

# **OPERATION & MAINTENANCE MANUAL**

## **MITSUBISHI DIESEL ENGINE S12R-Y2PTAW**

The operator and supervisor are requested to read this Operation and Maintenance Manual carefully before operating the engine or conducting inspection and maintenance.  
Never operate the engine or conduct maintenance work without completely understanding this manual.



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# INTRODUCTION

This operation and maintenance manual contains detailed operation, inspection, and maintenance information for engines from Mitsubishi Heavy Industries, Ltd.

Please read this manual thoroughly before proceeding with operation, inspection, and maintenance work for correct use and servicing.

Please observe the contents of the emission controls which are applied in the countries or areas where the engine is used.

Failure to follow directions in this manual may result in serious accidents.

## LIMITED WARRANTY

Mitsubishi Heavy Industries, Ltd. will repair or replace parts returned to us when we judge that the parts are defective in material and/or workmanship after conducting inspection.

Mitsubishi Heavy Industries, Ltd.'s warranty is limited to the compensation work of repair or replacement of parts. The warranty coverage is effective for the original purchaser only. Those to whom ownership is later transferred are not provided with the warranty. However, that the warranty coverage is effective for the ultimate purchaser and each subsequent purchaser for emission-related parts.

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- ♦Mitsubishi Heavy Industries, Ltd. makes no warranties, either expressed or implied, except as provided in this manual, including, but not limited to, warranties as to marketability, merchantability, fitness for a particular purpose or use, or against infringement of any patent.
  - ♦Mitsubishi Heavy Industries, Ltd. will not be liable for any damages or consequential damages, including, but not limited to, damages or other costs resulting from any abuse, misuse, misapplication of the engine and devices supplied from us.
  - ♦Mitsubishi Heavy Industries, Ltd. will not be liable for any damages or personal injuries resulting from any modification, without our written permission, of the engine and devices supplied from us.
  - ♦Mitsubishi Heavy Industries, Ltd. will not be liable for any damages or production losses caused by the use of fuel, engine oil and/or long life coolant (LLC) that we are not recommended.
  - ♦The owner of the engine is responsible for the performance of the required maintenance listed in this operation manual.  
When performing the maintenance, follow the service manual published by Mitsubishi Heavy Industries, Ltd.  
Mitsubishi Heavy Industries, Ltd. may deny the warranty coverage if the engine or part has failed due to inadequate or improper maintenance.
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# EMISSION WARRANTY

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## IMPORTANT

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The following warranty applies to the engines that are approved of the emission regulation of the U.S. Environmental Protection Agency.

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### Warranty coverage

Mitsubishi Heavy Industries, Ltd. warrants to the first owner and each subsequent purchaser of a new non-road diesel engine that the emission control system of your engine:

- is designed, built and equipped so as to conform at the time of sales with all applicable regulation of the U.S. Environmental Protection Agency. If the vehicle in which the engine is installed is registered in the state of California, a separate California emission regulation also applies.
- is free from the defects in material and workmanship which will cause the engine to fail to meet these regulations within the warranty period.

### Warranty period

Then its warranty period is 5 years or 3000 hours, whichever comes first.

However, if your engine warranty period is longer than the emission warranty period, the emission warranty period extends to same as the engine warranty period.

Below warranty period shall begin on the date the engine is delivered to the first owner.

### Warranted parts

Mitsubishi Heavy Industries, Ltd. warrants the parts which will increase the emission of pollutants when they become defective.

The followings are examples.

- Inlet/Exhaust manifold
- Crankcase ventilation system
- Fuel system
- Fuel injection nozzle

### Limited warranty

Refer to "Limited warranty" (Page ii).

## CALIFORNIA EMISSION CONTROL WARRANTY STATEMENT YOUR WARRANTY RIGHTS AND OBLIGATIONS

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### IMPORTANT

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The following warranty applies to the engines that are approved of the emission regulation of the California Air Resources Board (CARB).

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The California Air Resources Board (CARB) is pleased to explain the emission control system warranty on your 2008 or later engine. In California, new heavy-duty off-road engines must be designed, built, and equipped to meet the State's stringent anti-smog standards. Mitsubishi Heavy Industries, Ltd. must warrant the emission control system on your engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your engine.

Your emission control system may include parts such as the fuel-injection system and the air induction system. Also included may be hoses, belts, connectors and other emission-related assemblies.

Where a warrantable condition exists, Mitsubishi Heavy Industries, Ltd. will repair your heavy-duty off-road engine at no cost to you including diagnosis, parts, and labor.

#### Manufacturer's warranty coverage:

The 2008 and later heavy-duty off-road engines are warranted for the warranty period. If any emission-related part on your engine is defective, the part will be repaired or replaced by Mitsubishi Heavy Industries, Ltd.

#### Owner's warranty responsibilities:

- ♦As the heavy-duty off-road engine owner, you are responsible for the performance of the **required maintenance listed in your owner's manual**. Mitsubishi Heavy Industries, Ltd. recommends that you retain all receipts covering maintenance on your heavy-duty off-road engine, but Mitsubishi Heavy Industries, Ltd. cannot deny warranty solely for the lack of receipts or for your failure to ensure the performance of all scheduled maintenance.
- ♦As the heavy-duty off-road engine owner, you should however be aware that Mitsubishi Heavy Industries, Ltd. may deny you warranty coverage if your heavy-duty off-road engine or a part has failed due to abuse, neglect, improper maintenance or unapproved modifications.
- ♦Your engine is designed to operate on diesel fuel only. Use of any other fuel may result in your engine no longer operating in compliance with California's emissions requirements.
- ♦You are responsible for initiating the warranty process. The Air Resources Board suggests that you present your heavy-duty off-road engine to a Mitsubishi Heavy Industries, Ltd. dealer or distributor dealer as soon as problem exists. The warranty repairs should be completed by the dealer or distributor as expeditiously as possible.

If you have any questions regarding your warranty rights and responsibilities, you should contact Mitsubishi Engine North America at 1-630-268-0750.

**Warranty coverage:**

- (a) The warranty period shall begin on the date the engine or equipment is delivered to an ultimate purchaser.
- (b) Mitsubishi Heavy Industries, Ltd. warrants to the ultimate purchaser and each subsequent purchaser of the engine registered in the state of California that the engine is:
- (1) Designed, built and equipped so as to conform with all applicable regulations adopted by the Air Resources Board.
  - (2) Free from defects in materials and workmanship which cause the failure of a warranted part to be identical in all material respects to the parts as described in Mitsubishi Heavy Industries, Ltd.'s application for certification for a period of 5 years or 3,000 hours of operation, whichever occurs first. In the absence of a device to measure hours of use, the engine shall be warranted for a period of 5 years. For all engines rated less than 19 kW, and for constant-speed engines rated under 37 kW with rated speeds higher than or equal to 3,000 min<sup>-1</sup>, the period of 2 years or 1,500 hours of operation, whichever occurs first, shall apply. In the absence of a device to measure hours of use, the engine shall be warranted for a period of 2 years.
- (c) The warranty on emission-related parts shall be interpreted as follows:
- (1) Any warranted part which is not scheduled for replacement as required maintenance in the written instructions required by Subsection (e) shall be warranted for the warranty period defined in Subsection (b) (2). If any such part fails during the period of warranty coverage, it shall be repaired or replaced by Mitsubishi Heavy Industries, Ltd. according to Subsection (4) below. Any such part repaired or replaced under the warranty shall be warranted for the remaining warranty period.
  - (2) Any warranted part which is scheduled only for regular inspection in the written instructions required by Subsection (e) shall be warranted for the warranty period defined in Subsection (b) (2). A statement in such written instructions to the effect of "repair or replace as necessary" shall not reduce the period of warranty coverage. Any such part repaired or replaced under the warranty shall be warranted for the remaining warranty period.
  - (3) Any warranted part which is scheduled for replacement as required maintenance in the written instructions required in Subsection (e) shall be warranted for the period of time prior to the first scheduled replacement point for that part. If the part fails prior to the first scheduled replacement, the part shall be repaired or replaced by Mitsubishi Heavy Industries, Ltd. according to Subsection (4) below. Any such part repaired or replaced under warranty shall be warranted for the remainder of the period prior to the first scheduled replacement point for the part.
  - (4) Repair or replacement of any warranted part under the warranty provisions shall be performed at no charge to the owner at a warranty station.
  - (5) Notwithstanding the provisions of Subsection (4) above, warranty services or repairs shall be provided at all Mitsubishi Heavy Industries, Ltd. distribution centers that are franchised to service the subject engines.
  - (6) The owner shall not be charged for diagnostic labor that leads to the determination that a warranted part is in fact defective, provided that such diagnostic work is performed at a warranty station.
  - (7) Mitsubishi Heavy Industries, Ltd. shall be liable for damages to other engine components proximately caused by failure under warranty of any warranted part.
  - (8) Throughout the engine's warranty period defined in Subsection (b) (2), Mitsubishi Heavy Industries, Ltd. shall maintain a supply of warranted parts sufficient to meet the expected demand for such parts.
  - (9) Any replacement part may be used in the performance of any maintenance or repairs and must be provided without charge to the owner. Such use shall not reduce the warranty obligations of Mitsubishi Heavy Industries, Ltd.

