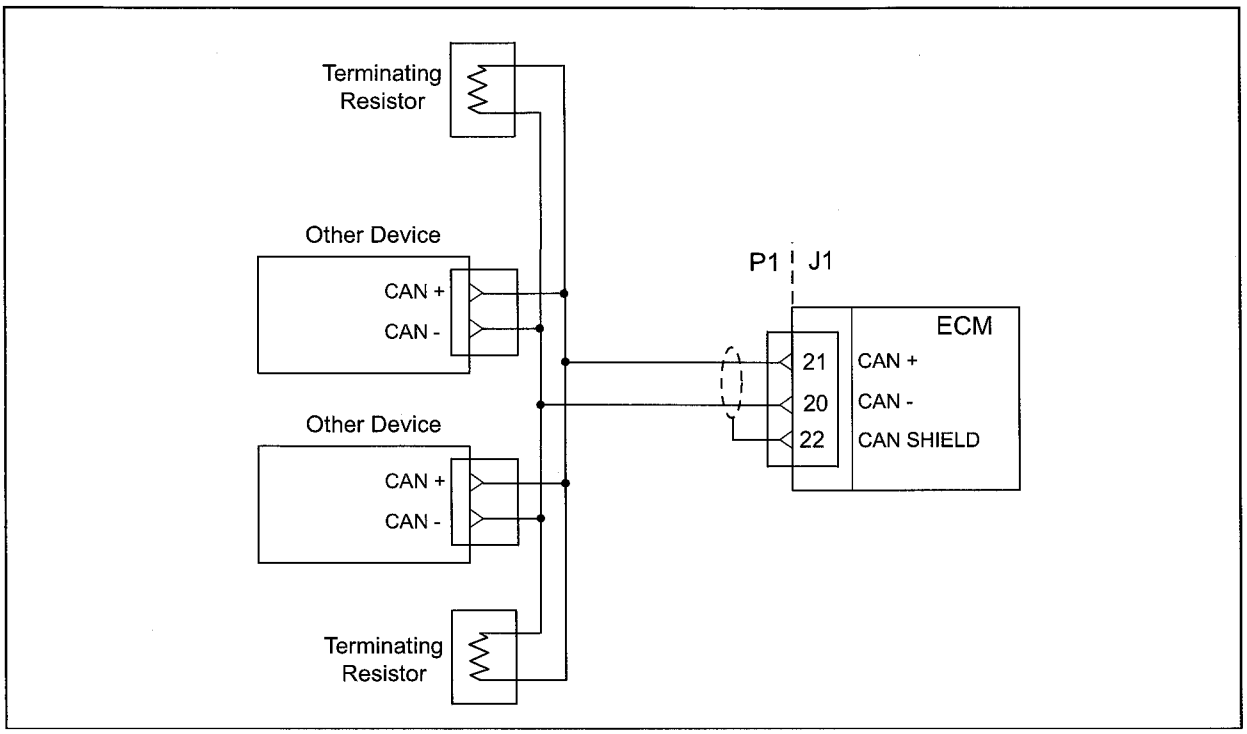
• OK

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.
• Not OK – The sensor is faulty.
Repair: Replace the sensor.
Verify that the repair has eliminated the fault.

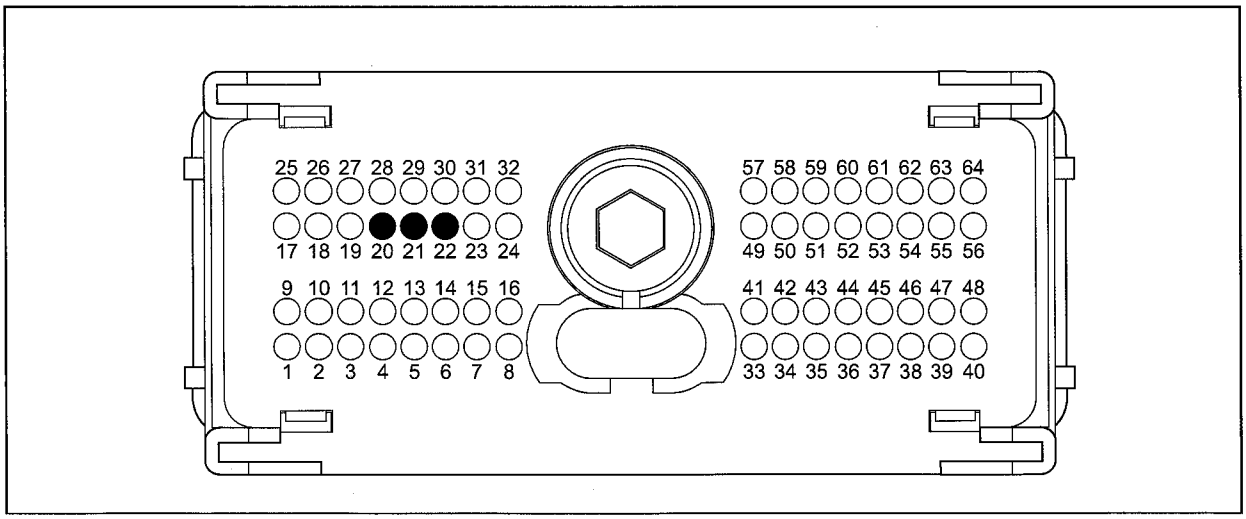
## 7.3 CAN data link circuit-test

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:
• J639-9 J1939 Data Link communications
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 Ω between the two wires to correctly transmit the data. This resistance is made up of two 120 Ω 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.




Typical example of the schematic for the CAN data link




Typical view of the P1 connector pin locations

20 CAN - 21 CAN + 22 CAN shield

### 7.3.1 Test step 1. Inspect electrical connectors

(1) Turn the keyswitch to the OFF position.

(2) Thoroughly inspect the harness connector P1/J1 and wiring. and any other connectors in the CAN data link circuit.
Refer to "Electrical connectors inspect" for details.

(3) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires that are associated with the CAN data link. Refer to illustration.

(4) 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.
Verify that the repair eliminates the fault.

### 7.3.2 Test step 2. Check the data link terminating resistance

(1) Disconnect the P1 connector from the ECM.
(2) Measure the resistance between P1:20 and P1:21.

Expected result:

The resistance is between 50 and 70 Ω.

Results:

- Result 1 – The resistance is between 50 and 70 Ω. 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 Ω. 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.
Verify that the repair eliminates the fault.

- Result 3 – The resistance is between 110 and 130 Ω. 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 Ω, proceed to Test step 4.

- Result 4 – The resistance is greater than 150 Ω. There may be a break in the harness. Proceed to Test step 3.

### 7.3.3 Test step 3. Check the data link wiring

(1) Disconnect each of the connectors that connect other devices on the data link.
(2) 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.
(3) 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.
(4) 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 below 2 Ω.

Results:

- OK – The resistance is below 2 Ω. Proceed to Test step 4.
- Not OK – Some resistances are greater than 2 Ω.

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.
Verify that the repair has eliminated the fault.

### 7.3.4 Test step 4. Check the other devices on the J1939 data link

(1) Use the appropriate service tools in order to diagnose other devices on the data link.

Expected result:

The other devices are working correctly.

Results:

- OK – The other devices are operating correctly. Restart the diagnostic process.
- 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.
Verify that the repair eliminates the fault.

## 7.4 Conventional data link circuit-test

System operation description:

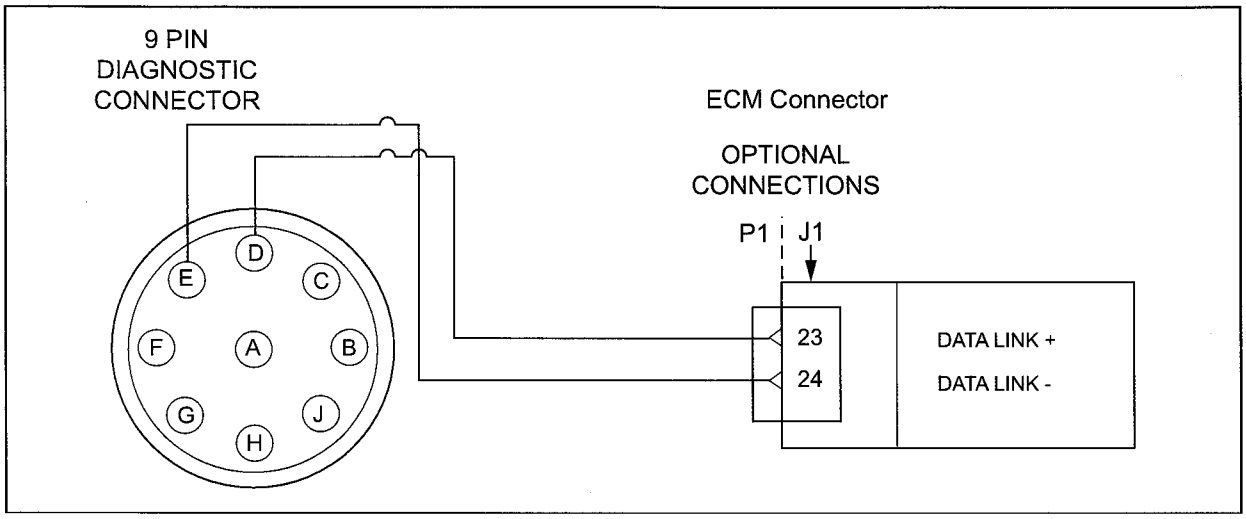
Use this procedure under the following circumstances:
Use this procedure if another procedure has directed you here.
Use this procedure if the Mitsubishi ET will not communicate with the ECM through the Conventional data link.
The following background information is related to this procedure:
The Conventional data link is the standard data link that is used by the ECM in order to communicate with the Mitsubishi ET.
The ECM provides multiple connections for the Conventional data link. The technician must ensure that the correct connector is being tested. The connection that is used is dependent on the application.
The positive data link signal will be from P1:23 to pin "D" of the diagnostic connector. The negative data link signal will be from P1:24 to pin "E" of the diagnostic connector.
The following information refers to the pin number. Ensure that the correct connector is used.

Communication

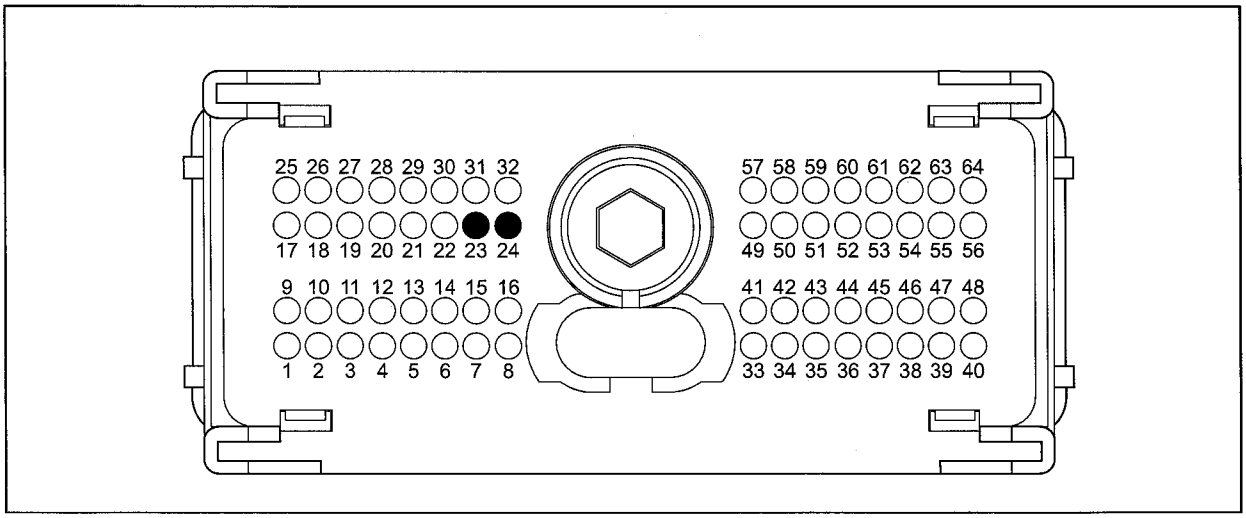
The Mitsubishi ET may indicate the following error message:

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 Mitsubishi ET is not the same version of the software that is in the ECM. Install the latest version of the Mitsubishi ET software in order to rectify the fault.




Schematic of the diagnostic connector and the Conventional data link connector




Typical view of the P1 pin locations for the diagnostic and Conventional data link connector

23 Data link (CDL) +  24 Data link (CDL) -

### 7.4.1 Test step 1. Inspect electrical connectors and wiring.

(1) Thoroughly inspect the following electrical connectors:
J1 ECM connector
Pin D for the data link connector
Pin E for the data link connector
Mitsubishi ET connectors
Refer to "Electrical connectors inspect" for details.

(2) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the ECM connectors that are associated with the data link.

(3) Check the screw for the ECM connectors for correct torque of 5.0 N·M {0.50 kgf·m} [3.7 lbf·ft] .

(4) 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.
Verify that the repair eliminates the fault.

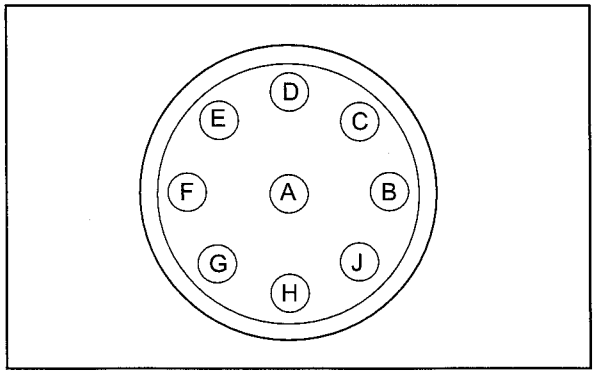
### 7.4.2 Test step 2. Determine the type of problem with the Conventional data link.

(1) Connect the Mitsubishi ET to the diagnostic connector that is on the engine harness or on the application.
(2) 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. Proceed to Test step 5.
- Not OK – The communications adapter is not receiving the correct voltage. Proceed to Test step 3.

### 7.4.3 Test step 3. Check the wiring of the diagnostic connector.




Typical view of the 9 pin diagnostic connector

A Switched battery +
B Battery ground (GND)
D Data link +
E Data link -

(1) 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.

### 7.4.4 Test step 4. Check the battery voltage at the diagnostic connector.

(1) Turn the keyswitch to the ON position.
(2) 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 VDC and 27.0 VDC.
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: Proceed to Test step 2.

### 7.4.5 Test step 5. Check the data link connections.

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the communications adapter from the diagnostic connector.
(3) Disconnect P1 connector from connector J1. Check the resistance between P1:23 and diagnostic pin "D".
(4) Check the resistance between P1:24 and diagnostic pin "E".

Expected result:
The resistance that is measured is less than 10 Ω.
Results:

- OK – The resistance is less than 10 Ω. Proceed to Test step 6.
- Not OK – The resistance is greater than 10 Ω.

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.
Verify that the repair eliminates the fault.

### 7.4.6 Test step 6. Change the Mitsubishi ET components.

(1) If another electronic engine is available, connect the Mitsubishi ET to the other engine. Ensure that the same cables are used.
(2) Turn the key switch to the ON position. Determine if the Mitsubishi ET operates correctly on the other engine.

(3) If another engine is not available, obtain a replacement communications adapter and a replacement set of Mitsubishi ET cables. Ensure that the set of Mitsubishi ET cables are a complete set.
(4) Install the replacement communications adapter and Mitsubishi ET cables and connect to the diagnostic connector.
(5) Turn the keyswitch to the ON position.
(6) If changing the communications adapter or the Mitsubishi ET cables allows the Mitsubishi ET to operate correctly, use the following procedure:
Replace the pieces from the old set of Mitsubishi ET cables into the new set of cables that operate. Replace one piece at a time.
Apply power to the Mitsubishi ET after each of the pieces is replaced. Use this method to find the faulty piece.
(7) If changing the Mitsubishi ET cables does not allow the Mitsubishi ET to operate correctly, connect another Mitsubishi ET.
(8) Turn the keyswitch to the ON position.

Expected result:

Result 1 - The original Mitsubishi ET works on another engine.

Result 2 - A different Mitsubishi ET 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 Mitsubishi ET for repairs.

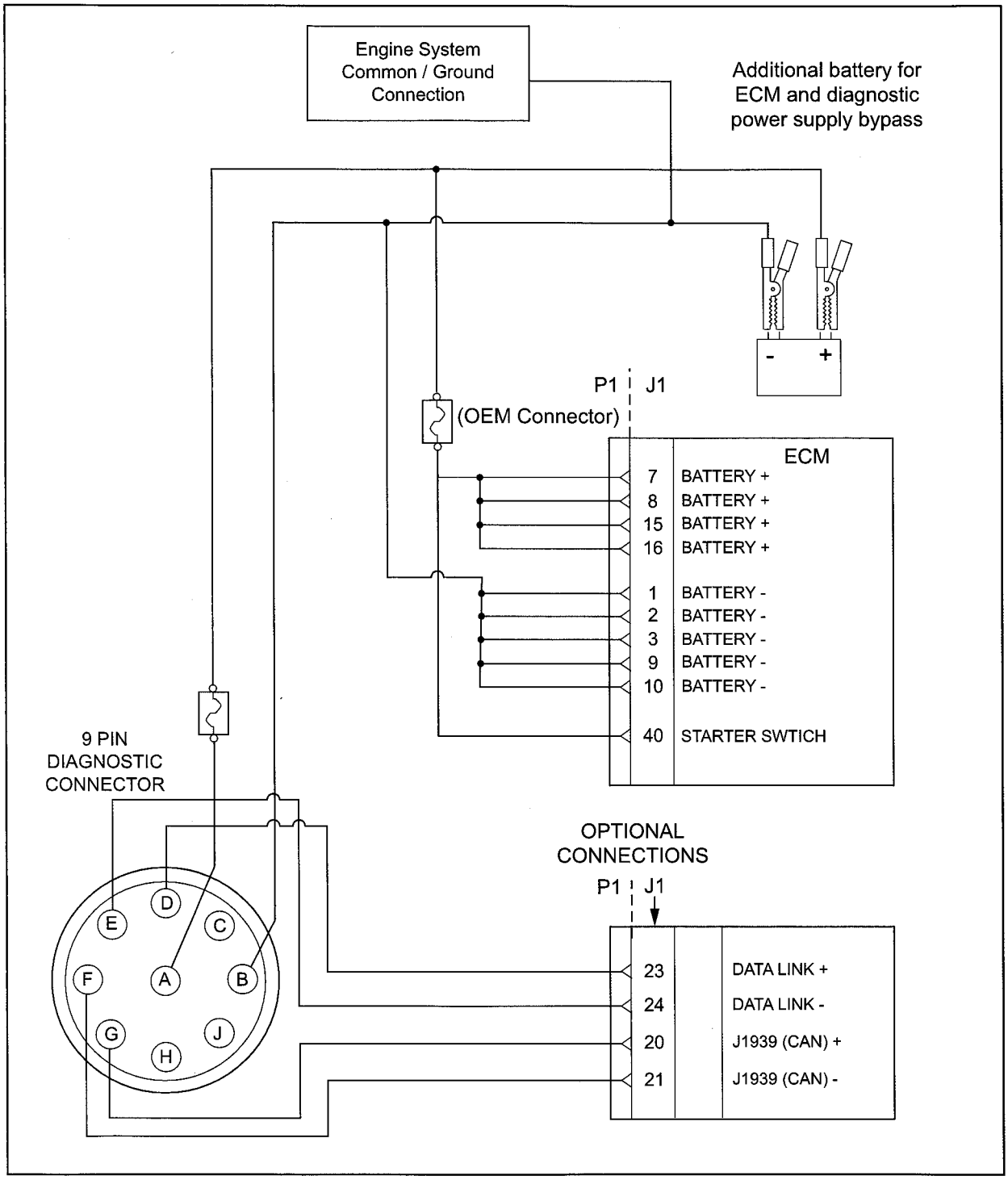
### 7.4.7 Test step 7. Connect a Mitsubishi ET and the ECM to another battery.

**⚠ WARNING**

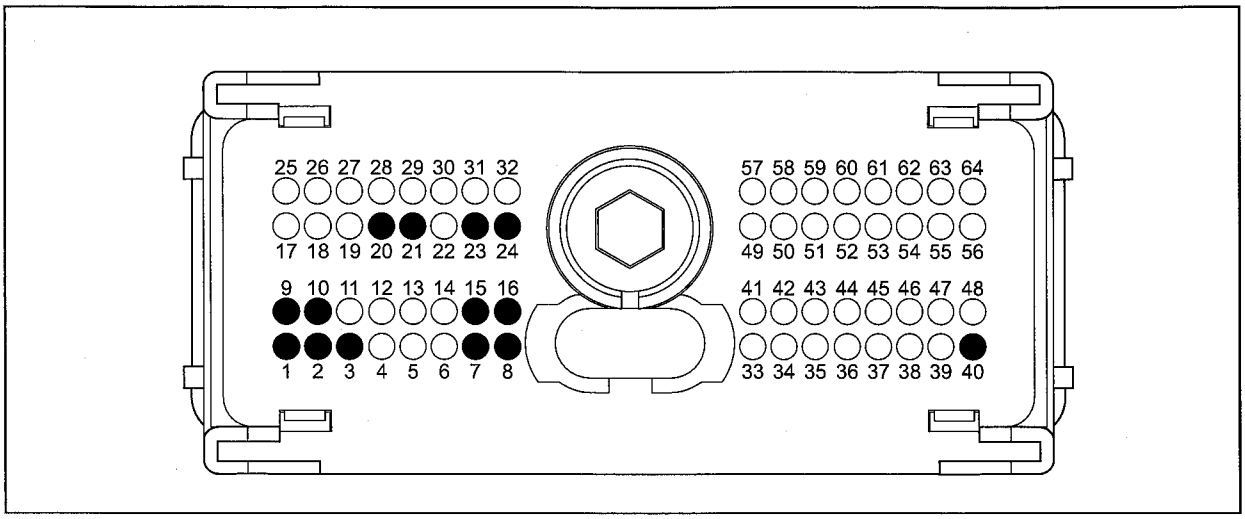
Batteries give off flammable fumes which can explode. To avoid injury or death, do not strike a match, cause a spark, or smoke in the vicinity of a battery.

**⚠ CAUTION**

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.




Schamatic of the bypass harness connector




Typical view of the P1 connector pin locations for the diagnostic and Cat data link connector

| | | |
|---|---|---|
| 1 Battery ground (GND) | 9 Battery ground (GND) | 21 J1939 (CAN) + |
| 2 Battery ground (GND) | 10 Battery ground (GND) | 23 Conventional data link (CDL) + |
| 3 Battery ground (GND) | 15 Battery + | 24 Conventional data link (CDL) + |
| 7 Battery + | 16 Battery + | 40 Keyswitch |
| 8 Battery + | 20 J1939 (CAN) - | |

(1) Connect the battery wires from the bypass harness of the Mitsubishi ET to a different battery that is not on the engine.

Expected result:

The Mitsubishi ET is operating correctly.

Results:

• Yes

Repair: Check the engine wiring.

• No

Repair: Perform the following repair:

Temporarily connect a test ECM.

Note: The test ECM should be programmed with the correct software. All parameters should be set to the same value as the suspect ECM.

Remove all jumper wires and reconnect all connectors.

Recheck the system for active diagnostic codes.

Repeat the Test step.

If the fault is resolved with the test ECM, reconnect the suspect ECM.

If the fault returns with the suspect ECM, replace the suspect ECM.

Verify that the repair eliminates the fault.

## 7.5 ECM memory-test

System operation description:

This procedure covers the following diagnostic codes:

• J631-02 Personality module mismatch

Background information

The flash file in the 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 J631-02 diagnostic code is active.

Results:

• A J631-02 code is active

Repair: Obtain the engine serial number. Refer to the specified website or contact product support to determine the latest available flash file for the engine. Verify that the latest available flash file is loaded into the ECM.

## 7.6 Electrical connectors-inspect

System operation description:

Most electrical faults are caused by poor connections. The following procedure will assist in detecting faults with connectors and with 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

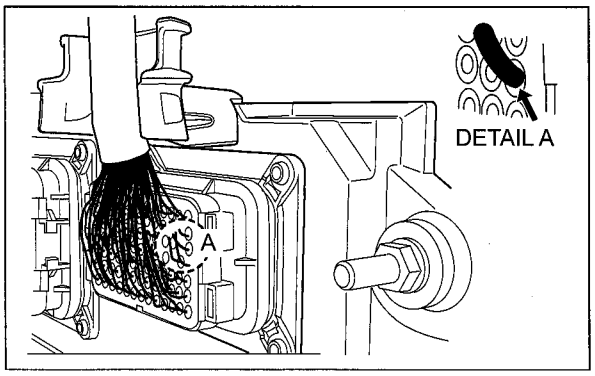
reasons are loose terminals, improperly crimped terminals, moisture, corrosion, and inadequate mating of a connection. Follow these guidelines:

- Always use 32E91-03100 crimp tool to service the connectors.
- Refer to "ECM harness connector terminals" in order to service the connectors for the 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.

### 7.6.1 Test step 1. Check connectors for moisture and corrosion




Leaky seal at the connector (typicl example)

(1) 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. This will create a path for the entrance of moisture. Verify that the seals for the wires are sealing correctly.

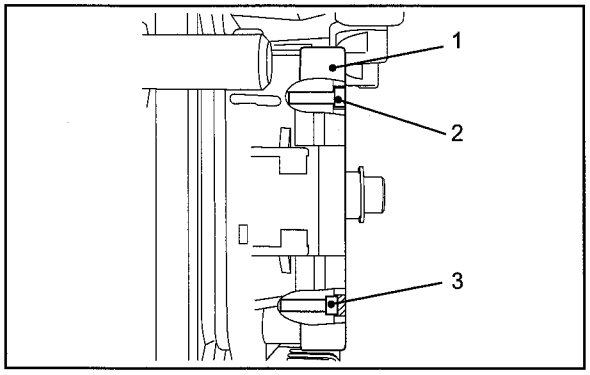


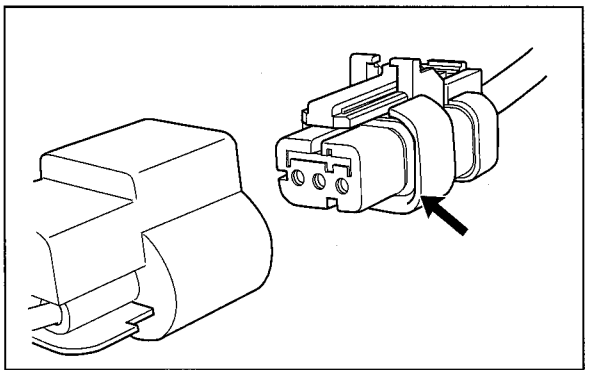

Diagram for the installation of a connector plug (typical example)

1 ECM connector

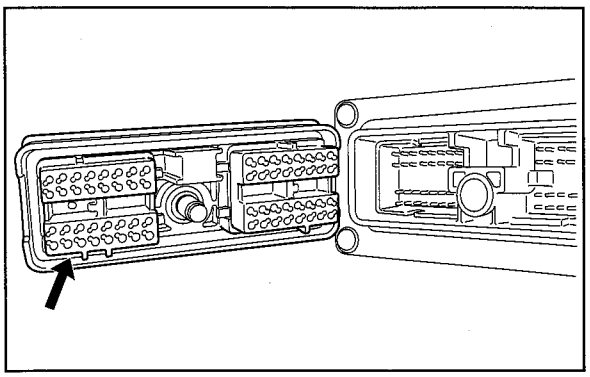
2 Correctly inserted plug

3 Incorrectly inserted plug

(2) 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.



Seal for a three-pin connector (typical example)



Seal for ECM connector (typical example)

(3) Disconnect the suspect connector and inspect the connector seal. Ensure that the seal is in good condition. If necessary, replace the connector.

(4) 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 swabor 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.

Verify that the repair eliminates the fault.

### 7.6.2 Test step 2. Check the wires for damage to the insulation

(1) Carefully inspect each wire for signs of abrasion, of nicks, and of cuts.

(2) Inspect the wires for the following conditions:
Exposed insulation
Rubbing of a wire against the engine
Rubbing of a wire against a sharp point

(3) Check all of the fasteners for 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, of nicks, and of cuts and the harness is correctly clamped.

Results:

- OK – The harness is OK. Proceed to Test step 3.
- Not OK – There is damage to the harness.

Repair: Repair the wires or replace the wires, as required. Verify that the repair eliminates the fault.

### 7.6.3 Test step 3. Inspect the connector terminals

(1) 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:

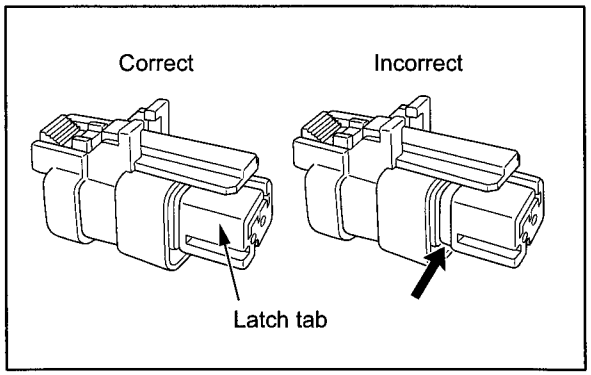
The terminals are correctly aligned and the terminals appear undamaged.