- (10) Add-on or modified parts that are not exempted by the Air Resources Board may not be used. The use of any non-exempted add-on or modified parts shall be grounds for disallowing a warranty claim. Mitsubishi Heavy Industries, Ltd. shall not be liable to warrant failures of warranted parts caused by the use of a non-exempted add-on or modified part.
- (11) The Air Resources Board may request and, in such case, Mitsubishi Heavy Industries, Ltd. shall provide, any documents which describe that Mitsubishi Heavy Industries, Ltd.'s warranty procedures or policies.
- (d) Warranted parts list.
- (1) Fuel metering system
    - (A) Fuel injection system.
    - (B) Air/fuel ratio feedback and control system.
    - (C) Cold start enrichment system.
  - (2) Air induction system
    - (A) Controlled hot air intake system.
    - (B) Intake manifold.
    - (C) Heat riser valve and assembly.
    - (D) Turbocharger/supercharger systems.
    - (E) Charged air cooling systems.
  - (3) Exhaust gas recirculation (EGR) system
    - (A) EGR valve body, and carburetor spacer if applicable.
    - (B) EGR rate feedback and control system.
  - (4) Air injection system
    - (A) Air pump or pulse valve.
    - (B) Valves affecting distribution of flow.
    - (C) Distribution manifold.
  - (5) Catalyst or thermal reactor system
    - (A) Catalytic converter.
    - (B) Thermal reactor.
    - (C) Exhaust manifold.
  - (6) Particulate controls
    - (A) Traps, filters, precipitators, and any other devices used to capture particulate emissions.
    - (B) Regenerators, oxidizers, fuel additive devices, and any other device used to regenerate or aid in the regeneration of the particulate control device.
    - (C) Control device enclosures and manifolding.
    - (D) Smoke puff limiters.
  - (7) Advances oxides of nitrogen (NOx) controls
    - (A) NOx absorbers.
    - (B) Lean NOx catalysts.
    - (C) Selective catalyst reduction.
    - (D) Reductant (urea/fuel) containers/dispensing systems.
  - (8) Positive crankcase ventilation (PCV) system
    - (A) PCV valve.
    - (B) Oil filler cap.
  - (9) Miscellaneous items used in above systems
    - (A) Vacuum, temperature, and time sensitive valves and switches.
    - (B) Electronic control units, sensors, solenoids, and wiring harnesses.

- (C) Hoses, belts, connectors, assemblies, clamps, fittings, tubing, sealing gaskets or devices, and mounting hardware.
  - (D) Pulleys, belts and idlers.
  - (E) Emission control information labels.
  - (F) Any other part with the primary purpose of reducing emissions or that can increase emission during failure without significantly degrading engine performance.
- (e) Mitsubishi Heavy Industries, Ltd. shall furnish with each new engine written instructions for the maintenance and use of the engine by the owner.

**Limited warranty:**

Refer to "Limited warranty" (Page II).

## IMPORTANT INFORMATION

- ♦To avoid the potential hazard, accident prevention activities must be planned methodically and conducted continually by considering all aspect of engine operation, maintenance and inspection. All related personnel, including managers and supervisors, should actively participate, recognize their roles and organize themselves and their work to ensure a safe environment.
- ♦The foremost safety objective is to prevent accidents which may result in injury or death, or equipment damage.
- ♦Always observe laws or regulations of the local or federal/national government.
- ♦Mitsubishi Heavy Industries, Ltd. cannot foresee all potential dangers of the engine, potential danger resulting from human error and other causes, or danger caused by a specific environment in which the engine is used. Since there are many actions that cannot be performed or must not be performed, it is impossible to indicate every caution in this manual or on warning labels. As such, it is extremely important to follow directions in this manual and also to take general safety measures when operating, maintaining and inspecting the engine.
- ♦When the engine is used by individuals whose native language is not English, the customer is requested to provide thorough safety guidance to the operators. Also add safety, caution and operating signs that describe the original warning label statements in the native language of the operators.
- ♦The engine must be operated, maintained and inspected only by qualified persons who have thorough knowledge of engines and their dangers and who also have received risk avoidance training.
- ♦To prevent an accident, do not attempt to carry out any operation other than those described in this manual, and do not use the engine for any unapproved purpose.
- ♦When the ownership of the engine is transferred, be sure to provide this manual with the engine to the new owner. Also inform Mitsubishi Heavy Industries, Ltd. of the name and address of the new owner of the engine.
- ♦This manual is copyrighted and all rights are reserved.No part of this manual, including illustrations and technical references, may be photocopied, translated, or reproduced in any electronic medium or machine readable form without prior written consent from Mitsubishi Heavy Industries, Ltd.
- ♦The contents in this manual are subject to change at any time without notice for improvement of the engine.
- ♦Pictures or illustrations of the product in this manual may differ from those of product you have. Please note that, depending on specifications, items described in this manual may differ from those on your engine in shape, or may not be installed on your engine.
- ♦Please contact a dealer of Mitsubishi Heavy Industries, Ltd. if you need more information or if you have any questions.
- ♦If you lost or damaged this manual, obtain a new copy at a dealer of Mitsubishi Heavy Industries, Ltd. as soon as possible.
- ♦Mitsubishi Heavy Industries, Ltd. recommends the engine owner to install an hour meter on the engine due to monitor correct running intervals and to perform the maintenance at the appropriate timing.

## WARNING INDICATION

The following means are used to call the attention of the operators and maintenance personnel to potential dangers of the engine.

- Warning statements in the manual
- Warning labels affixed on the engine

### Warning statements

The warning statements in this manual describe potential danger in operating, inspecting or maintaining the engine, using the following five classifications to indicate the degree of potential hazard.

Failure to follow these directions could lead to serious accidents which could result in personal injury, or death in the worst case.

Understand the directions well, and handle engines with following directions.



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



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



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



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

Note:

Indicates important information or information which is useful for engine operation.

## UNITS OF MEASUREMENT

Measurements are based on the International System of Units (SI), and they are converted to the metric system units in this manual using the following conversion rates.

- ♦ Pressure :1 MPa = 10.197 kgf/cm<sup>2</sup>
- ♦ 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 = 0.75 cmHg
- ♦ Meter of water:1 kPa = 10.197 cmH<sub>2</sub>O (cmAq)
- ♦ Rotational speed:1 min<sup>-1</sup> = 1 rpm
- ♦ Kinetic viscosity:1 mm<sup>2</sup>/s = 1 cSt

## ABBREVIATIONS, STANDARD AND OTHERS

- ♦ API = American Petroleum Institute
- ♦ ASTM = American Society for Testing and Materials
- ♦ ISO = International Organization for Standardization
- ♦ JIS = Japanese Industrial Standards
- ♦ LLC = Long Life Coolant
- ♦ MIL = Military Specifications and Standards
- ♦ MSDS = Material Safety Data Sheet
- ♦ SAE = Society of Automotive Engineers

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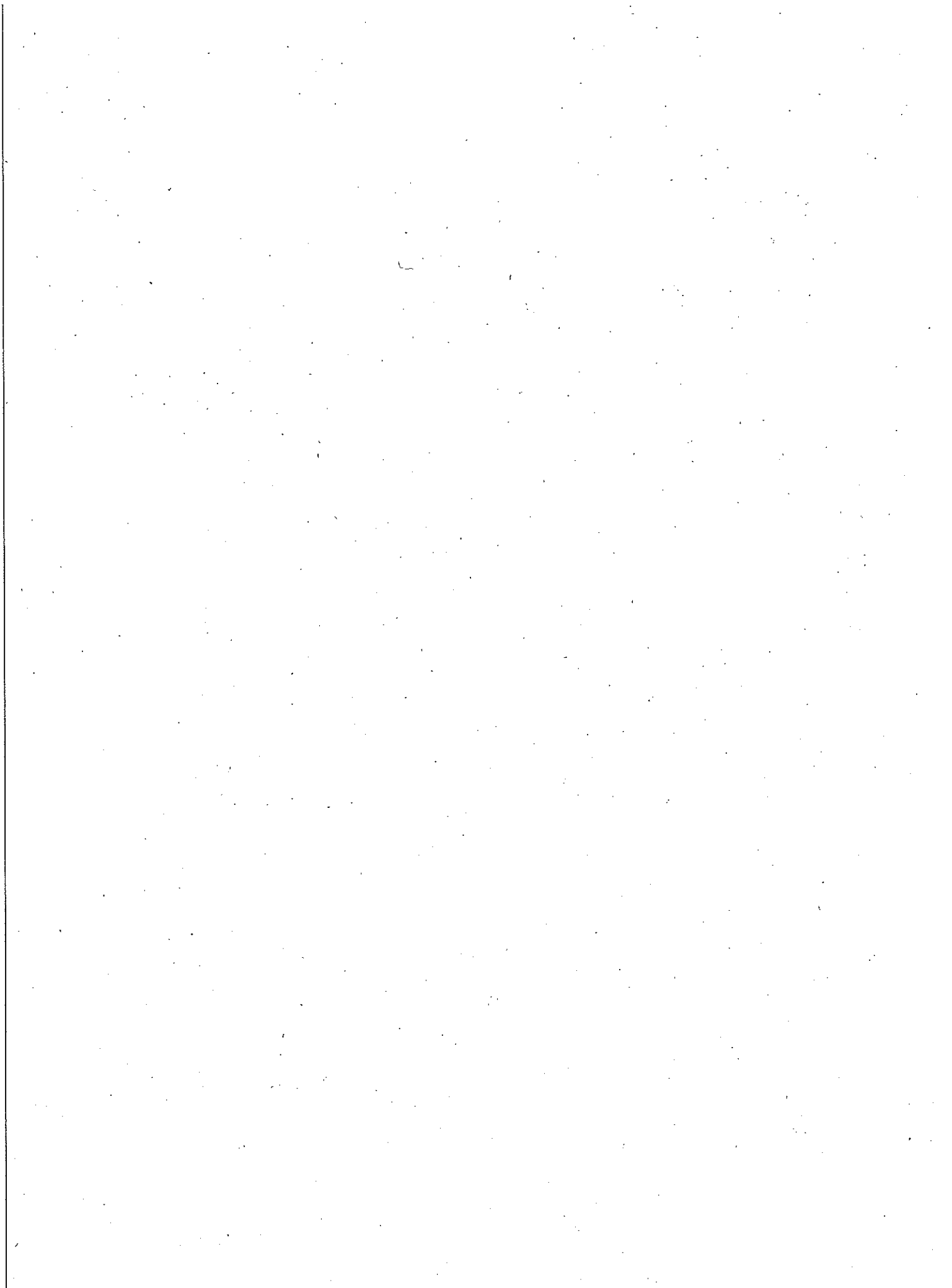
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# Chapter 1 BASIC SAFETY PRECAUTIONS

## Fire and explosions

 **WARNING**

### Keep flames away

Do not use flames near the engine (in the engine room). Fuel vapor or other gas can catch fire and produce dangerous situations.