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. Verify that the repair eliminates the fault.

### 7.6.4 Test step 4. Perform a pull test on each wire terminal connection




Typical example of the lock wedge 1

(1) 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.

(2) Perform the 45 N {4.6 kgf} [10 lbf] pull test on each wire. Each terminal and each connector should easily withstand 45 N {4.6 kgf} [10 lbf] 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 {4.6 kgf} [10 lbf] 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 32E91-03100 crimp tool to replace the terminal. Replace damaged connectors, as required.

Verify that the repair eliminates the fault.

### 7.6.5 Test step 5. Check individual pin retention into the socket

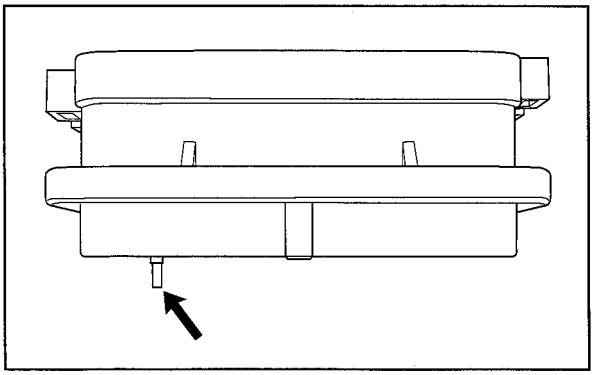


Diagram for testing pin retention (typical example)

(1) Verify that the sockets provide good retention for the pins. Insert anew pin in to 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.

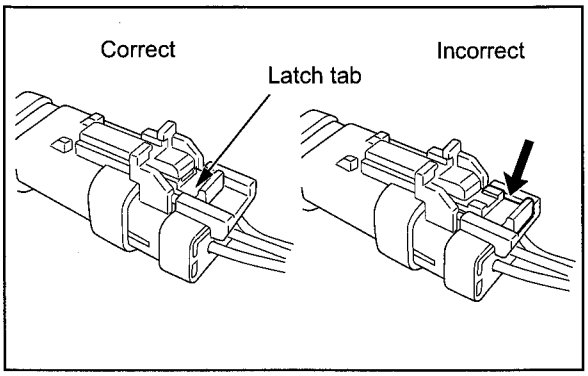
Results:

- OK – The terminals are OK. Proceed to Test step 6.
- Not OK – Terminals are damaged.

Repair: Use the 32E91-03100 crimp tool to replace the damaged terminals.

Verify that the repair eliminates the problem. Verify that the repair eliminates the fault.

### 7.6.6 Test step 6. Check the locking mechanism of the connectors




Typical example of the sensor connector (AMP seal 16)

(1) Ensure that the connectors lock correctly. After locking the connectors, ensure that the two halves cannot be pulled apart.

(2) 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 will securely lock. The connector and the locking mechanism are without cracks or breaks.

Results:

- OK – The connectors are in good repair. Proceed to Test step 7.
- Not OK – The connector's locking mechanism is damaged or missing.

Repair: Repair the connector or replace the connector, as required.

Verify that the repair eliminates the fault.

### 7.6.7 Test step 7. Check the screws on the ECM connectors (64 way) and extension harness connector

Visually inspect the screws for the ECM connectors and extension harness connector. Ensure that the threads on each screw are not damaged.

(1) Connect the ECM connectors.

Use a 7 mm HEX-head drive socket in order to retain each of the ECM connectors.

Tighten the two screws for the ECM connector to the correct torque of 5.0 ± 1.0 N·m {0.50 ± 0.10 kgf·m} [3.7 ± 0.7 lbf·ft].

(2) Connect the extension harness connector.

Use a 4 mm HEX-head drive socket in order to retain

extension harness connector..

Tighten the screw for the ECM connector to the correct torque of 2.8 ± 0.3 N·m {0.29 ± 0.03 kgf·m} [2.07 ± 0.22 lbf·ft].

Expected result:

The ECM connectors and extension harness connector are secure and the screws are correctly torqued.

Results:

- OK – The ECM connectors and extension harness connector 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.

Verify that the repair eliminates the fault.

### 7.6.8 Test step 8. Perform the "Wiggle test" on the Mitsubishi ET

(1) Select the "Wiggle test" from the diagnostic tests on Mitsubishi ET.

(2) Choose the appropriate group of parameters to monitor.

(3) 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 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.
- Not OK – At least one intermittent fault was indicated.

Repair: Repair the harness or the connector.

Verify that the repair eliminates the fault.

## 7.7 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:

- J100-03 Engine oil pressure open/short to +batt
- J100-04 Engine oil pressure short to ground
- J100-10 Engine oil pressure densor abnormal rate of change
- J102-03 Inlet manifold pressure sensor voltage high
- J102-04 Inlet manifold pressure sensor voltage low
- J157-03 Common rail pressure sensor open/short to +batt
- J157-04 Common rail pressure sensor short to ground

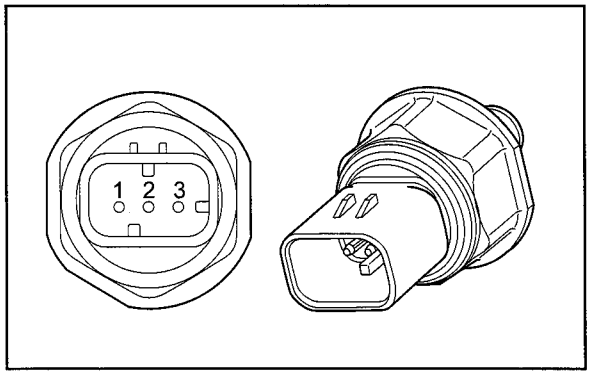
The following background information is related to this procedure:

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 ECM supplies 5.0 ± 0.2 VDC 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

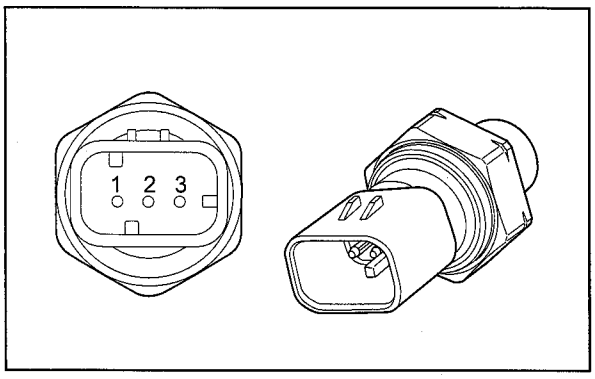
The ECM continuously outputs a pull-up voltage on the circuit for the sensor signal wire. The ECM uses this pull-up voltage in order to detect an open in the signal circuit. When the ECM detects the presence of a voltage that is above a threshold on the signal circuit, the ECM will generate an open circuit diagnostic code 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.




Common rail pressure sensor

1 Voltage supply (Vs) 2 Ground (GND) 3 Signal (SIG)




Inlet manifold and oil pressure sensors

1 Voltage supply (Vs) 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 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.

### 7.7.1 Test step 1. Verify all active diagnostic codes.

(1) Turn the keyswitch to the ON position. Wait at least 10 seconds for activation of the diagnostic codes.

(2) Verify if any of the following diagnostic codes are active:

- J100-03 Engine oil pressure open/short to +batt
- J100-04 Engine oil pressure short to ground
- J100-10 Engine oil pressure sensor abnormal rate of change
- J102-03 Inlet manifold pressure sensor voltage high
- J102-04 Inlet manifold pressure sensor voltage low
- J157-03 Common rail pressure sensor open/short to +batt
- J157-04 Common rail pressure sensor short to ground

Expected result:

One or more of the preceding diagnostic codes are active.

Results:

- OK – Proceed to Test step 2.
- Not OK

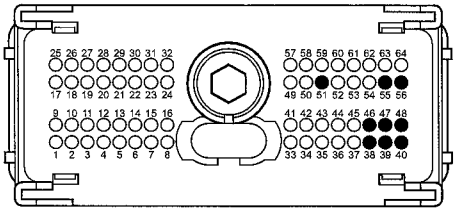
Repair: Do not use this procedure if J100-10 diagnostic codes are active. Refer to "5 volt sensor supply circuit-test". When this test is complete, return to the start of this test.

If the preceding codes are logged, an intermittent condition may be causing the logged codes. Refer to "Electrical connectors-inspect".

Perform a "Wiggle test" by using the Mitsubishi ET in order to identify intermittent connections.

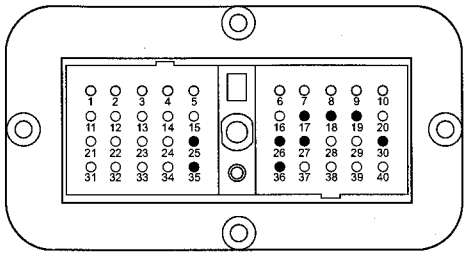
### 7.7.2 Test step 2. Inspect electrical connectors and wiring.

P2 ECM connector




| | |
|---|---|
| 38 | Ground (GND) inlet manifold pressure sensor |
| 39 | Ground (GND) oil pressure sensor |
| 40 | Ground (GND) common rail pressure sensor |
| 46 | Voltage supply (5V) inlet manifold pressure sensor |
| 47 | Voltage supply (5V) oil pressure sensor |
| 48 | Voltage supply (5V) common rail pressure sensor |
| 51 | Signal (SIG) common rail pressure sensor |
| 55 | Signal (SIG) inlet manifold pressure sensor |
| 56 | Signal (SIG) oil pressure sensor |

Extension harness connector




| | |
|---|---|
| 17 | Ground (GND) inlet manifold pressure sensor |
| 18 | Ground (GND) oil pressure sensor |
| 19 | Ground (GND) common rail pressure sensor |
| 25 | Voltage supply (5V) inlet manifold pressure sensor |
| 26 | Voltage supply (5V) oil pressure sensor |
| 27 | Voltage supply (5V) common rail pressure sensor |
| 30 | Signal (SIG) common rail pressure sensor |
| 35 | Signal (SIG) inlet manifold pressure sensor |
| 36 | Signal (SIG) oil pressure sensor |

Pressure sensor pin locations

(1) Thoroughly inspect the terminal connections on the P2/J2 ECM sensor connectors and extension harness connector.

(2) Thoroughly inspect the following engine pressure sensor connectors:
Inlet manifold pressure sensor
Engine oil pressure sensor
Common rail pressure sensor

(3) Refer to "Electrical connectors-inspect".

(4) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the ECM connector, the extension harness connector and the sensor connector that are associated with the active diagnostic code.

(5) Check the screw for the ECM connector for the correct torque of 5.0 N·M {0.50 kgf·m} [3.7 lbf·ft] .

(6) Check the harness for abrasions and for pinch points from the sensors back to the ECM.

(7) Use the Mitsubishi ET 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.

Verify that the repair eliminates the fault.

Use the Mitsubishi ET in order to clear all logged diagnostic codes.

### 7.7.3 Test step 3. Verify that the diagnostic code is still active.

(1) Turn the keyswitch to the ON position. Wait at least 30 seconds for activation of the diagnostic codes.
(2) Use the Mitsubishi ET to check for active diagnostic codes. Record all active diagnostic codes.
(3) 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 short circuit diagnostic code is active at this time. Proceed to Test step 4.
- OK - Open circuit – An open circuit 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: By using the Mitsubishi ET, perform a "Wiggle test". If faults are indicated then go to the appropriate procedure.

### 7.7.4 Test step 4. Disconnect the sensor in order to create an open circuit.

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the sensor connector of the sensor with the short circuit diagnostic code.
(3) Turn the keyswitch to the ON position. Wait at least 30 seconds for activation of the diagnostic codes.
(4) Use the Mitsubishi ET to check the"Active diagnostic code" screen. Check for an open circuit diagnostic code.

Expected result:

An open circuit diagnostic code for the disconnected sensor is now active.

Results:

- OK – A short circuit diagnostic code was active before disconnecting the sensor. An open circuit diagnostic code became active after disconnecting the sensor. Proceed to Test step 6.
- Not OK – There is a short circuit between the sensor harness connector and the ECM. Leave the sensor disconnected. Proceed to Test step 8.

### 7.7.5 Test step 5. Measure the sensor supply voltage.

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the sensor from the engine harness.
(3) Turn the keyswitch to the ON position.
(4) 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 VDC.

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: Perform "5 volt sensor supply circuit-test"

### 7.7.6 Test step 6. Determine if the short circuit is in the connector or in the sensor.

(1) Thoroughly inspect the connector for moisture.
(2) Inspect the seals and reconnect the sensor.
(3) Refer to "Electrical connectors-inspect".
(4) If the short circuit diagnostic code reappears, the sensor or the sensor connector has a fault.
Temporarily connect a new sensor to the harness, but do not install the new sensor in the engine.
(5) Use the Mitsubishi ET 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 Mitsubishi ET to verify that the repair eliminates the fault. Use the Mitsubishi ET to clear the logged diagnostic codes.
- Not OK – Repair the engine harness connector. Use the Mitsubishi ET to clear the logged diagnostic codes.

### 7.7.7 Test step 7. Create a short circuit between the signal and the common terminals at the engine harness connector.

(1) Turn the keyswitch to the ON position.
(2) Fabricate a jumper wire long enough. Crimp a terminal to both ends of the wire.
(3) Monitor the "Active diagnostic code" screen of the Mitsubishi ET before installing the jumper wire and after installing the jumper wire.
(4) 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.

(2) Use the Mitsubishi ET to verify if the diagnostic code remains active.

(3) If the diagnostic code is active replace the sensor.

(4) Use the Mitsubishi ET to verify that the repair eliminated the fault.

• 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.

### 7.7.8 Test step 8. Check the operation of the ECM by creating open and short circuits at the ECM connector.

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P2 connector from the ECM. Thoroughly inspect both halves of the connector for signs of corrosion or moisture. Refer to "Electrical connectors-inspect".

(3) Reconnect P2 connector.

(4) Turn the keyswitch to the ON position. Use Mitsubishi ET in order to monitor the "Active diagnostic code" screen. Wait at least 30 seconds for activation of the code.

An open circuit diagnostic code should be active for the suspect sensor.

Note: When 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. Direct your attention to the diagnostic codes for the suspect sensors only.

(5) Turn the keyswitch to the OFF position.

(6) Fabricate a jumper wire long enough. Crimp a terminal to both ends of the wire.

(7) 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 Mitsubishi ET to verify that there is a short circuit diagnostic code.

Expected result:

Open circuit diagnostic codes and short circuit 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 open circuit diagnostic code is not active when the harness is disconnected. The short circuit diagnostic code is not active when the jumper wire is installed.

Repair: Perform the following repair:

(1) Temporarily connect a test ECM.

Note: The test ECM should have the same values and the same parameters as the suspect ECM.

(2) Remove all jumpers and replace all connectors.

(3) Use Mitsubishi ET to recheck the system for active diagnostic codes.

(4) Repeat the Test step.

(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) Verify that the repair eliminates the fault.

### 7.7.9 Test step 9. Bypass the harness wiring between the ECM and the sensor connector.

(1) Turn the keyswitch to the OFF position.

(2) Disconnect P2 connector and disconnect the connector from the suspect sensor.

(3) Remove the sensor signal wire from the P2 connector.

(4) Remove the signal wire (terminal 3) from the sensor connector on the engine harness.

(5) Fabricate a jumper wire that is long enough to reach from the ECM to the sensor connector.

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.

(6) 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.

(7) Reconnect P2 connector and the sensor connector.

(8) Turn the keyswitch to the ON position.

(9) Use the Mitsubishi ET 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 Mitsubishi ET to check active diagnostic codes in order to verify that the repair eliminates the fault.

• Not OK – The most likely cause is an intermittent fault.

Repair: By using the Mitsubishi ET, perform a "Wiggle test". If no fault is found, restart this procedure and carefully perform each step.

### 7.8 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.

• There is an active diagnostic code or a recently logged diagnostic code that is related to the following:

• J190-08 Engine speed signal abnormal

• J723-08 Secondary engine speed signal abnormal

The engine uses two engine speed/timing sensors. The speed/timing (crankshaft side) sensor is located on the right hand side of the flywheel housing. The speed/timing (fuel pump side) sensor is mounted on the fuel pump. The speed/timing (crankshaft side) sensor generates a signal by detecting the movement of the holes that are located on the flywheel. The flywheel is connected to the crankshaft. The signal that is generated by the speed/timing sensor is transmitted to the ECM. The ECM uses the speed/timing sensor signal to calculate the position of the crankshaft. To determine the engine speed, the ECM measures the time between the pulses that are created by the sensor as the flywheel rotates.

The speed/timing (fuel pump side) sensor is located in the fuel pump. The speed/timing (fuel pump side) sensor generates a signal that is related to the camshaft position. The fuel pump is mechanically connected to the camshaft. The speed/timing (fuel pump side) sensor detects the movement of the teeth on the speed/timing wheel in the fuel pump. The signal that is generated by the speed/timing (fuel pump side) sensor is transmitted to the ECM. The ECM calculates the speed and the rotational position of the engine by using the signal. During normal operation, the speed/timing (fuel pump side) sensor is used to determine the timing for starting purposes.

During normal operation, the speed/timing (fuel pump side) sensor is used to determine when the number 1 piston is at the top of the compression stroke for starting purposes. When the timing has been established, the speed/timing (crankshaft side) sensor is then used to determine the engine speed.

The loss of signal to the cranckshaft side sensor and/or the camshaft side sensor will result in one of the following faults:

• The loss of signal from the speed/timing (fuel pump side) 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 crankshaft side sensor or the camshaft side sensor.

• The loss of signal from the speed/timing (crankshaft side) sensor during operation of the engine will result in engine operation in the derate mode.

• Loss of signal from the crankshaft side sensor and the camshaft side sensor during operation of the engine will cause fuel injection to be terminated and the engine will stop.

The crankshaft side sensor and the camshaft side sensor are interchangeable components. If a sensor is suspect the sensors can be exchanged in order to eliminate a fault. If a camshaft side sensor is suspect and a replacement camshaft side sensor is not available, then the crankshaft side sensor and the camshaft side sensor can be exchanged. This will allow testing to determine if the camshaft side sensor is faulty.

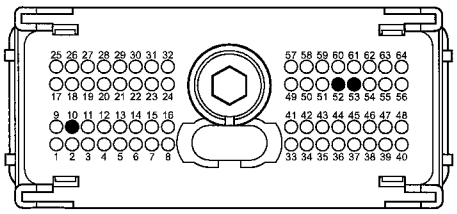
Table 14-12 P2/J2 pin connections

| Function | Sensor pin | Speed/timing (Crankshaft side) sensor | Speed/timing (Fuel pump side) sensor |
|---|---|---|---|
| +8 Volt Supply | 1 | 10 | 10 |
| Signal | 2 | 52 | 53 |

Table 14-13 Extension harness connector pin connections

| Function | Sensor pin | Speed/timing (Crankshaft side) sensor | Speed/timing (Fuel pump side) sensor |
|---|---|---|---|
| +8 Volt Supply | 1 | 6 | 7 |
| Signal | 2 | 32 | 33 |

P2 ECM connector

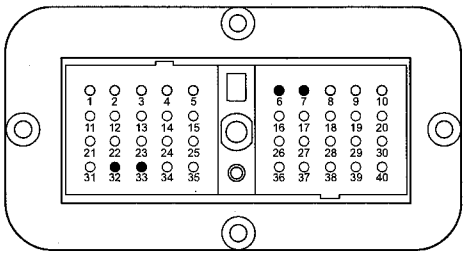


10 Speed/timing sensor supply (8v)

52 Speed/timing sensor (crankshaft side) signal

53 Speed/timing sensor (fuel pump side) signal

Extension harness connector



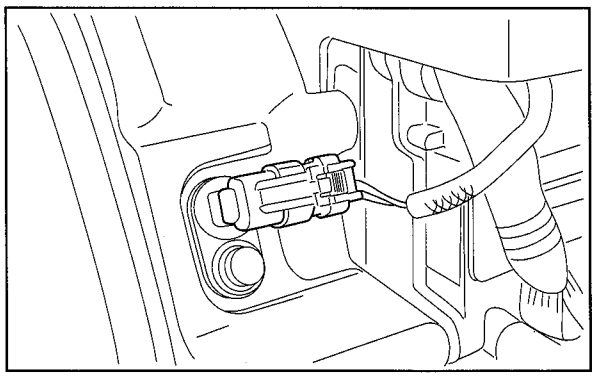
6 Speed/timing sensor (crankshaft side) supply (8v)

7 Speed/timing sensor (fuel pump side) supply (8v)

32 Speed/timing sensor (crankshaft side) signal

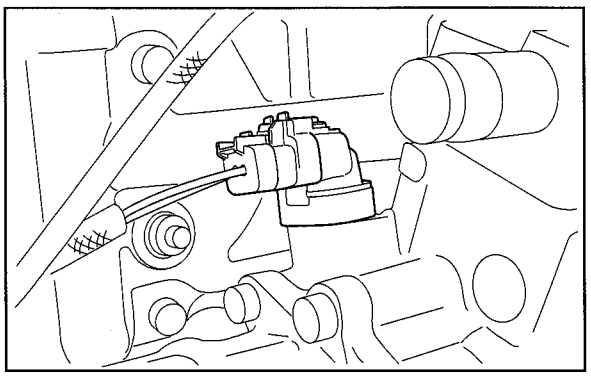
33 Speed/timing sensor (fuel pump side) signal

Speed/timing sensor pin locations



Speed/timing (crankshaft side) sensor

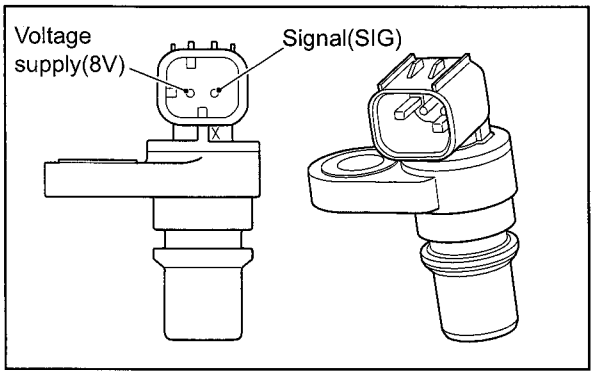
1 Speed/timing (crankshaft side) sensor



Speed/timing (fuel pump side) sensor

1 Speed/timing (fuel pump side) sensor

### 7.8.1 Test step 1. Inspect the electrical connectors and the harness




Typical example for the speed/timing sensor (crankshaft, fuel pump side)

(1) Turn the keyswitch to the OFF position.
(2) Thoroughly inspect the P2 connector, the extension harness connector and the suspect sensor connections. Refer to "Electrical connectors - inspect".
(3) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the suspect sensor connector and the sensor connections at the ECM. The wire connectors are shown in illustration.
(4) Check the screws for the ECM connector for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].
(5) Check the harness for abrasion and pinch points from the suspect sensor to the ECM.
(6) Check that the suspect sensor is installed correctly. Check that the suspect sensor is fully seated into the engine. Check that 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:

- If speed/timing (fuel pump side) sensor must be replaced, 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.

Verify that the repair has eliminated the fault.

### 7.8.2 Test step 2. Check for active diagnostic codes and recently logged diagnostic codes

(1) Turn the keyswitch to the OFF position.
(2) Connect the Mitsubishi ET to the diagnostic connector.
(3) Turn the keyswitch to the ON position. If the engine will start, then run the engine.
(4) Use the Mitsubishi ET 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:

- J190-08 Engine speed signal abnormal
- J723-08 Secondary engine speed signal abnormal

Results:

- J190-08 – Proceed to Test step 4.
- J723-08 – Proceed to Test step 3.
- Not OK – No active diagnostic codes or recently logged diagnostic codes are displayed.

### 7.8.3 Test step 3. Check the harness between the speed/timing (fuel pump side) sensor and the ECM

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the P2 connector. Disconnect the connector for the speed/timing (crankshaft side) sensor. Disconnect the connector for the speed/timing (fuel pump side) sensor.
(3) Check the resistance between P2:53 to the speed/timing (fuel pump side) sensor terminal 2. The resistance should be less than 2.0 Ω.
(4) Check the resistance between P2:10 to the speed/timing (fuel pump side) sensor terminal 1. The resistance should be less than 2.0 Ω.
(5) Repeat above proceduer (1) to (4) for the extension harness connector. Sensor signal is pin 33, +8 V supply is pin 7.

Expected result:

The readings agree with the values that are listed above.

Results:

- OK – The harness is not open circuit. Proceed to Test step 5.

• Not OK – The harness or the connector is an open circuit or high resistance.

Repair: Repair the faulty connectors or the harness. Replace the faulty connectors or the harness. Reconnect all sensor, ECM connector, and extension harness connector. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

Verify that the repair has eliminated the fault.

### 7.8.4 Test step 4. Check the harness between the speed/timing (crankshaft side) sensor and the ECM.

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P2 connector. Disconnect the connector for the speed/timing (crankshaft side) sensor. Disconnect the connector for the speed/timing (fuel pump side) sensor.

(3) Check the resistance between P2:52 to the speed/timing (crankshaft side) sensor terminal 2. The resistance should be less than 2.0 Ω.

(4) Check the resistance between P2:10 to the speed/timing (crankshaft side) sensor terminal 1. The resistance should be less than 2.0 Ω.

(5) Repeat above proceduer (1) to (4) for the extension harness connector. Sensor signal is pin 33, +8 V supply is pin 6.

Expected result:

The readings agree with the values that are listed above.

Results:

• OK – The harness is not open circuit. Proceed to Test step 6.

• Not OK – The harness is open circuit.

Repair: Repair the faulty connectors or the harness and/or replace the faulty connectors or the harness. Reconnect all sensor, ECM connector, and extension harness connector. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

Verify that the repair eliminates the fault.

### 7.8.5 Test step 5. Check that the connections and the wiring to the speed/timing (fuel pump side) sensor and the ECM are isolated from other power sources

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P2 connector. Disconnect the connector for the speed/timing (crankshaft side) sensor. Disconnect the connector for the speed/timing (fuel pump side) sensor.

(3) Measure the resistance from P2:53 speed/timing (fuel pump side) sensor signal input to all other pins on the P2. Measure the resistance from P2:53 speed/timing (fuel pump side) sensor signal input to the ground and battery + terminals. The resistance should be more than 20,000 Ω.

(4) Measure the resistance from P2:10 speed/timing sensor (+8 V supply) to all other pins on the P2. Measure the resistance from P2:10 speed/timing sensor (+8 V supply) to the ground and the battery+ terminals. The resistance should be more than 20,000 Ω.

(5) Repeat above proceduer (1) to (4) for the extension harness connector. Sensor signal is pin 33, +8 V supply is pin 7.

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, ECM connector, and extension harness connector. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

Verify that the repair eliminates the fault.

### 7.8.6 Test step 6. Check that the connections and the wiring to the speed/timing (crankshaft side) sensor and the ECM are isolated from the other power sources

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P2 connector. Disconnect the connector for the speed/timing (crankshaft side) sensor. Disconnect the connector for the speed/timing (fuel pump side) sensor.

(3) Check the resistance between P2:52 to each of the other pins on P2. Check the resistance between P2:52 to the ground and battery + terminals. The resistance should be more than 20,000 Ω.

(4) Check the resistance between P2:10 to each of the other pins on P2. Check the resistance between P2:10 to the ground and battery + terminals. The resistance should be more than 20,000 Ω.

(5) Repeat above proceduer (1) to (4) for the extension harness connector. Sensor signal is pin 32, +8 V supply is pin 6.

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, ECM connector, and extension harness connector. Ensure that all of the seals are correctly in place. Ensure that all connectors are correctly coupled.

Verify that the repair eliminates the fault.

### 7.8.7 Test step 7. Check if a replacement sensor eliminates the fault

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the suspect sensor and remove the suspect sensor from the engine.
(3) If a sensor must be replaced or a sensor must be reinstalled, complete all of the following tasks:
If speed/timing (fuel pump side) sensor must be replaced, 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.
(4) Turn the keyswitch to the ON position.
(5) Start the engine.
(6) Use the Mitsubishi ET in order to monitor the diagnostic codes.
(7) Verify that the replacement sensor has eliminated the fault.

Expected result:

The fault has been rectified.

Results:

• OK –If the faultis eliminated with the test sensor, reconnect the suspect sensor. If the fault returns with the suspect sensor, replace the suspect sensor.

Repair: Verify that the repair eliminates the fault.

• Not OK – The fault still exists. Proceed to Test Step 8.

### 7.8.8 Test step 8. Check if the replacement of the ECM eliminates the fault

(1) Temporarily connect a test ECM. The test ECM must be programmed with the correct software. All parameters should be set to the same value of the suspect ECM.
(2) Reconnect all connectors.
(3) Connect the Mitsubishi ET to the diagnostic connector.
(4) Turn the keyswitch to the ON position.
(5) Start the engine.
(6) Use the Mitsubishi ET in order to monitor the diagnostic codes.
(7) Verify that the replacement sensor has eliminated the fault.

Expected result:

The fault is eliminated.