Wipe off spilled fuel, oil and LLC

immediately and thoroughly. Spilled fuel, oil and LLC may ignite and cause a fire.

Store fuel and engine oil in a well-ventilated area.

Make sure that the caps of fuel and engine oil containers are tightly closed.

### Keep engine surrounding area tidy 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 surrounding 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.

### Ventilation of engine room

Always provide adequate ventilation in the engine room. Insufficient air in the room can cause an increase in the engine temperature and a decrease in the output power and performance. It is highly recommended to calculate the required amount of air supply to the engine and install an adequate ventilation system before installing the engine.

### Do not open side cover until engine cools

Do not attempt to open the side cover of the crankcase before the engine cools down. Wait at least 10 minutes after stopping the engine.

Opening the cover when the engine is hot allows fresh air to flow into the crankcase, which can cause oil mist to ignite and explode.

### Care for 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 lighting apparatus may ignite gas and cause it to explode.

### 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 fire extinguishers handy, and become familiar with their usage.

Keep a first-aid kit at the designated place where it is easily accessible by anyone at any time.



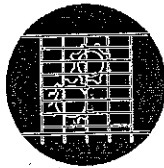
Establish response procedures to follow in the event of fire or accident. Provide an emergency evacuation route and contact points and means of communication in case of emergency.

## Stay clear of all rotating and moving parts

### ⚠ WARNING

#### Install protective covers around rotating parts

Make sure the protective covers of the engine are correctly installed. Repair any damaged or loose covers. Never remove the covers protecting the rotating parts while engine is running.



When the engine is coupled to the radiator or other equipment, install protective covers around the exposed connecting belt and coupling. Never remove protective covers.

#### Check work area for safety

Before starting the engine, make sure no one is near the engine and tools are not left on or near the engine. Verbally notify persons within the immediate area when starting the engine.

When the starter device is posted with a sign that prohibits startup operation, do not operate the engine.

#### Stay clear of moving parts while engine is running

Do not approach rotating or sliding parts of the engine while the engine is running. 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.

#### 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

Be sure to remove all turning tools used during maintenance and inspection work. Remember also that the turning gear shaft must be pulled out 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.

## Be careful of exhaust fume poisoning

### ⚠ WARNING

### Operate engine in a well-ventilated area

Check the exhaust pipes and where the pipes joint together for gas leaks. Exhaust gas from the engine contains carbon monoxide and other harmful substances. Operating the engine in an poorly-ventilated area can produce gas poisoning.



## Protect ears from noise

### ⚠ WARNING

### 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.



## Be careful of falling down

### ⚠ WARNING

### Lift engine carefully

To lift the engine, use slings capable of supporting the weight of the engine.

Attach the wire rope to the hangers provided 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.

The hangers equipped with the engine are designed for lifting the engine only. Be careful not to affect the hangers by added weight if installing the generator or marine gear to the engine.

Keep the angle formed by slings attached to hangers within 60°. If the angle exceeds this limit, excessive load could be imposed on the hangers and this could damage the hangers and result in a serious accident. If the wire rope contacts the engine directly, place a cloth or other soft padding to avoid damage to the engine and wire rope.



### Do not climb onto the engine

Do not climb onto 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., that was firmly secured.

Climbing on the engine may not only damage engine parts but also cause falling down from the engine and result in personal injuries.

### Always prepare stable scaffold

When working on the upper part of the engine and other hard-to-reach places, use a stable work platform.

Standing on a decrepit stool or parts box may result in personal injury.

Do not place any unnecessary objects on a work platform.



## Be careful of burns

**▲ CAUTION**

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

To avoid burns, do not touch the engine during or immediately after operation.

A hot engine can cause burns.

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



### Refill coolant only after the coolant temperature dropped

Do not add coolant immediately after the engine stops. Wait until the coolant temperature lowers sufficiently. Adding coolant immediately after the engine stops cause burns.

### Never remove heat shields

The exhaust system, which becomes extremely hot while the engine is operating, is provided with various heat shields. Do not remove these heat shields. If any of these heat shields have been removed owing to unavoidable circumstances during the work, be sure to restore them after the work is completed.

### Do not open the radiator filler cap when the engine is hot

Never open the radiator filler cap while the engine is running or immediately after the engine is stopped. When opening the cap, stop the engine and allow the coolant temperature to lower sufficiently.

When opening the radiator filler cap, open slowly to discharge the pressure inside the tank. Also to avoid a risk of getting scalded by steam, wear thick rubber gloves or wrap a cloth around the cap.

When closing the cap, be sure to tighten securely.

The coolant is hot while engine is running and immediately after the engine stops. If the cap is opened when the coolant is at operating temperature, steam and hot coolant may blow out and result in burns.

### Do not touch high pressure injection fuel

If fuel leaks or sprays out from the high pressure injection pipe, do not touch the fuel.

Fuel in the fuel injection pipes is under high pressure and if the fuel contact your skin, it goes into deep tissues and may result gangrene.

## Be careful when handling fuel, engine oil or LLC

### ⚠ CAUTION

### Use only specified fuel, engine oil and LLC

Use fuel, oil and LLC specified in this manual, and handle them carefully.

Use of any other fuel, oil or LLC, or improper handling may cause various engine problems and malfunctions.

Obtain the MSDS issued by the fuel, oil and LLC suppliers, and follow the directions in the MSDSs for proper handling.

### Handle LLC carefully

When handling LLC, always wear rubber gloves and a 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. Coolant (containing LLC) drained from the engine is toxic. Never dispose of coolant into regular sewage. Abide by the applicable law and regulations when discarding drained coolant.

### Proper disposal of waste oil, LLC and coolant

Do not discharge waste engine oil, LLC and 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, LLC and coolant and other environmentally hazardous waste in accordance with the applicable law and regulations.

## When abnormality occurs

### ⚠ CAUTION

### Do not add coolant immediately after a sudden stop due to overheating

If the engine stops suddenly or if you have no choice but stop the engine suddenly due to overheating, do not add coolant immediately.

Adding water while the engine is hot can damage parts such as cylinder heads due to a sudden drop of temperature. Add coolant gradually after the engine has completely cooled.

### 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 continuous engine operation at low oil pressure

If an abnormal engine oil pressure drop is indicated, stop the engine immediately, and inspect the lubrication system to locate the cause. Continuous engine operation with low oil pressure could cause bearings and other parts to seize.

### If belt breaks, stop engine immediately

If the belt breaks, stop the engine immediately and replace the belt. Sustained use of the engine without any remedy could cause defective charge and cooling failure, and result in serious engine problems.

## Service battery

 CAUTION

### Handle the 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 when the battery electrolyte level of which is below the "LOWER LEVEL" 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 removing battery, always remove the plug from the negative (-) terminal first. When connecting battery, always connect the plug to the positive (+) terminal first.

♦Remove all plugs, then charge the battery in a well-ventilated area.

♦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 [Open/OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.

♦Battery electrolyte contains dilute sulfuric acid. Careless handling of the battery can cause the loss of sight and/or skin burns. Also, do not consume the battery electrolyte.

♦Wear protective goggles and rubber gloves when working with the battery (when adding water, charging, etc.)

♦If battery electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to thoroughly clean.

♦The battery electrolyte can cause the loss of sight if splashing into the eyes. If it gets into the eyes, immediately flush it away with plenty of clean water, and seek immediate medical attention.

♦If the battery electrolyte is accidentally consumed, gargle with plenty of water, then drink lots of water, and seek immediate medical attention.

## Other cautions



**CAUTION**

### Never modify engine

Unauthorized modification of the engine will void our warranty.

Modification of the engine may not only cause engine damage but also produce personal injuries.

If there is a need to modify the engine, contact a dealer of Mitsubishi Heavy Industries, Ltd.

### Observe safety rules at work site

Observe the safety rules established at your workplace when operating and maintaining the engine.

Do not operate the engine if you are feeling ill, inform your supervisor of your condition. Operation of the engine with reduced awareness may cause improper operation that could result in accidents.

When working in a team for two or more people, use specified hand signals to communicate among 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, a hardhat, gloves and other necessary protective gear. Works without wearing proper protective gear could result in serious injuries.

### Never break the seals

To ensure proper engine operation, the fuel control links are sealed to prevent accidental change of the injection volume and rotation speed settings. Operating the engine without these seals in place can cause problems described below, and also invalidates the warranty.