Results:

• OK – If the fault is eliminated with the test ECM, reconnect the suspect ECM. If the fault returns with the suspect ECM, replace the suspect ECM.

Repair: Verify that the repair eliminates the fault.

• Not OK – The fault was not resolved with a test ECM.

Repair: Repeat this diagnostic process. If the fault persists, the fault may be a damaged timing ring. Check the timing ring and/or replace the timing ring.

Verify that the repair eliminates the fault.

## 7.9 Engine temperature sensor open or short circuit-test

System operation description:

Use this procedure under the following conditions:

This procedure covers open circuit diagnostic codes and short circuit diagnostic codes that are associated with the following sensors:

• Coolant temperature sensor
• Inlet 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.

• J110-03 Engine coolant temperature open/short to +batt
• J110-04 Engine coolant temperature short to ground
• J105-03 Inlet manifold air temperature open/short to +batt
• J105-04 Inlet manifold air temperature short to ground

The following background information is related to this procedure:

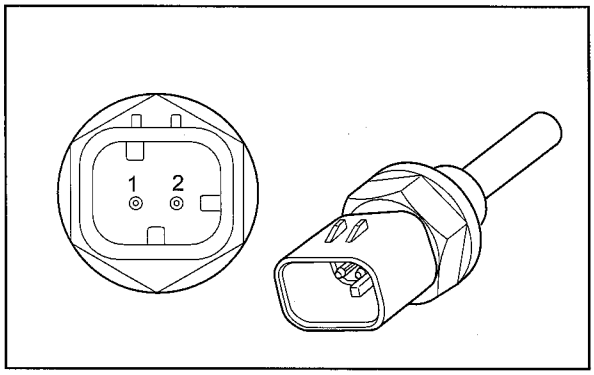
The troubleshooting procedures for the diagnostic codes of each temperature sensor are identical. The temperature sensors are sensors that have two terminals. The connector P2:37 ECM is the common connection for the engine temperature sensors. The sensor common connection is shared between the temperature sensors. The common line is connected to each sensor connector terminal 2. 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.

Table 14-14 P2/J2 pin connections

| Function | Sensor pin | Coolant temperature sensor | Inlet manifold temperature sensor |
|---|---|---|---|
| Signal | 1 | 43 | 42 |
| Sensor ground | 2 | 37 | 37 |

Table 14-15 Extension harness connector pin connections

| Function | Sensor pin | Coolant temperature sensor | Inlet manifold temperature sensor |
|---|---|---|---|
| Signal | 1 | 22 | 21 |
| Sensor ground | 2 | 16 | 16 |




Engine coolant temperature sensor and inlet manifold air temperature sensor

### 7.9.1 Test step 1. Verify all active diagnostic codes.

(1) Connect the Mitsubishi ET to the data link connector.

(2) Turn the keyswitch to the ON position.

Note: Wait at least 30 seconds for activation of the diagnostic codes.

(3) Use the Mitsubishi ET in order to verify if any of the following diagnostic codes are active or recently logged:

- J110-03 Engine coolant temperature open/short to +batt
- J110-04 Engine coolant temperature short to ground
- J105-03 Inlet manifold air temperature open/short to +batt
- J105-04 Inlet manifold air temperature short to ground

Expected result:

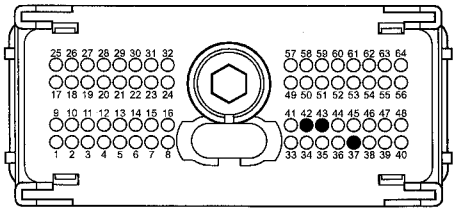
One or more of the preceding diagnostic codes are active or recently logged.

Results:

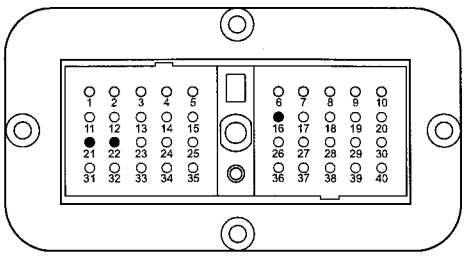
- Yes – Proceed to Test step 2.
- No

### 7.9.2 Test step 2. Inspect electrical connectors and wiring.

P2 ECM connector



Extension harness connector



| P2 ECM connector | | Extension harness connector | |
|---|---|---|---|
| 37 | Grourd (GND) temperatature sensor | 16 | Grourd (GND) temperatature sensor |
| 42 | Signal (SIG) inlet manifold air temperatature sensor | 21 | Signal (SIG) inlet manifold air temperatature sensor |
| 43 | Signal (SIG) coolant temperatature sensor | 22 | Signal (SIG) coolant temperatature sensor |

Temperature sensor pin locations

(1) Thoroughly inspect ECM engine harness connector P2, the extension harness connector and the suspect sensor connector.. Refer to "Electrical connectors - inspect".
(2) Perform a 45 N {4.6 kgf} [10 lbf] 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.
(3) 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.
(4) Check the screw for the ECM connector for the correct torque of 5.0 N·M {0.50 kgf·m} [3.7 lbf·ft].
(5) Check the harness for abrasions and for pinch points from the sensor to the ECM.
(6) Use the Mitsubishi ET to perform a"Wiggle test". The "Wiggle test" will identify intermittent connections.

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.

### 7.9.3 Test step 3. Verify that the diagnostic code is still active.

(1) Turn the keyswitch to the ON position.
Note: Wait at least 30 seconds for activation of the diagnostic codes.
(2) Access the "Active diagnostic code" screen on the Mitsubishi ET and check for active diagnostic codes.
(3) Determine if the problem is related to an open circuit diagnostic code or a short circuit diagnostic code.

Expected result:

A short circuit diagnostic code or an open circuit diagnostic code is active.

Results:

- OK - Short circuit – A short circuit diagnostic code is active at this time. Proceed to Test step 4.
- OK - Open circuit – An open circuit 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: By Using the Mitsubishi ET, perform a "Wiggle test". If faults are indicated then go to the appropriate procedure.

### 7.9.4 Test step 4. Disconnect the sensor in order to create an open circuit.

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the sensor connector of the sensor with the short circuit diagnostic code.
(3) Turn the keyswitch to the ON position.
Note: Wait at least 30 seconds for activation of the diagnostic codes.
(4) Access the "Active diagnostic code" screen of the Mitsubishi ET. Check for an active open circuit diagnostic code.

Expected result:

An open circuit diagnostic code for the disconnected sensor is now active.

Results:

- OK – A short circuit diagnostic code was active before disconnecting the sensor. An open circuit diagnostic code became active after disconnecting the sensor.

Repair: Refer to "Electrical connectors - inspect".
Inspect the seals of the connectors for damage.
Connect the sensor and verify that the fault returns. If the fault returns, the sensor is faulty.
Replace the sensor.
Remove all inactive diagnostic fault codes.

- Not OK – There is a short circuit between the sensor harness connector and the ECM. Leave the sensor disconnected. Proceed to Test step 6.

### 7.9.5 Test step 5. Create a short circuit between the signal and the common terminals at the sensor harness connector.

(1) Disconnect the suspect sensor connector for the coolant temperature sensor or disconnect the connector for the inlet manifold temperature sensor.
(2) Turn the keyswitch to the ON position.
Note: Wait at least 30 seconds for the activation of any diagnostic fault codes.
(3) Fabricate a jumper wire long enough. Crimp a terminal to both ends of the wire.
(4) Monitor the "Active diagnostic code" screen on the Mitsubishi ET before installing the jumper wire and after installing the jumper wire.

(5) Install the jumper on the engine harness connector for the suspect sensor, connector for the coolant temperature sensor and connector for the inlet 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 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:

Temporarily connect the suspect sensor.

If the diagnostic code remains active, replace the sensor.

Verify that the repair eliminates the fault.

Clear all inactive diagnostic codes.

• Not OK – The open circuit 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.

### 7.9.6 Test step 6. Check the operation of the ECM by creating an open and a shortcircuit at the ECM connector.

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P2/J2 ECM connector.

(3) Thoroughly inspect both halves of the connector for signs of corrosion or moisture. Refer to "Electrical connectors - inspect".

(4) Turn the keyswitch to the ON position. Use the Mitsubishi ET in order to monitor the "Active diagnostic code" screen. Wait at least 30 seconds for activation of the code.

An open circuit diagnostic code should be active for the suspect sensor.

Note: When P2 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. Direct your attention to the diagnostic codes for the suspect sensors only.

(5) Turn the keyswitch to the OFF position.

(6) Fabricate a jumper wire long enough. Crimp a terminal to both ends of the wire.

(7) Monitor the "Active diagnostic code" screen on the Mitsubishi ET before installing the jumper wire and after installing the jumper wire.

(8) Remove the suspect sensor signal pin from the connector P2, either pin P2:42 for the inlet manifold temperature sensor or P2:43 for the coolant temperature sensor. Remove the P2:37 sensor common connector. Install the jumper on the connector P2. Install one end of the jumper at the suspect sensor signal pin. Install the other end of the jumper to P2:37 common connection for the sensors. Reassemble the P2 connector to the ECM. Use the Mitsubishi ET in order to check the diagnostic codes. Wait at least 30 seconds for activation of the short circuit diagnostic code.

Note: The open circuit 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 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 – Proceed to Test step 7.

• Not OK

Repair: The ECM does not operate correctly.

• Temporarily connect a test ECM.

Note: The test ECM should be programmed with the correct software. All parameters should be set to the same value of the suspect ECM.

• Remove all jumpers and reconnect all connectors.

• If the fault is eliminated with the test ECM, reconnect the suspect ECM and verify that the fault returns.

• If the fault returns replace the suspect ECM. Refer to "Replacing the ECM".

• Verify that the repair eliminates the fault.

### 7.9.7 Test step 7. Bypass the harness wiring between the ECM and the sensor connector.

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P2/J2 connector for the ECM harness, and the suspect sensor connector.

(3) Remove the sensor signal wire from the P2 connector.

(4) Remove the signal wire (terminal 1) from the sensor connector on the engine harness.

(5) Fabricate a jumper wire that is long enough to reach from the ECM to the sensor connector with sockets on both ends.

(6) 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.
(7) Reconnect the connector for the ECM harness and the sensor connector.
(8) Turn the keyswitch to the ON position.
(9) Use the Mitsubishi ET in order 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 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) Verify that the repair eliminates the fault.

• Not OK – The most likely cause is an intermittent fault.

Repair: By using the Mitsubishi ET, perform a "Wiggle test". If no fault is found, restart this procedure and carefully perform each step.

### 7.10 Fuel 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:

• J1347-05 Fuel pump solenoid open circuit
• J1347-06 Fuel pump solenoid short to ground

Note: The fuel pump is installed on the engine at the factory. The fuel pump is not serviceable part. The fuel pump delivers fuel into the common rail at very high pressure.

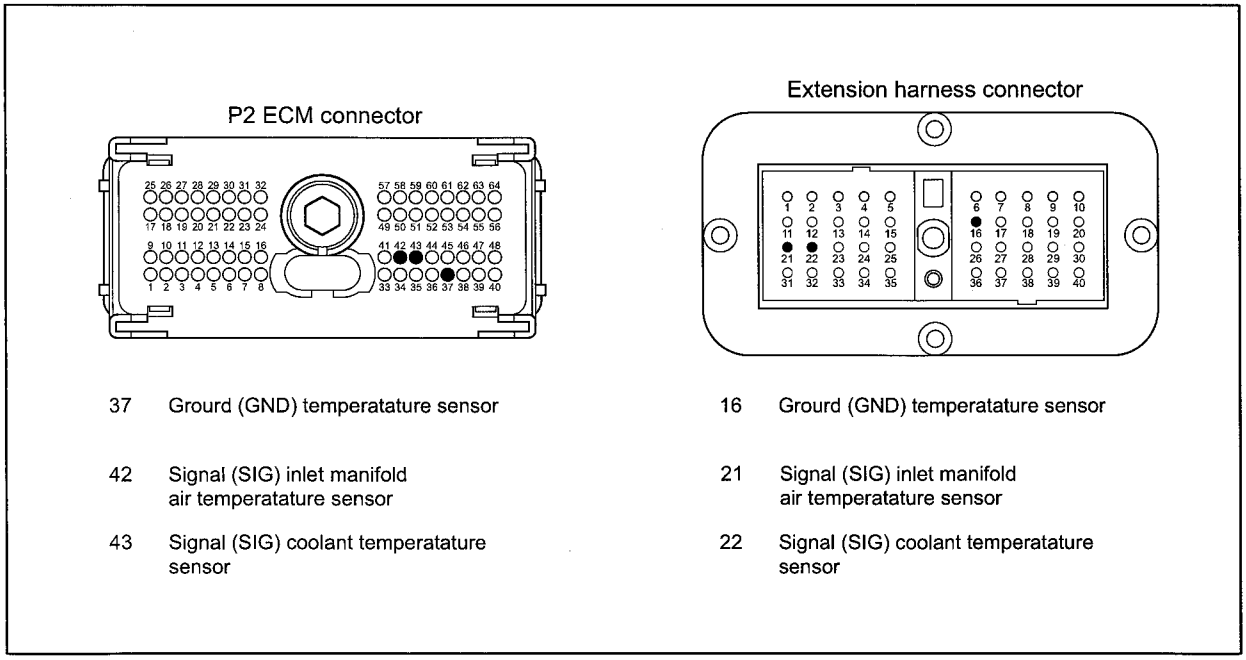
Use this procedure to troubleshoot the system when there is an active diagnostic code or if a diagnostic code can easily be activated or when another procedure has directed you here.

The fuel pump solenoid is used to control the output from the fuel pump. The solenoid receives an electrical supply from the ECM. The fuel pump solenoid is then energized when the fuel is required to be pumped into the common rail. Varying the duration and the timing of the solenoid controls the fuel delivery from the fuel pump.

When the fuel pump solenoid is deactivated, the fuel that is not sent to the common rail is returned to the fuel tank.

The fuel pump solenoid forms part of the closed loop control system for the common rail pressure in conjunction with the common rail pressure sensor, ECM and the software. The common rail pressure sensor measures the fuel pressure in the high pressure common rail. The common rail pressure sensor signal is processed by the ECM and software. The measured pressure is compared to the desired common rail pressure for the given engine operating conditions.

If the fuel pump solenoid fails, it is likely that the fuel will not be pumped into the high pressure common rail and engine shutdown or failure to start the engine is expected. No common rail pressure can be observed on the status screen of the Mitsubishi ET.




Fuel pump solenoid pin locations

### 7.10.1 Test step 1. Inspect the electrical connectors and the harness

**⚠ WARNING**

Electrical shock hazard. The fuel pump solenoid uses 63 to 73 volts.

(1) Turn the keyswitch to the OFF position.
(2) Thoroughly inspect the harness connector P2/J2, the extension harness connector, and the suspect connector. Refer to "Electrical connectors - inspect" for details.
(3) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the solenoid connector, the P2 connector pins 25 and 26, and extension harness connector pin 9 and 10 that are associated with the fuel pump solenoid. Refer to illustration.
(4) 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.
(5) Perform a "Wiggle test" by using the Mitsubishi ET 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.

Verify that the repair has eliminated the fault.

### 7.10.2 Test step 2. Check for active diagnostic codes

(1) Connect the Mitsubishi ET to the diagnostic connector.
(2) Turn the keyswitch to the ON position.
(3) Use the Mitsubishi ET to verify if any of the following diagnostic codes are active or recently logged:

- J1347-05 Fuel pump solenoid open circuit
- J1347-06 Fuel pump solenoid short to ground

Expected result:

One or more of the following diagnostic codes are active or recently logged:

- J1347-05 Fuel pump solenoid open circuit
- J1347-06 Fuel pump solenoid short to ground

Results:

- J1347-05 – Proceed to Test step 3.
- J1347-06 – Proceed to Test step 5.
- Not OK – No active diagnostic codes or recently logged diagnostic codes are displayed.

### 7.10.3 Test step 3. Check the harness for an open circuit

(1) Turn the keyswitch to the OFF position.
(2) Disconnect P2 from the ECM.
(3) Measure the resistance between P2:25 and P2:26.
(4) Repeat above proceduer (1) to (3) for the extension harness connector. Signal is pin 9, return is pin 10.

Expected result:

The resistance is less than 2 Ω.

Results:

- OK – The harness and the solenoid are not an open circuit.

Repair: The diagnostic code J1347-05 may have been set as a safety feature. The safety feature has been set if the fuel pump cannot reach operating pressure. Check the high pressure fuel system for leaks. A mechanical relief valve is installed in the high pressure common rail. Check that there is no flow of fuel from the mechanical relief valve.

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.

### 7.10.4 Test step 4. Check the fuel pump solenoid for an open circuit

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the fuel pump solenoid connector from the fuel pump solenoid.
(3) Measure the resistance of the fuel pump solenoid.

Expected result:

The resistance is less than 1 Ω.

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 Mitsubishi ET in order to perform the "fuel pump solenoid-test".

Verify that the repair eliminated the fault.

- Not OK – The fuel pump solenoid is faulty.

Repair: Temporarily connect a new fuel pump to the harness, but do not install the fuel pump to the engine.

Reconnect P2 and extension harness connector. Check the screw for the ECM connector for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].
Use the Mitsubishi ET in order to perform the "fuel pump solenoid-test".
Verify that the repair eliminated the fault.
If the diagnostic code has been cleared, then install the new fuel pump to the engine.
Verify that the repair eliminates the fault.

### 7.10.5 Test step 5. Check the ECM and the harness

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the connector from the fuel pump solenoid.
(3) Insert a jumper and create a short circuit to connetor.
(4) Turn the keyswitch to the ON position.
(5) Use the Mitsubishi ET in order to perform the fuel pump solenoid-test.
(6) Use the Mitsubishi ET in order to monitor the status screen.

Expected result:
A J1347-06 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 6.
- Not OK – The ECM is suspect. Proceed to Test step 8.

### 7.10.6 Test step 6. Check the fuel pump solenoid for a short circuit

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the fuel pump solenoid connector.
(3) Turn the keyswitch to the ON position.
(4) Use the Mitsubishi ET in order to perform the fuel pump solenoid-test.

Expected result:
A low current diagnostic code is displayed. The high current diagnostic code is not displayed.
Results:
- OK – A low current diagnostic code is displayed. The harness has no shorts to supply or ground. The fuel pump solenoid is faulty.

Repair: Temporarily connect a new fuel pump to the harness, but do not install the fuel 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 {0.50 kgf·m} [3.7 lbf·ft].
Use the Mitsubishi ET in order to perform the "fuel pump solenoid-test".
Verify that the repair eliminates the fault.
If the diagnostic code has been cleared, then install the new fuel pump to the engine.
Verify that the repair eliminates the fault.
- Not OK – The harness is a short circuit or the ECM is a short circuit. Proceed to Test Step 7.

### 7.10.7 Test step 7. Check the fuel pump solenoid harness for a short circuit

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the fuel pump solenoid from the connector.
(3) Measure the resistance between P2:26 and P2:25.
(4) Measure the resistance between P2:25 and voltage +.
(5) Measure the resistance between P2:25 and the voltage (-).
(6) Measure the resistance between P2:26 and voltage +.
(7) Measure the resistance between P2:26 and voltage (-).
(8) Repeat above proceduer (1) to (7) for the extension harness connector. Signal is pin 9, and return is pin 10.

Expected result:
The resistance is greater than 20,000 Ω.
Results:
- OK – The harness has no short circuit to supply or ground. The ECM is suspect. Proceed to Test step 8.
- Not OK – The harness has a short circuit.

Repair: Repair the harness and connectors or replace the faulty harness and connectors.
Reconnect the sensor connector P2 and extension harness connector.
Turn the keyswitch to the ON position.
Use the Mitsubishi ET in order to perform the "fuel pump solenoid-test".
Verify that the repair has eliminated the fault.

### 7.10.8 Test step 8. Check the ECM function

(1) Temporarily connect a test ECM. The test ECM should be programmed with the correct software. All parameters should be set to the same value of the suspect ECM.
(2) Replace all connectors.
(3) Connect the Mitsubishi ET to the diagnostic connector.
(4) Turn the keyswitch to the ON position.
(5) Use the Mitsubishi ET in order to monitor the status screen.
(6) Use the Mitsubishi ET in order to perform the fuel pump solenoid-test.
(7) Monitor the status screen on the Mitsubishi ET.

Expected result:
The fault is eliminated.
Results:

- OK – If the fault is eliminated with the test ECM, reconnect the suspect ECM. If the fault returns with the suspect ECM, replace the ECM. Verify that the repair eliminates the fault.

### 7.11 Ignition keyswitch circuit and battery supply circuit-test

System operation description:

This procedure tests that the correct voltage is being supplied to the ECM.

Use this procedure to troubleshoot the system when one of the following diagnostic codes is active or easily repeated:

- J168-00 System voltage high
- J168-01 System voltage low
- J168-02 System voltage intermittent/erratic
- J158-02 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).

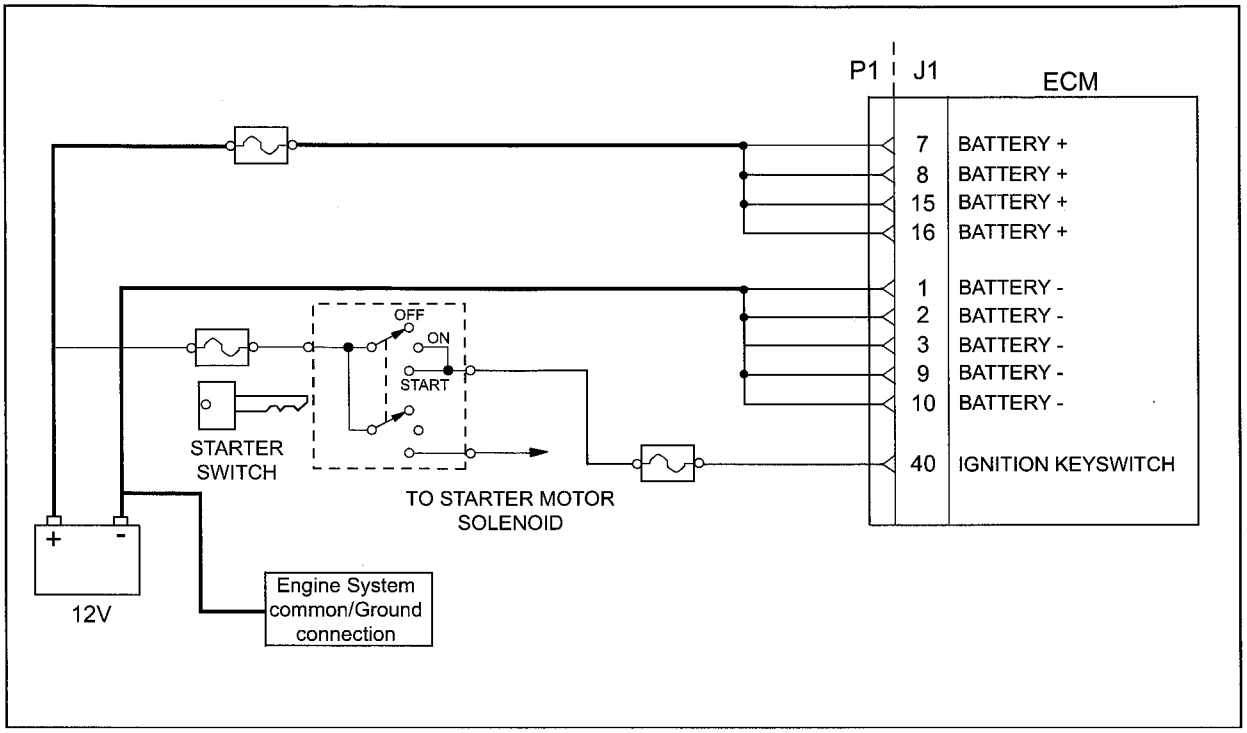
Some applications may be equipped with an engine protection shutdown system or an idle timer shutdown system that interrupts electrical power to the keyswitch. The engine protection shutdown system can be an aftermarket device and the idle timer shutdown system can be external to the ECM. Some of these 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.

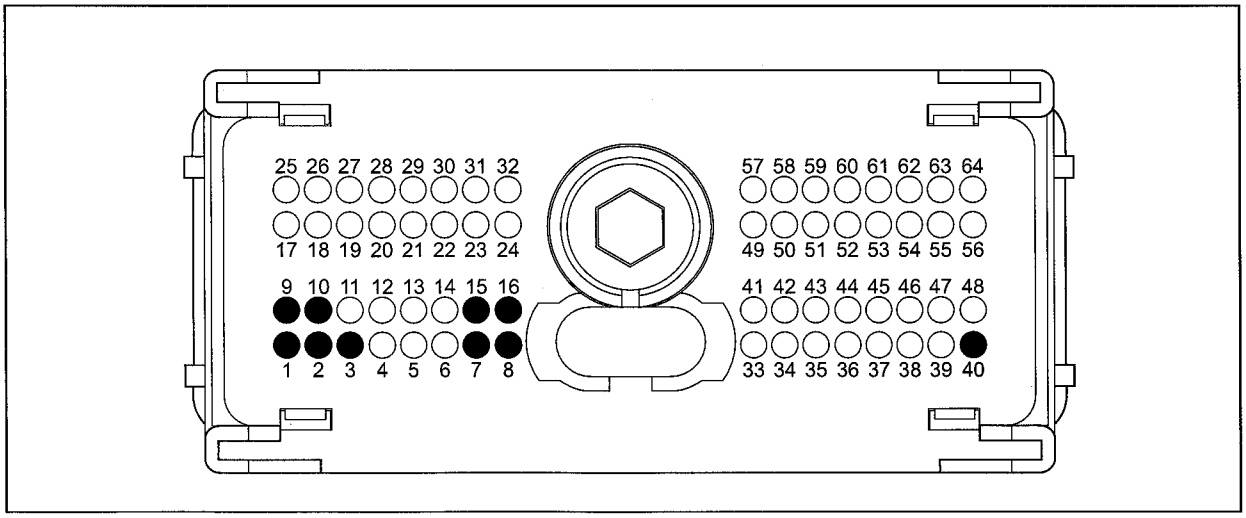
Keep in mind that these devices may be the cause of intermittent power to the ECM. These devices may also shut down the engine.

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 Mitsubishi ET, 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 Mitsubishi ET if the keyswitch is in the OFF position. This is normal.

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. If the symptoms disappear with the bypass wiring, the application wiring is the cause of the problem. 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.




Schematic for the ignition keyswitch and battery supply circuit




Typical rear view of the pin locations for the ignition key switch 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 (GND)
16 Battery ground )GND)
40 Ignition keyswitch

### 7.11.1 Test step 1. Inspect electrical connectors and wiring

(1) Thoroughly inspect P1 connector, the battery connections and the connections to the keyswitch. Refer to "Electrical connectors - inspect" for details.

(2) Perform a 45 N {4.6 kgf} [10 lbf] 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)

(3) Use the Mitsubishi ET 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

(4) Check the ECM connector for the correct torque of 5.0 N·M {0.50 kgf·m} [3.7 lbf·ft].

(5) 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 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.

Verify that the repair eliminates the fault.

### 7.11.2 Test step 2. Check for active diagnostic codes or logged diagnostic codes

(1) Connect Mitsubishi ET to the diagnostic connector.

(2) Turn the keyswitch to the ON position.

(3) Monitor the active diagnostic code screen on Mitsubishi ET. 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:

- J168-00 System voltage high
- J168-01 System voltage low
- J168-02 System voltage intermittent/erratic
- J158-02 Ignition keyswitch loss of signal

Note: A J158-02 code can be generated by rapidly cycling the keyswitch. If the J158-02 keyswitch fault is logged but not active, this may be the cause.

Results:

- OK – A J168-02 diagnostic code or a J158-02 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 problem is intermittent, refer to "Electrical connectors - inspect".

### 7.11.3 Test step 3. Check the battery voltage at the ECM connector

(1) Disconnect the P1 connector from the ECM connector.

(2) Turn the keyswitch to the ON position.

(3) Measure the voltage between P1:7 (Unswitched +battery) and P1:1 (-battery).

(4) Measure the voltage between P1:8 (Unswitched +battery) and P1:2 (-battery).

(5) Measure the voltage between P1:15 (Unswitched +battery) and P1:9 (-battery).

(6) Measure the voltage between P1:16 (Keyswitch) and P1:10 (-battery).

(7) Measure the voltage between P1:40 (Keyswitch) and P1:3 (-battery).

(8) Turn the keyswitch to the OFF position.

Expected result:

The measured voltage is a constant 22.0 to 27.0 VDC 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 "Electrical connectors - inspect".

- 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.

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 on P1: 7, 8, 15, 16 – No voltage was 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 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 - Battery voltage is out of range – Proceed to Test Step 4.

### 7.11.4 Test step 4. Check the batteries

(1) Measure no-load battery voltage at the battery terminals.

(2) Load test the batteries. Use a suitable battery load tester.

Expected result:

The batteries pass the load test. The measured voltage is at least 22.0.

Results:

- OK – The batteries pass the load test. The measured voltage is at least 22.0.

Repair: Troubleshoot the application harness and repair the application harness, as required.

Verify that the repairs eliminate the fault.

- Not OK – The batteries do not pass the load test. The measured voltage is less than 22.0.