- ♦ Rapid wear of moving and rotating parts
- ♦ Engine troubles such as damage and seizure of engine parts
- ♦ Increased consumption of fuel and lubricating oil
- ♦ Degradation of engine performance due to improper balance between fuel injection volume and governor operation or overrunning of the engine which could result in a serious accident

### Perform all specified pre-operation inspections and periodic inspections

Conduct the pre-operation inspections and periodic inspections as described in this manual.

Failure to conduct the specified inspections may cause various engine problems, damage to parts, and serious accidents.

### Break-in the engine

To break-in new engines or overhauled engines, operate the engine at a speed lower than the rated speed in a light load condition during the first 50 hours of operation.

Operating new engines or overhauled engines in a severe condition during the break-in period shortens the service life of the engine.

### Warm-up the engine before use

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.

Warm-up operation circulates lubricants in the engine and contributes to a longer service life and economical operation.

Do not conduct warm-up operation for prolonged period of time. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion.

### Never operate the engine in an overloaded condition

If the engine shows an overloaded condition such as black exhaust smoke, reduce the load immediately to operate the engine at an appropriate output and load. Overloading causes not only high fuel consumption but also excessive carbon deposits inside the engine. Carbon deposits cause various problems and will shorten the service life of the engine.

### **Conduct cooling operation before stopping the engine**

Before stopping the engine, idle the engine in low gear for 5 to 6 minutes to cool down.

Stopping the engine immediately after high-load operation will cause engine parts to heat up and shorten the service life of the engine.

During cooling operation, check the engine for abnormalities.

### **Protection of the 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.

### **Conduct proper maintenance of air cleaner**

Maintain the engine with air cleaner according to the following instructions.

- Never service the air cleaner while the engine is running. The turbocharger may suck particles of foreign materials into the engine and could result in serious accidents.
- Remove the air cleaner slowly to prevent foreign materials accumulated on the element from falling off. After removing the air cleaner, immediately cover the air inlet with plastic sheet or similar means to prevent foreign materials from entering the engine.

### **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 them with new tools.

### **Avoidance of prolonged time of starter operation**

Do not use the starter for more than 10 seconds at a time. If the engine does not start, wait for at least 1 minute before cranking again.

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

### **Do not turn off the battery switch during operation**

Do not turn off the 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 the 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.

### **Do not operate engine continuously under low load**

When operating the engine with a 30 % of rated load or lower, limit each operation to 10 minutes. Operating the engine at low load tends to result in unburned fuel, which can adhere on internal engine parts, and cause malfunctions and shorten the engine service life.

## Warning labels

### ⚠ CAUTION

#### Maintenance of warning labels

Make sure all warning/caution labels are legible.

Clean or replace the warning/caution labels when the description and/or illustration are not clear to read.

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 new warning labels, contact a dealer of Mitsubishi Heavy Industries, Ltd.

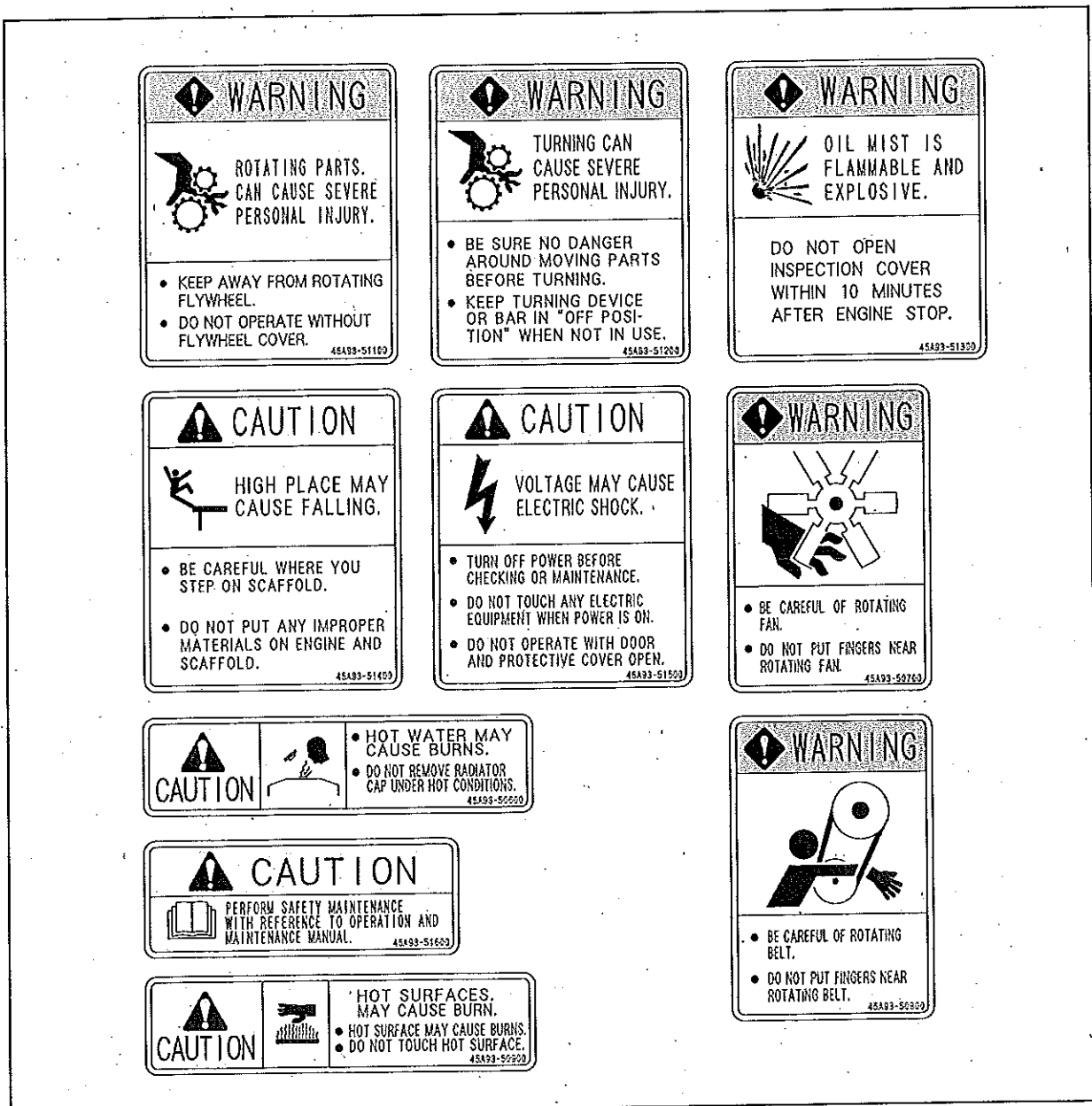
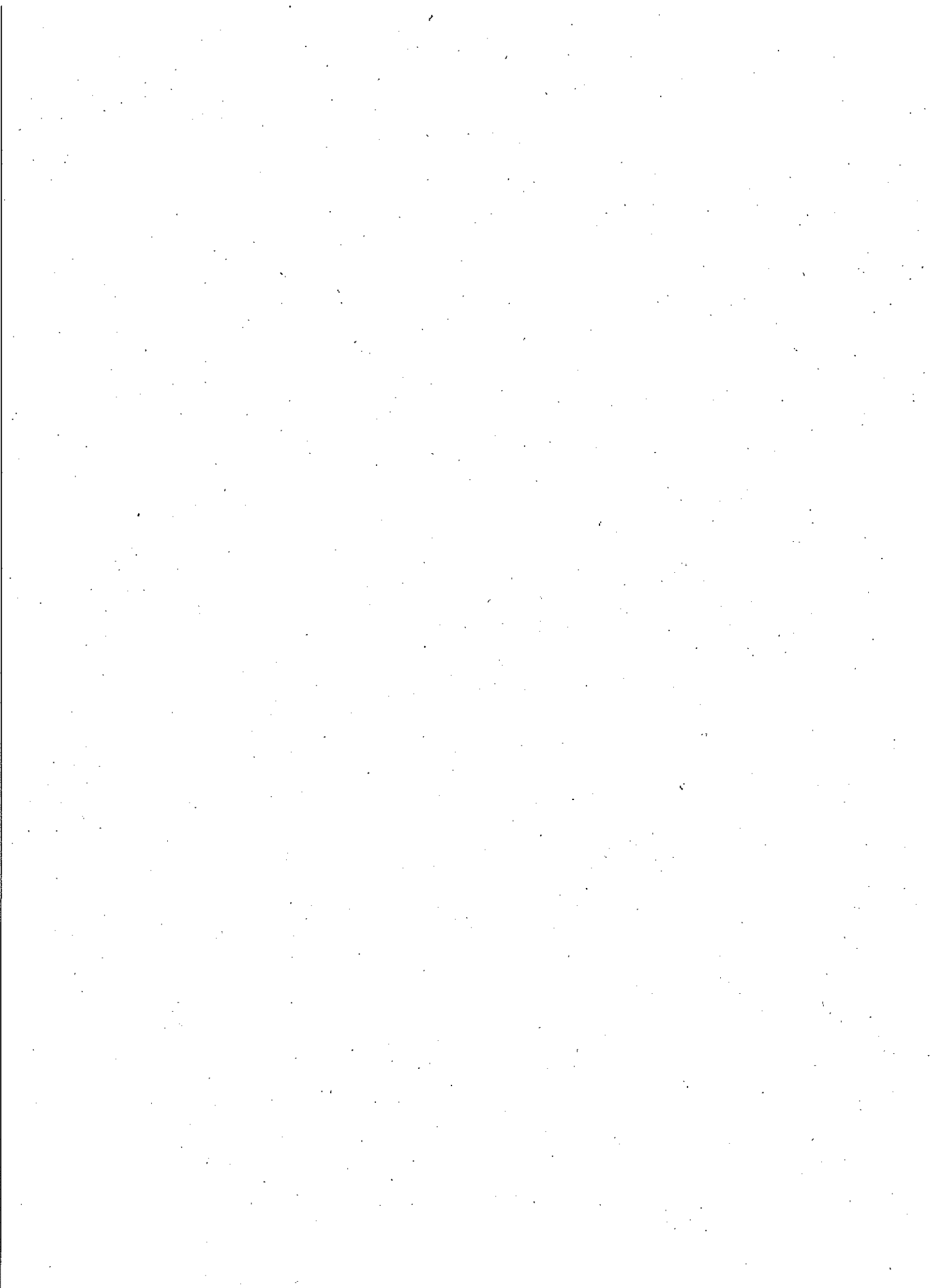