Repair: Recharge or replace the faulty batteries.

Verify that the repair eliminates the fault.

### 7.11.5 Test step 5. Bypass the application harness

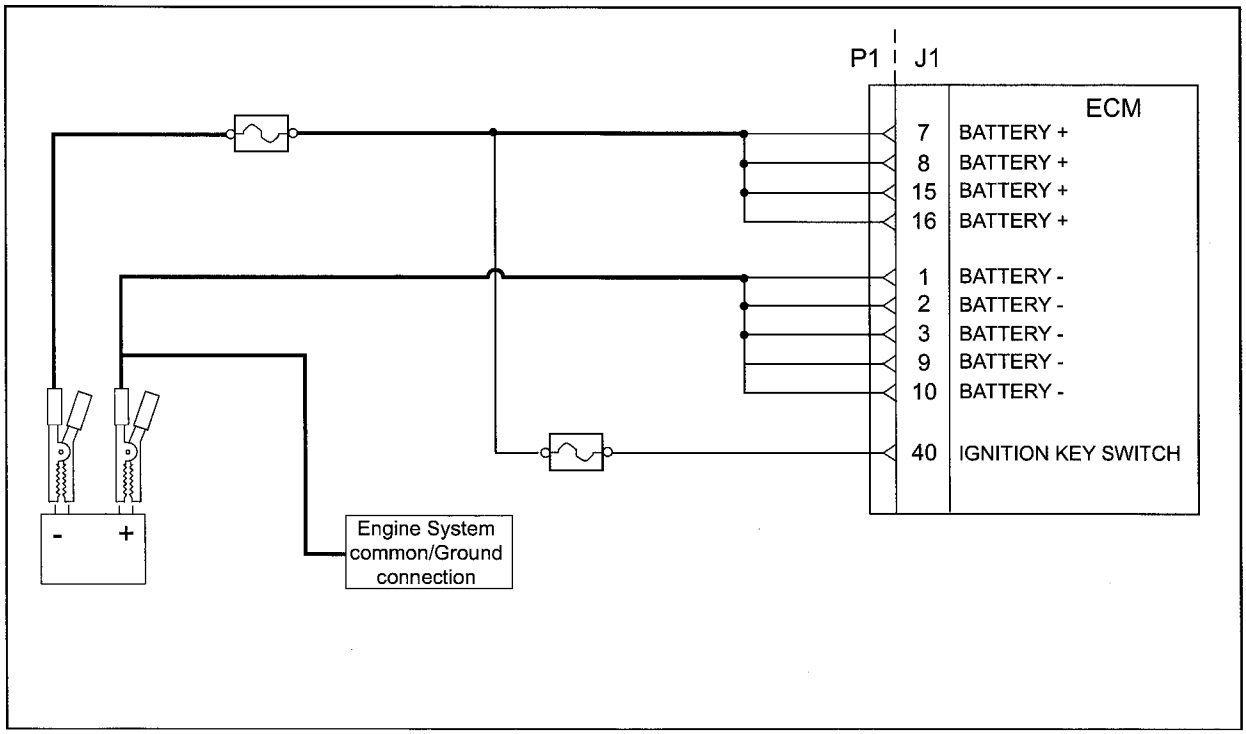
**⚠ WARNING**

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.

**⚠ CAUTION**

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: This 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 problem is interruptions in battery power to the ECM or to the keyswitch circuit.




Schematic for the bypass application harness

(1) Turn the keyswitch to the OFF position.

(2) Disconnect the P1 connector from the ECM connector.

(3) Connect a bypass harness to the ECM.

(4) Remove the fuses from the +battery wire of the bypass harness and connect the +battery and the - battery wires directly to the battery terminals.

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.

(5) Connect the Mitsubishi ET 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.

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 symptoms disappear when the bypass harness is installed. Also, the symptoms return 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.
- Not OK

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, temporarily connect a test ECM. Remove all jumpers and replace all connectors. Recheck the system for active diagnostic codes and repeat the Test step. If the fault is resolved with the test ECM, reconnect the suspect ECM. If the fault returns with the suspect ECM, replace the ECM.

Verify that the repair eliminates the fault.

## 7.12 Injector data incorrect-test

System operation description:

Use this procedure under the following situation:

Use this procedure for any of the following diagnostic codes:

- J651-2 Cylinder #1 injector data incorrect
- J652-2 Cylinder #2 injector data incorrect
- J653-2 Cylinder #3 injector data incorrect
- J654-2 Cylinder #4 injector data incorrect

The following background information is related to this procedure:

The engine has electronic unit injectors that are electronically controlled. The ECM sends a 24 to 108 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 codes are not programmed:

- J631-02 Personality module mismatch

Refer to "Injector trim file" for further information.

If the ECM is replaced then the replacement ECM must be correctly programmed. Refer to "Replacing the ECM" for further information.

Use the Mitsubishi ET 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.

### 7.12.1 Test step 1. Check for diagnostic codes that are related to this procedure.

(1) Connect the Mitsubishi ET to the diagnostic connector.

(2) Turn the keyswitch to the ON position.

(3) Check for logged diagnostic codes that are related to this procedure.

(4) Make a note of the logged diagnostic codes.

Expected result 1

One or more of the following diagnostic codes are logged:

- J651-2 Cylinder #1 injector data incorrect
- J652-2 Cylinder #2 injector data incorrect
- J653-2 Cylinder #3 injector data incorrect
- J654-2 Cylinder #4 injector data incorrect

Expected result 2

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 these 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 Injectors that share a common supply indicate a diagnostic code. Proceed to Test step 3.
- Not OK – No related diagnostic codes are logged.

### 7.12.2 Test step 2. Check the faulty cylinder numbers

(1) Use the Mitsubishi ET in order to make a note of the logged diagnostic codes.

(2) 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.
- Not OK – The diagnostic codes indicate the cylinder numbers that have faulty injectors.

Repair: Replace the faulty injectors. Use the Mitsubishi ET in order to program the replacement injector trim files . Refer to "Injector trim file" for further information.

Use the Mitsubishi ET in order to clear the logged codes.

Turn the keyswitch to the ON position.
Start the engine.
Use the Mitsubishi ET in order to perform the "Fuel system verification-test". If the cylinders indicate "PASS", then the fault has been cleared.
Verify that the repair eliminates the fault.

### 7.12.3 Test step 3. Check the ECM

(1) Temporarily connect a test ECM.
Note: The test ECM must be correctly programmed. Refer to "Replacing the ECM".
(2) Use the Mitsubishi ET 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.
(3) If the test ECM eliminates the fault, reconnect the suspect ECM.
(4) Use the Mitsubishi ET in order to perform the "Fuel system verification-test".

Expected result:
The test ECM clears the fault. Using the Mitsubishi ET in order to perform the "Fuel system verification-test" with the suspect ECM indicates a "FAIL" condition.
Results:
- OK – The test ECM eliminates the fault and the suspect ECM indicates a "FAIL" condition. Replace the faulty ECM. Verify that the repair eliminates the fault.
- Not OK – The test ECM did not eliminate the fault. Proceed to Test step 2.

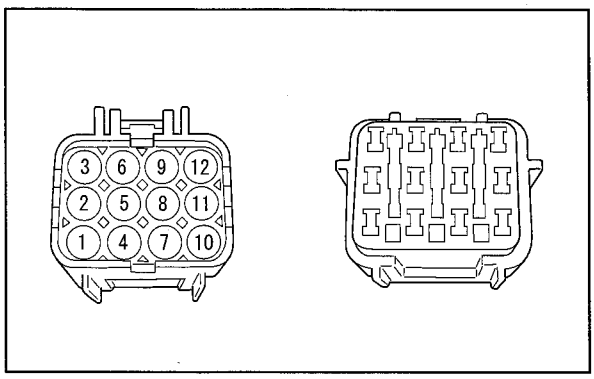
## 7.13 Injector solenoid circuit-test

System operation description:
Use this procedure to troubleshoot any suspect problems with the injector solenoids.
Use this procedure for the following diagnostic codes:
- J651-5 Cylinder #1 injector open circuit
- J651-6 Cylinder #1 injector short
- J652-5 Cylinder #2 injector open circuit
- J652-6 Cylinder #2 injector short
- J653-5 Cylinder #3 injector open circuit
- J653-6 Cylinder #3 injector short
- J654-5 Cylinder #4 injector open circuit
- J654-6 Cylinder #4 injector short

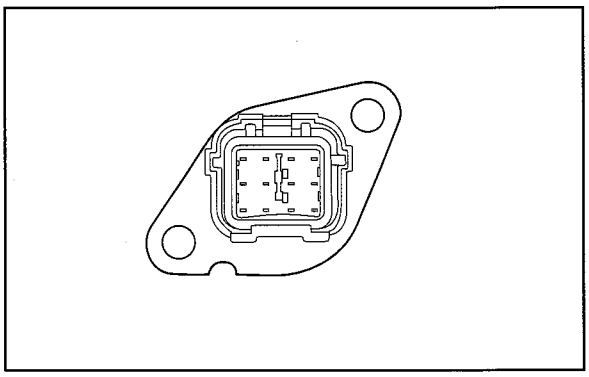
Perform this procedure under conditions that are identical to the conditions that exist when the fault occurs. Typically, faults with the injector solenoid occur when the engine is warmed up and/or when the engine is under vibration (heavy loads).
These engines have electronic unit injectors that are mechanically actuated and electronically controlled. The ECM sends a 24 to 108 volt pulse to each injector solenoid. The pulse is sent at the correct time and at the correct duration for a given engine load and speed. The solenoid is mounted on top of the fuel injector body.
If an open is detected in the solenoid circuit, a diagnostic code is generated. The ECM continues to try to fire the injector. If a short 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 shortcircuit remains this sequence of events will be repeated until the fault is corrected.

"Injector solenoid-test"
Use the "Injector solenoid-test" on the Mitsubishi ET 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 Mitsubishi ET will indicate the status of the solenoid as "OK", "Open", or "Short". Due to the use of a shared supply, a short circuit in the wire that is used as a supply for the injector solenoid will cause two cylinders to have diagnostic codes.

"Cylinder cutout-test"
Use the "Cylinder cutout test" on the Mitsubishi ET to diagnose a malfunctioning injector while the engine is running. All active diagnostic codes must be repaired before running the "Cylinder cutout test". When a good injector is cut out, the "Fuel position" should change. The change in the fuel position is caused by the other injectors that are compensating for the cut out injector. If a malfunctioning injector is cut out, the "Fuel position" will not change. The "Cylinder cutout test" is used to isolate the malfunctioning injector in order to avoid replacement of good injectors.

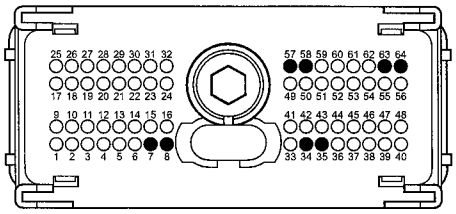



Typical example of the injector harness connector

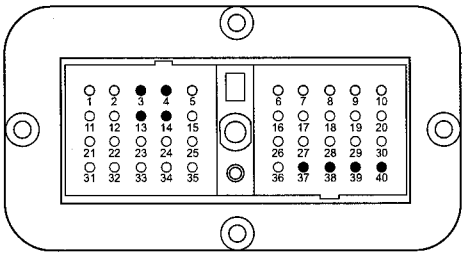


Typical example of the cylinder head mounted connector

P2 ECM connector




Extension harness connector




| P2 ECM connector | | Extension harness connector | |
|---|---|---|---|
| 7 | Injector cylinder (Number2 return) | 3 | Injector cylinder (Number2 return) |
| 8 | Injector cylinder (Number3 return) | 4 | Injector cylinder (Number3 return) |
| 34 | Injector cylinder (Number4 return) | 13 | Injector cylinder (Number4 return) |
| 35 | Injector cylinder (Number1 return) | 14 | Injector cylinder (Number1 return) |
| 57 | Injector cylinder (Number1) | 37 | Injector cylinder (Number1) |
| 58 | Injector cylinder (Number4) | 38 | Injector cylinder (Number4) |
| 63 | Injector cylinder (Number2) | 39 | Injector cylinder (Number2) |
| 64 | Injector cylinder (Number3) | 40 | Injector cylinder (Number3) |

Injector solenoid pin locations

### 7.13.1 Test step 1. Inspect electrical connectors and wiring

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Thoroughly inspect connector P2 and extension harness connector. Thoroughly inspect the connectors at the

injector harness. Refer to "Electrical connectors inspect" for details.

(3) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the ECM connector that are associated with injector solenoids.

(4) Check the screw for the ECM connector for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].

(5) 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 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.

Verify that the repair eliminates the fault.

### 7.13.2 Test step 2. Check for logged diagnostic codes that are related to the injector solenoids

(1) Connect the Mitsubishi ET to the diagnostic connector.

(2) Turn the keyswitch to the ON position.

(3) Check for logged diagnostic codes that are related to the injector solenoids on the Mitsubishi ET.

Expected result:

One or more diagnostic codes that are related to the injector solenoids have been logged:

- J651-5 Cylinder #1 injector open circuit
- J651-6 Cylinder #1 injector short
- J652-5 Cylinder #2 injector open circuit
- J652-6 Cylinder #2 injector short
- J653-5 Cylinder #3 injector open circuit
- J653-6 Cylinder #3 injector short
- J654-5 Cylinder #4 injector open circuit
- J654-6 Cylinder #4 injector short

Results:

- OK – One or more diagnostic codes have been logged. Proceed to Test step 4.
- Not OK – No diagnostic codes have been logged. proceed to Test step 3.

### 7.13.3 Test step 3. Check the variation of the injectors between cylinders

(1) Start the engine.

(2) Allow the engine to warm up to normal operating temperature.

(3) After the engine is warmed to operating temperature, access the "Cylinder cutout test" by accessing the following display screens in order:
"Diagnostics"
"Diagnostic Tests"
"Cylinder cutout test"

(4) Set the engine speed to 1000 ± 20 $min^{-1}$.

(5) Select the start button at the bottom of the screen for the cylinder cutout test on the Mitsubishi ET.

(6) Select the"1 cylinder cutout test".

(7) 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 "1 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.

(8) 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 Mitsubishi ET.

Results:

- OK – All cylinders indicate "OK".

If a diagnostic code results from running the cylinder cutout test, proceed to Test step 4.

- Not OK – One or more cylinders displayed "Not OK" during the test. Proceed to Test Step 4.

### 7.13.4 Test step 4. Use the "Injector solenoid-test"

(1) Start the engine.

(2) Allow the engine to warm up to the normal operating temperature.

(3) Stop the engine.

(4) Turn the keyswitch to the ON position.

(5) Access the "Injector solenoid-test" by accessing the following display screens in order:
"Diagnostics"
"Diagnostic tests"
"Injector solenoid-test"

(6) 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 solenoids to be heard while the engine is off in order to determine that the circuit is functioning correctly.

(7) As each solenoid is energized by the ECM, an audible click can be heard at the valve cover.

(8) Perform the "Injector solenoid-test" at least two times.

Expected result:

All cylinders indicate "OK".

Results:

- OK – There is not an electronic fault with the injectors at this time.
- Open – Note the cylinders that indicate "Open". Proceed toTest step 5.
- Short – Note the cylinders that indicate "Short". Proceed toTest step 8.

### 7.13.5 Test step 5. Check the harness between the ECM and the injector harness for an open circuit

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Disconnect the connectors from the injector harness.

(3) Turn the keyswitch to the ON position.

(4) Fabricate a jumper wire long enough with terminals on both ends of the wire.

(5) 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.

(6) Perform the "Injector solenoid-test" at least two times.

(7) Repeat this test for each suspect injector. Stop the "Injector solenoid-test" before handling the jumper wires.

Expected result:

Mitsubishi ET displays "Short" for the cylinder with the jumper wire.

Results:

- OK – The harness between the ECM and the injector harness is OK. Proceed to Test step 6.
- Not OK – There is a fault between the ECM and the injector harness. Proceed to Test step 7.

### 7.13.6 Test step 6. Check the injector harness under the rocker cover

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Remove the rocker cover.

(3) Disconnect the harness from the suspect injector. Disconnect the harness from the injectors that shares the same supply circuit as the suspect injector.

Note: 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 two injectors that share a common supply indicate "Open", the open circuit is probably caused by a faulty ECM.

(4) Thoroughly clean the terminals on two injectors and on the harness connectors.

(5) Exchange the harness between the two injectors that share the common driver.

(6) Turn the keyswitch to the ON position.

(7) 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 rocker cover.

Repair: Repair the injector harness or replace the injector harness under the rocker cover.

Verify that the repair eliminates the fault.

- Not OK – The injector may be faulty.

Repair: Replace the faulty injector.

Restore the wiring to the correct injectors.

Perform the "Injector solenoid-test".

Verify that the repair eliminates the fault.

### 7.13.7 Test step 7. Check the ECM for an open circuit

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Disconnect connector P2 from the ECM.

(3) 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.

(4) Reinstall connector P2 to the ECM.

(5) Turn the keyswitch to the ON position.

(6) Perform the "Injector solenoid-test" at least two times.

Expected result:

Mitsubishi ET displays "Short" for the cylinder with the jumper wire.

Note: Shorting a shared supply will affect the status of two injectors. Ignore the status of the other injectors that are on the shared shared supply.

Results:

• OK – The ECM is OK.

Repair: If two injectors that share a supply indicate "Open", the open circuit is probably caused by a faulty ECM.

Repair the engine harness or replace the engine harness, as required.

Verify that the repair eliminates the fault.

• Not OK – There may be a fault with the ECM.

Repair: Temporarily connect a test ECM.

Remove the jumper wire from connector P2 and reinstall the injector wires.

Perform the "Injector solenoid-test".

If the test ECM fixes the fault, reconnect the suspect ECM.

If the fault returns with the suspect ECM, replace the ECM.

Verify that the repair eliminates the fault.

### 7.13.8 Test step 8. Check the harness between the ECM and the injector harness for a short circuit

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximu 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Disconnect the connectors from the injector harness.

(3) Turn the keyswitch to the ON position.

(4) Perform the "Injector solenoid-test" at least two times.

Expected result:

All cylinders indicate "Open".

Results:

• OK – All cylinders indicate "Open". Proceed to Test step 10.

• Not OK – One or more cylinders indicate "Short". Note the cylinders that indicate "Short". Proceed to Test step 9.

### 7.13.9 Test step 9. Check the ECM for a short circuit

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Disconnect connector P2 from the ECM and check for evidence of moisture entry.

(3) Turn the keyswitch to the ON position.

(4) Perform the "Injector solenoid-test" at least two times.

Expected result:

All cylinders indicate "Open" 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 these 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.

Verify that the repair eliminates the fault.

• Not OK – There may be a fault with the ECM.

Repair: Temporarily connect a test ECM.

Perform the "Injector solenoid-test".

If the test ECM fixes the fault, reconnect the suspect ECM.

If the fault returns with the suspect ECM, replace the ECM.

Verify that the repair eliminates the fault.

### 7.13.10Test step 10. Check the injector harness under the rocker cover for a short circuit

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum 108 volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Remove the valve cover.

(3) 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.

(4) Turn the keyswitch to the ON position.

(5) Perform the "Injector solenoid-test" at least two times.

Expected result:

All of the injectors that were disconnected indicate "Open".

Results:

- OK – All of the injectors that were disconnected indicate "Open".

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 "Short".

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 rocker cover.

Verify that the repair eliminates the fault.

### 7.13.11Test step 11. Check for a short circuit in the return wire

**⚠ WARNING**

Electrical shock hazard. The electronic unit injector system uses maximum volts.

(1) Turn the keyswitch to the OFF position. A strong electrical shock hazard is present if the keyswitch is not turned OFF.

(2) Disconnect the connector P2 from the ECM.

(3) 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 Ω.

Results:

- OK – The resistance is greater than 10 Ω.

Repair: Reconnect connector P2.

Replace the faulty injector.

Perform the "Injector solenoid-test".

Verify that the repair eliminates the fault.

- Not OK – There is a short in the return line.

Repair: Disconnect the connectors from the injector harness. Measure the resistance of the return wire between connector P2 and the engine ground stud.

If the resistance is less than 10 Ω, the fault is in the return wire between the ECM and the valve cover base.

If the resistance is greater than 10 Ω, the fault is in the return wire under the rocker cover.

Repair the injector harness or replace the injector harness.

Perform the "Injector Solenoid-Test" in order to verify that the repair eliminates the fault.

### 7.14 Air heater relay circuit-test

System operation description:

Use this procedure if another test procedure has directed you here. Also use this procedure when there is an active fault for the air heater relay current.

Use this procedure for the following diagnostic codes:

- J729-05 Air heater relay current low
- J729-06 Air heater relay current high

The following background information is related to this procedure:

Air heater is used to improve the engine starting when the engine is cold. With the keyswitch in the ON position, the engine ECM will monitor the coolant temperature and the engine inlet manifold air temperature in order to decide if the air heater are required to be switched ON. If the air heater are required, then the ECM will activate the air heater relay for a controlled period of time. While the air heater relay is activated the air heater relay will switch power to the air heater. If a "Wait to start" lamp is installed then this 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 an option.

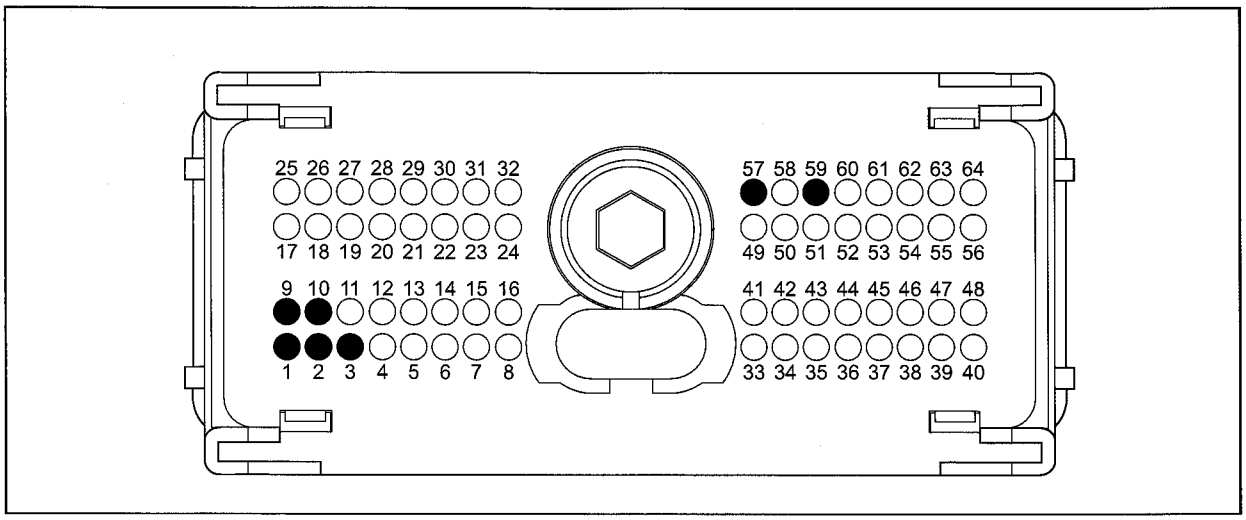
On a cold start, when the ECM decides that it is necessary for the air heater to be activated prior to starting, a lamp output will indicate that the operator needs to "Wait to start". It is possible that air heater may be used during the cranking of the engine. Air heater may be used if the engine has previously been started. The "Wait to start" lamp will not be active in these conditions.

Mitsubishi ET test aid

The Mitsubishi ET includes the test "Air heater override test". The "Air heater override test" will assist the analysis of the cold starting aid.

Overview of the air heater override test

This air heater override test switches on the air heater when the engine is not running. The air heater override test aids the analysis of the circuit for the air heater relay.




Typical view of the P1 connector pin locations

1 Ground (GND)
2 Ground (GND)
3 Ground (GND)
9 Ground (GND)
10 Ground (GND)
57 Start aid control
59 Wait to start lamp

### 7.14.1 Test step 1. Inspect electrical connectors and wiring

(1) Inspect the following connectors:
P1 connector
P2 connector
(2) Inspect the terminal connections on the air heater relay. Refer to "Electrical connectors - inspect" for details.
(3) Perform a 45 N {4.6 kgf} [10 lbf] pull test on each of the wires in the ECM connector that are associated with the air heater.
(4) Check the screw for the ECM connector for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].
(5) Check the harness for abrasion and pinch points from the air heater back to the ECM.
(6) 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 connectors.

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. Replace blown fuses.

Verify that the repair has eliminated the fault.

### 7.14.2 Test step 2. Check for active diagnostic codes

(1) Connect the Mitsubishi ET to the diagnostic connector.
(2) Turn the keyswitch to the ON position.

Note: The engine has not been started at this test step.

(3) Use the Mitsubishi ET to select the "Air heater override test" in order to turn on the power for the air heater.
(4) Check for active diagnostic codes or recently logged diagnostic codes.

Expected result:

The following diagnostic code is active or recently logged:

- J729-05 Air heater relay current low
- J729-06 Air heater relay current high

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 Mitsubishi ET to perform a "Wiggle test" in order to locate intermittent connections.
- If there is a fault on the air heater or a fault on the air heater relay and a diagnostic code is not displayed then there may be a fault with the air heater switched power circuit or there may be an open circuit in the relay coil circuit. The ECM does not monitor the status of these tests.

### 7.14.3 Test step 3. Check the wiring for a short circuit

(1) Turn the keyswitch to the OFF position.
(2) Remove the P1 connector from the ECM.
(3) Check the connector, pins and the sockets for corrosion or damage.
(4) 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 Ω.

Results:

- OK – The harness connects the ECM to the air heater relay and there are no shorts to other circuits. The ECM or the air heater relay is suspect. Proceed to Test step 4.
- Not OK – The harness is faulty.

Repair: If the resistance between P1:57 and each of the other pins on the J1 OEM connector is less than 10,000 Ω 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.

Verify that the repair has eliminated the fault.

If the fault still exists, proceed to Test step 4.

### 7.14.4 Test step 4. Bypass the ECM in order to check the operation of the air heater relay

(1) Turn the keyswitch to the OFF position.
(2) Disconnect the connection from test point "D" on the air heater relay.
(3) Connect a jumper wire between the battery ground and terminal "D" on the air heater relay.
(4) Measure the voltage from the battery ground and terminal "B" on the air heater relay.
(5) Turn the keyswitch to the ON position.

Note: The engine has not been started at this test step.

(6) Measure the voltage from the battery ground and terminal "B" on the air heater relay.

Expected result:

The keyswitch is in the OFF position. The voltage should be 0 VDC.

The keyswitch is in the ON position. The measured voltage is a constant 21.0 to 27.0 VDC.

Results:

- OK – The air heater relay is operating correctly. Reconnect the connection to test point "D" on the air heater relay. Proceed to Test step 5.
- Not OK – The air heater relay is faulty.

Repair: Replace the air heater relay. Verify that the repair eliminates the fault.

If the fault still exists, proceed to Test step 5.

### 7.14.5 Test step 5. Check the ECM

(1) Disconnect the P2 connector and disconnect the P1 connector from the ECM.
(2) Temporarily connect a test ECM. The test ECM should be programmed with the same values and parameters as the suspect ECM.
(3) Check the screw for the ECM connector for the correct torque of 5.0 N·m {0.50 kgf·m} [3.7 lbf·ft].
(4) Ensure that all connectors, pins and sockets are correctly coupled and/or inserted.
(5) Use the Mitsubishi ET in order to perform a "Air heater override test".

Expected result:

The replacement ECM functions correctly. Performing the "Air heater override test" energizes the air heater.

Results:

- OK – Install the replacement ECM. Refer to "ECM replacement".

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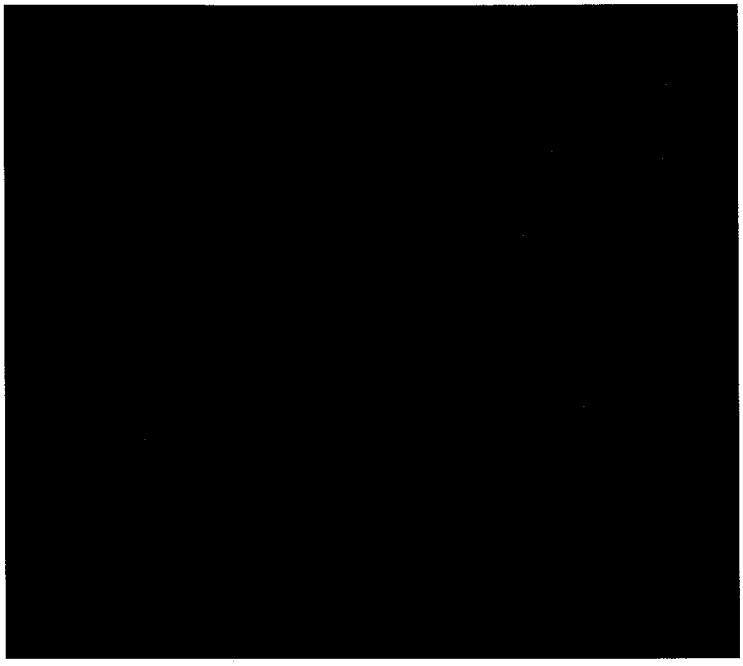

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