Fig. 1-1 Warning labels



# Chapter 2 NAME OF PARTS

## Engine external diagrams

### Engine front

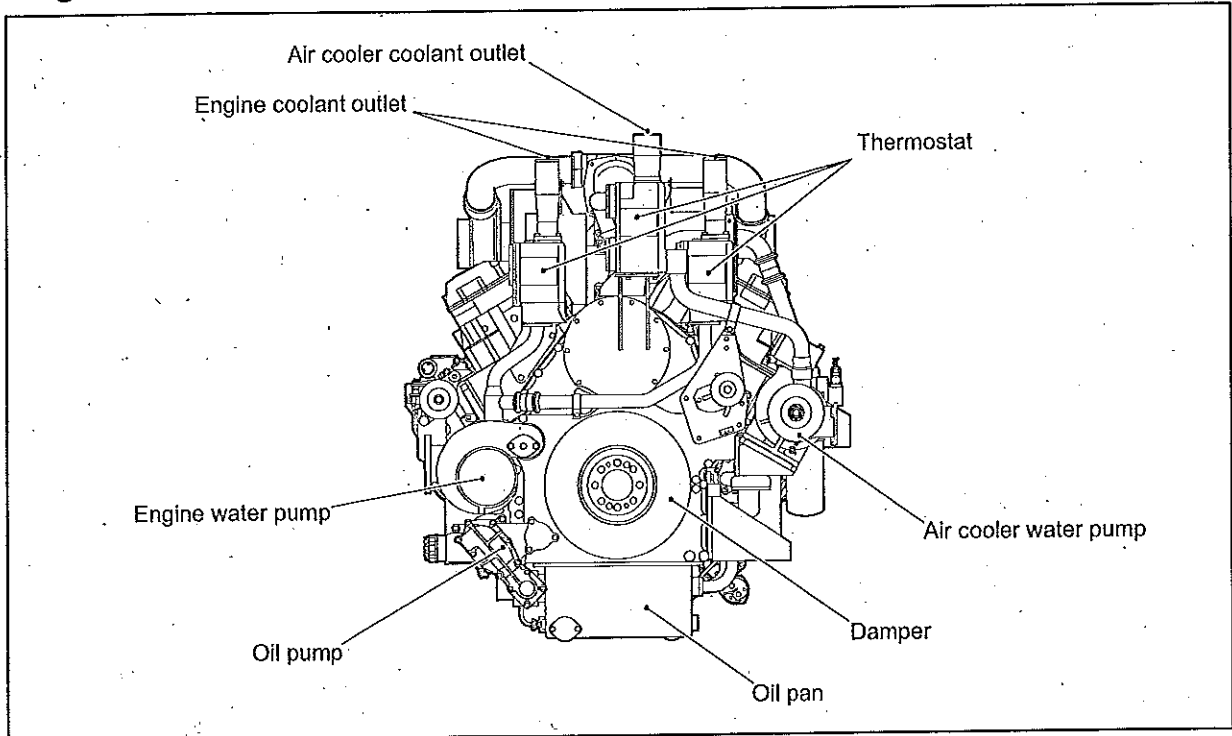


Fig. 2-1 Engine front view

### Engine rear

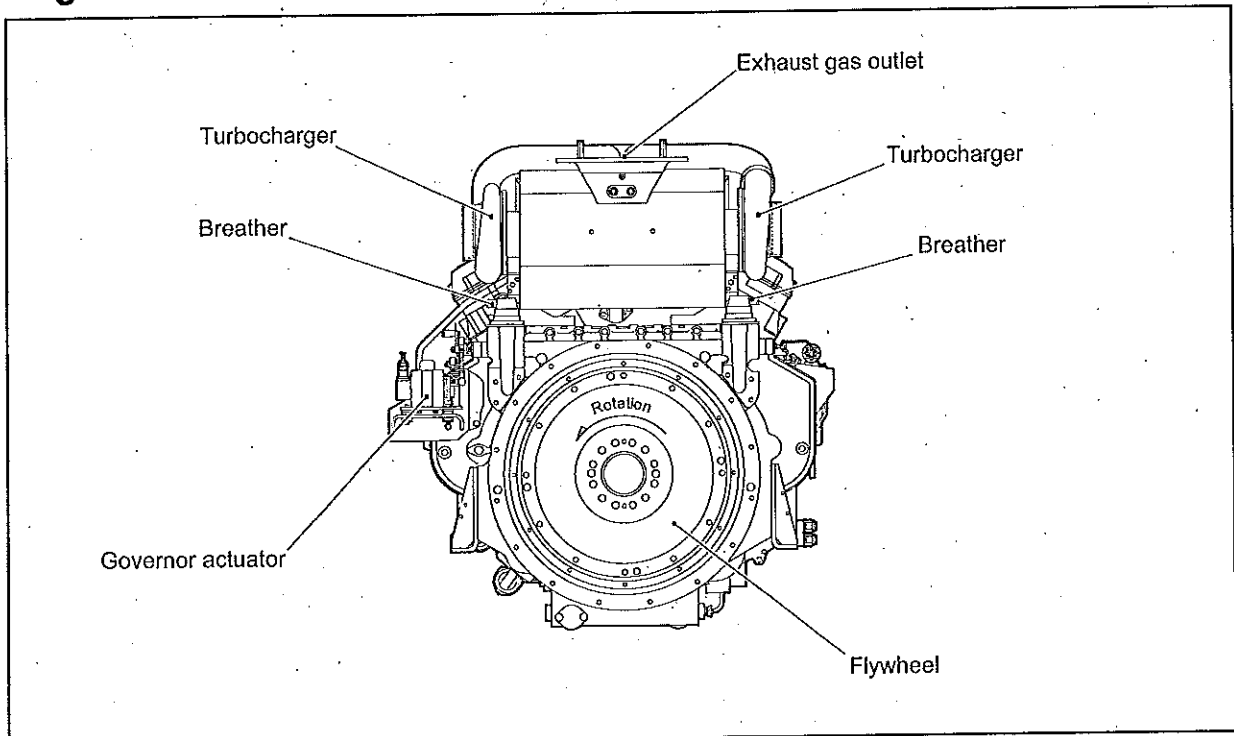


Fig. 2-2 Engine rear view

### Left view

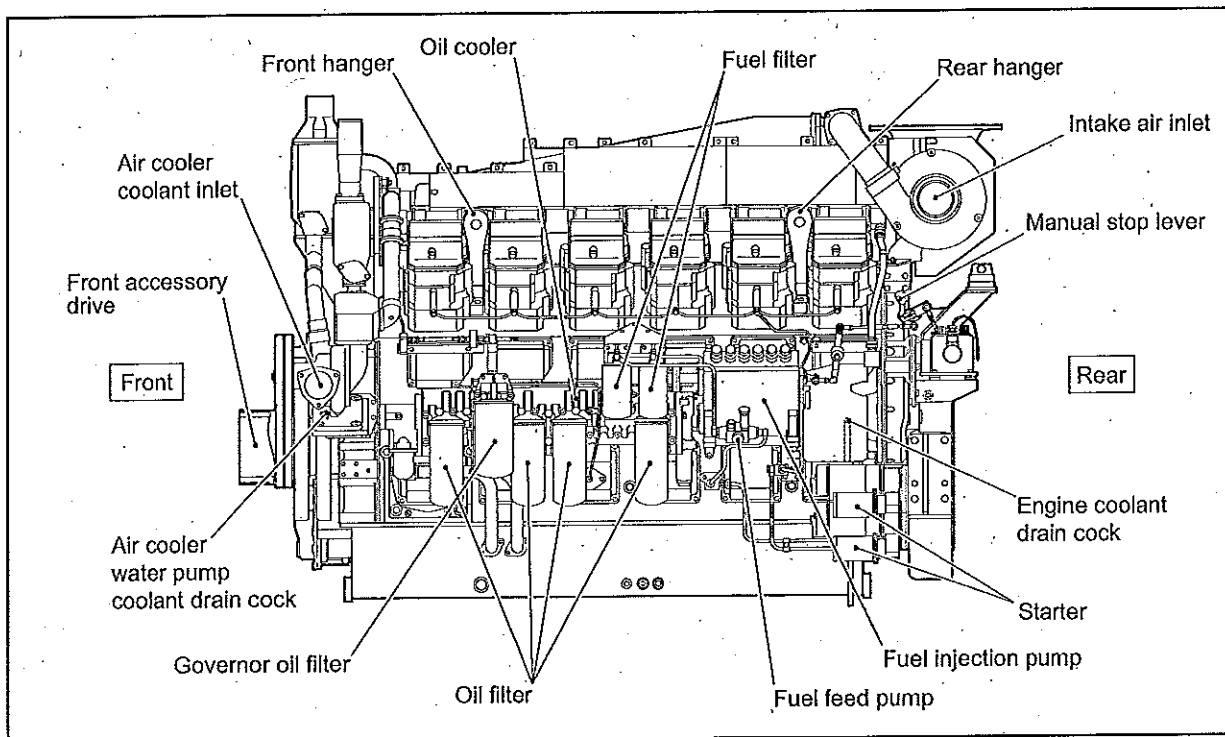


Fig. 2-3 Engine left view

### Right view

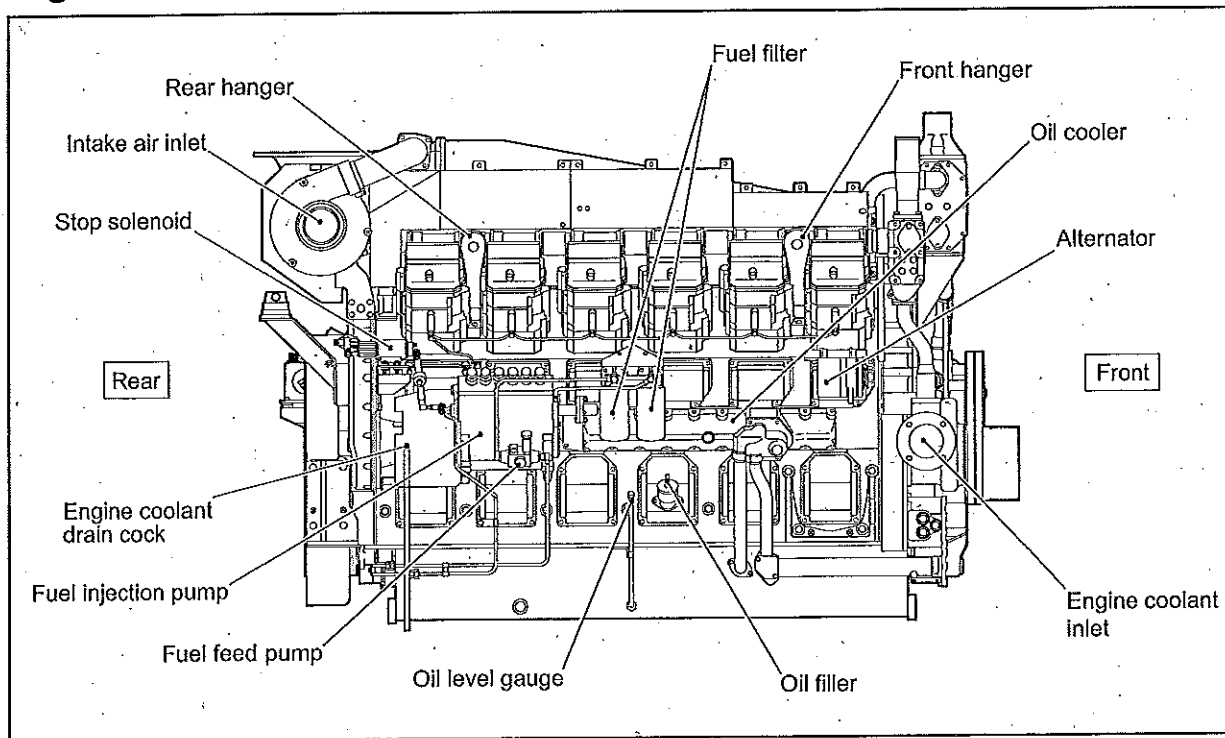


Fig. 2-4 Engine right view

## Equipment and instrument

The installed equipment and shapes differ on the engine type.

### Start and stop instrument

#### Manual stop lever

Use the manual stop lever to shut down the engine in the event of an emergency. If the starter switch fails to stop engine operation, use the manual stop lever.

When the manual stop lever, which is located in the fuel control link, is moved in the "STOP" direction, the engine stops.

If the engine continues to operate even after the manual stop lever is moved in the "STOP" direction, cut off the fuel supply to stop the engine.

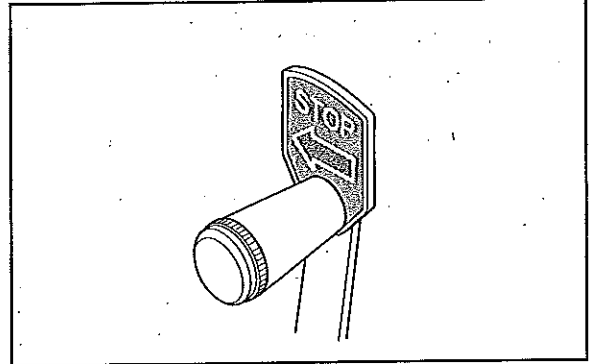


Fig. 2-5 Manual stop lever

#### Stop solenoid

The stop solenoid operates for normal shutdown of engine operation.

The stop solenoid moves the rack of fuel injection pump to cut the fuel, and consequently stops the engine.

The RUN OFF type stop solenoid is equipped in this engine. Not energized while the engine is running. Energized by a stop signal to stop the engine.

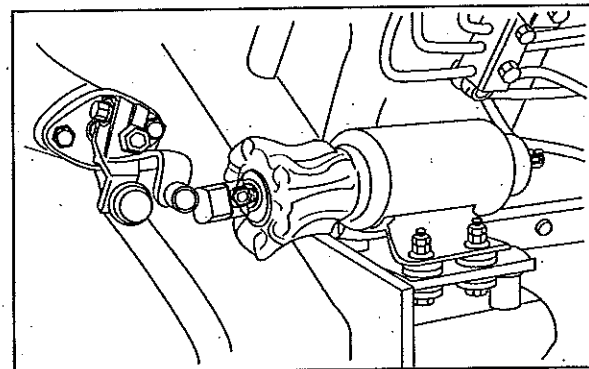


Fig. 2-6 Stop solenoid

### Instruments

This section describes about devices which transmit signals to necessary instruments of the engine operation. Read carefully and understand functions of each device.

#### Revolution detection pickup

It is installed in the timing gear case, and always detect engine speed.

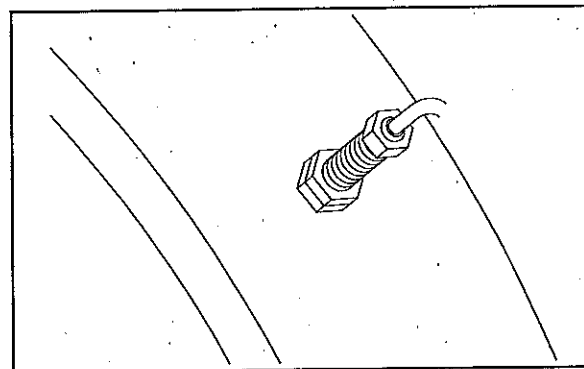


Fig. 2-7 Revolution detection pickup

## Engine protection devices

The engine protection devices activate an alarm when an abnormality occurs in the engine in order to protect the engine and prevent serious problems and accidents. When a protection device is activated, stop the engine, examine the cause of the abnormality, and take corrective measures. If the cause of the problem is unknown, contact a dealer of Mitsubishi Heavy Industries, Ltd. Protection devices installed on the engine and their types (setting values) and shapes vary depending on the engine specifications.

### Oil filter alarm switch

The oil filter alarm switch generates an alarm when oil filters become clogged, the difference in pressure between inlet and outlet of oil and reaches the specified value.

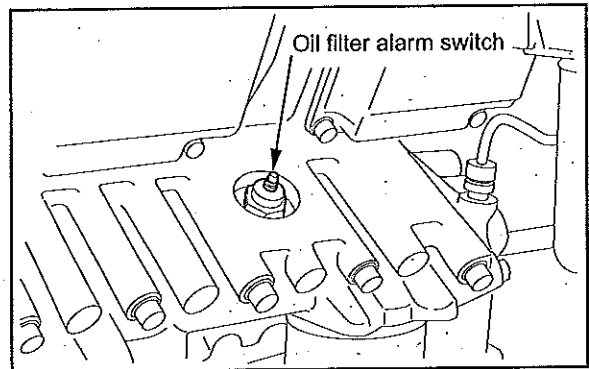


Fig. 2-8 Oil filter alarm switch

### Air cleaner indicator

The air cleaner indicator alarms with its red signal when air cleaner elements become clogged, the difference in pressure between front air cleaner and rear air cleaner, and reaches the specified value. The air cleaner indicator indicates the signal only, and does not generate an alarm. Therefore, the periodic visually inspection is needed.

Press the reset button on the top of air cleaner indicator and restore the signal after cleaned the air cleaner indicator or replaced with a new one.

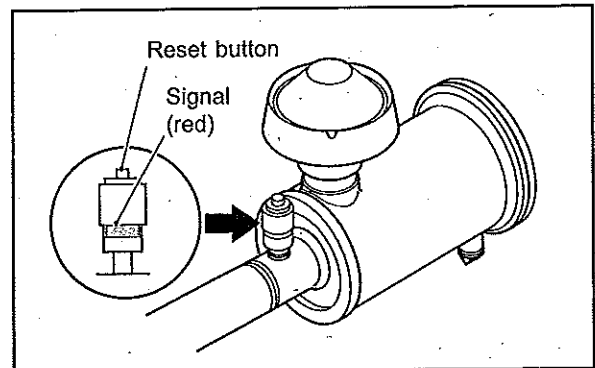


Fig. 2-9 Air cleaner indicator

## Using turning gear

### ⚠ WARNING

Before starting the engine, make sure that the turning gear is pulled out in the original position. Starting the engine with the turning gear pushed in not only damages the ring gear but also may result in personal injury.

1. Loosen the two bolts, and remove the plate from the shaft groove.

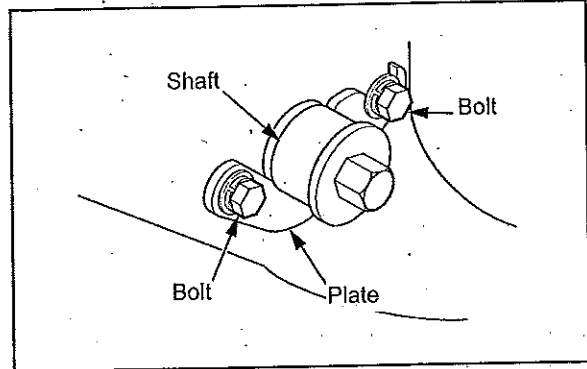


Fig. 2-10 Turning gear position (while engine is running)

2. Push in the shaft fully to engage it with the ring gear.

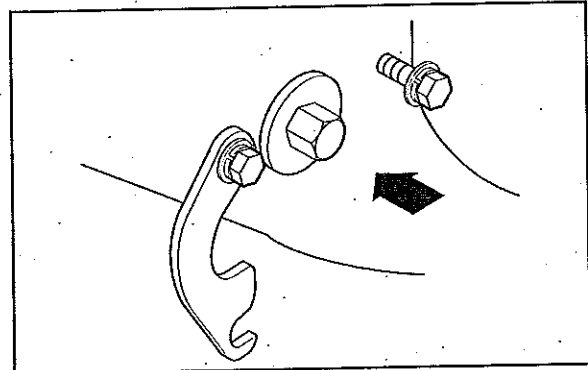


Fig. 2-11 Turning gear position (when pushing shaft in)

3. Using a socket wrench and a ratchet handle, turn the shaft.
4. After turning, pull out the shaft, insert the plate in the shaft groove, and tighten the bolts.

### ⚠ CAUTION

Make sure the plate is securely installed in the shaft groove.

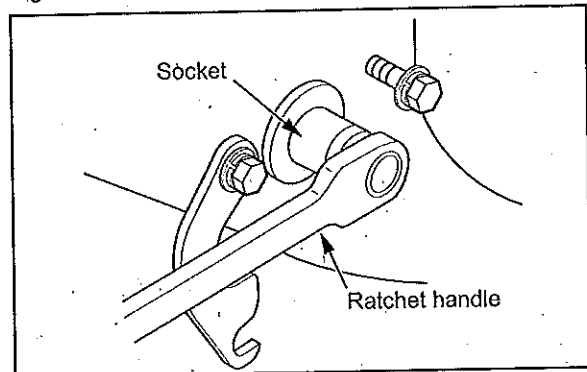
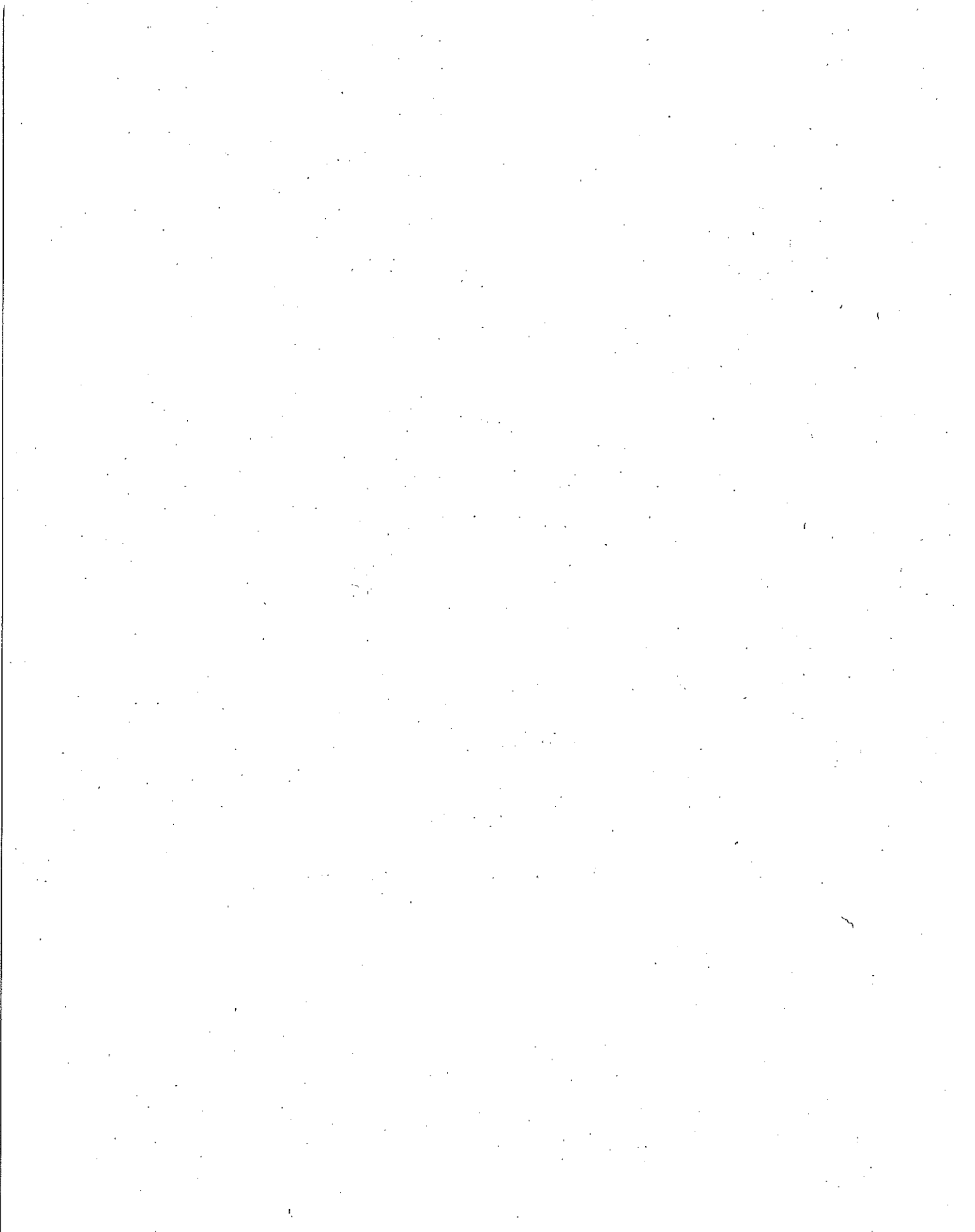


Fig. 2-12 Turning gear position (when turning shaft)



# Chapter 3 OPERATION

## Operational environment

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### CAUTION

---

Check that the following contents are performed before the engine is operated. Failure to do so may cause various problems and will shorten the service life of the engine.

- Prevent from spreading water (especially, seawater or rainwater) and entering foreign materials to the air inlet opening.
- Prevent from entering foreign materials to the rotating parts.
- Prevent from attaching water and dust to the electrical system.
- Use the engine at 5 to 40 °C [41 to 104 °F].

---

## Preparation for operating new or overhauled engine

Before proceeding with operation of a new overhauled engine, conduct the inspections described in this section. For second operation onward, follow the instructions described in the "Normal engine operation" (3-8).

## Preparation of fuel system

---

### ⚠ CAUTION

---

When handling fuel, make sure there are no open flames or other fire hazards near the engine.  
Wipe off any spilled fuel completely. Spilled fuel can ignite and cause a fire.

---

### CAUTION

---

Do not remove the strainer when filling the fuel tank.  
For fuel to be used, refer to "FUEL" (4-1).

1. Make sure the insides of the fuel tank and fuel supply pipes to the engine are thoroughly clean.
2. Fill fuel tank with fuel.
3. Remove the fuel feed pipe and drain plug from the fuel inlet of engine, and check the discharged fuel for foreign materials such as dust.
4. Reinstall the drain plug and the fuel feed pipe.
5. Refill fuel tank until fuel level gauge indicates "FULL" level line.

## Fuel system - Bleed air

### **WARNING**

When fuel overflow from the air vent plug, wipe thoroughly. Spilled fuel causes fire hazard.

After bleeding, lock the priming pump securely. If the cap is not locked tightly, the priming pump can be damaged, causing a fuel leak that could lead to a fire.

While feeding fuel with priming pump, bleed air from the location closest to the fuel tank that are the water separator, fuel filter, then the fuel injection pump. Lock the priming pump according to "Priming pump tightening method".

## Fuel filter - Bleed air

### **CAUTION**

If air vent plugs, the thread portion of the bracket, or sealing washers are damaged, replace them with new ones.

1. Loosen the air vent plug on the fuel filter about 1.5 turns.
2. Move the priming pump up and down, then feed fuel.
3. When the fuel from the air vent plug becomes free from air bubbles, stop priming and tighten the air vent plug to the specified torque.

## Fuel injection pump - Bleed air

1. Loosen the air vent plug on the fuel injection pump by rotating about 1.5 turns.
2. Move the priming pump up and down until the fuel flow from the air vent plug is free from air bubbles. Push and turn the priming pump clockwise to lock in the original position when the fuel flows is free from bubbles.
3. Tighten the air vent plug on the fuel injection pump.

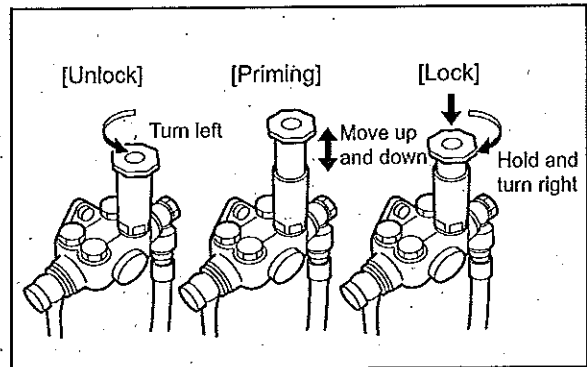


Fig. 3-1 Priming pump - Handle

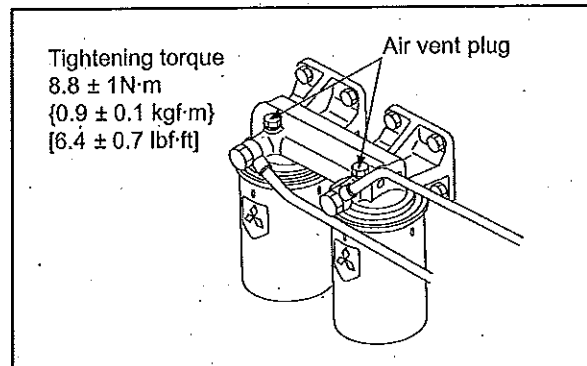


Fig. 3-2 Fuel filter - Bleed air

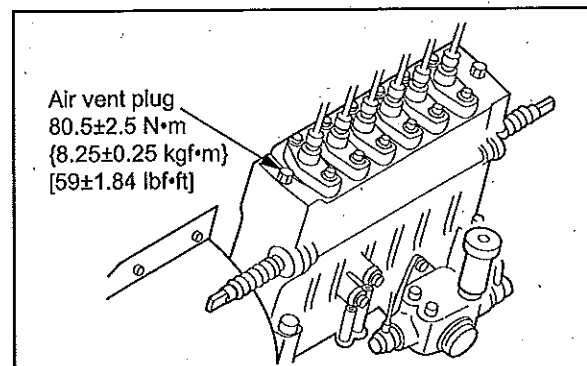


Fig. 3-3 Fuel injection pump - Bleed air

## Priming pump tightening method

### **CAUTION**

Never fail to tighten the priming pump to the specified angle. If the priming pump is not firmly tightened, internal thread will be worn due to engine vibration, resulting in sudden ejection of the cap to cause fuel flow-out. Or if the priming pump is excessively tightened, the head of the priming pump can be damaged.

1. Tighten the priming pump firmly by hand, and place a mark on the priming pump.
2. Use a wrench or another appropriate tool to tighten the priming pump  $90 \pm 10^\circ$ .
3. Check the mounting position of head packing.

Note: If the head packing has abnormality such as deformation or scratches, consult a dealer of Mitsubishi Heavy Industries, Ltd., as the priming pump needs to be changed.

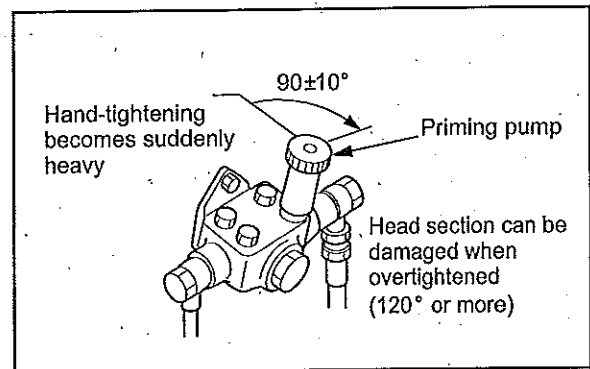


Fig. 3-4 Priming pump tightening method

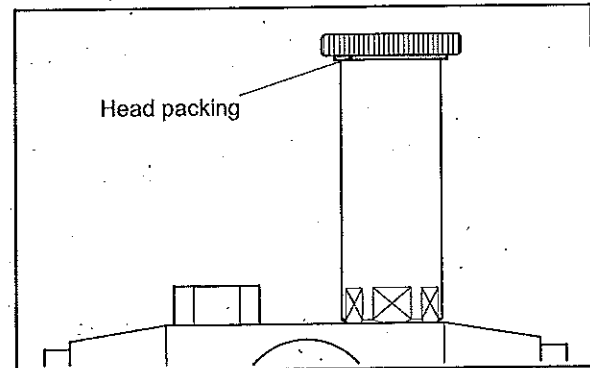


Fig. 3-5 Priming pump head packing

## Preparation of lubrication system

### Engine oil - Refill

**CAUTION**

Refilling engine oil must be specified level. If the refilling oil goes over the high marks on the oil level gauge, engine oil may blow out. And also, the engine component parts are adversely affected by increasing in oil temperature.

1. Remove the cap from the oil filler.
2. Fill the engine oil pan with specified engine oil to the specified level.

Note: For engine oil, refer to "ENGINE OIL" (5-1). For engine oil capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Remove the rocker cover, and pour engine oil to the valve mechanism and camshaft oil bath. Pour engine oil to camshaft oil bath from cylinder head side.

Oil capacity per cylinder: 0.8 L [0.2 U.S. gal.]

4. Reinstall the rocker covers.
5. Check the oil level in the oil pan as follows:
6. Pull out the oil level gauge and wipe it clean with a waste cloth.
7. Insert the oil level gauge fully into the oil level gauge guide, then pull out the gauge again.
8. The proper oil level is between the high and low marks on the oil level gauge.  
If the oil level is low, add engine oil of the specified type.
9. Check the oil pan and other area for oil leaks. Repair the oil leakage if any.
10. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times. Circulate engine oil to each engine parts.

Note: Prepare for the Cooling system.

11. Check the oil level with the oil level gauge again, and add oil to the specified level.

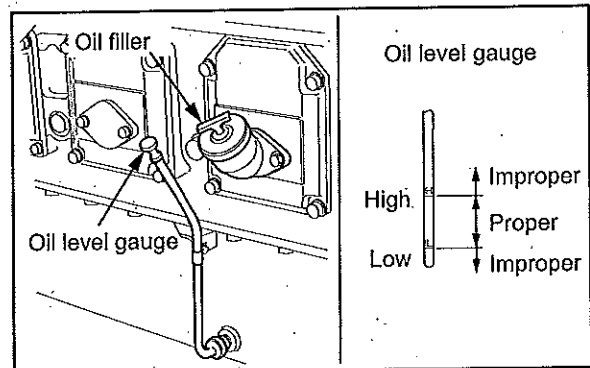


Fig. 3-6 Oil filler and Oil level gauge

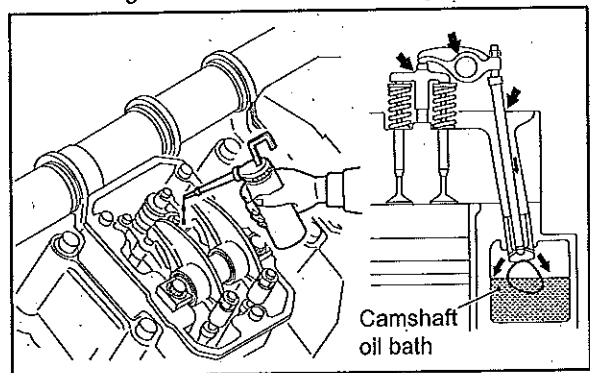


Fig. 3-7 Pouring engine oil on valve mechanisms and chamber

## Preparation of cooling system Coolant - Refill (Engine)

### CAUTION

Always use the coolant with the same LLC concentration.

1. Make sure coolant drain cocks are closed securely.
2. Remove the radiator filler cap, and pour in undiluted LLC.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.

For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Pour in water (soft water with minimal impurities, such as tap water) slowly to the full level.

Note: For absolute air bleeding, loosen the air vent plug.

4. Check the radiator and other parts for coolant leaks. Repair leakage if found.
5. When coolant reaches the full level, close the radiator cap securely.
6. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times to bleed the cooling system.

Note: Prepare for the lubricating system and refilling the coolant to the air cooler.

7. Check the coolant level in the radiator.

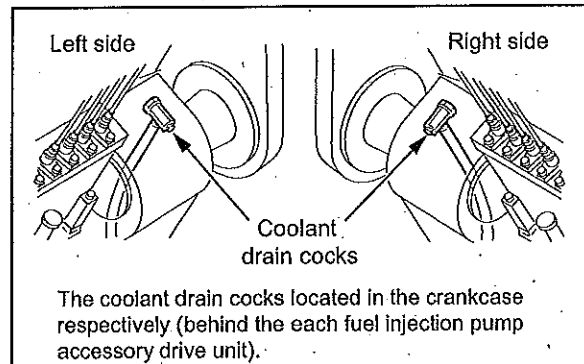


Fig. 3-8 Coolant drain cock (Engine)

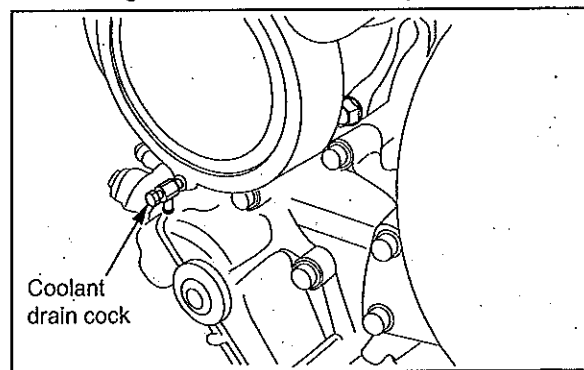


Fig. 3-9 Coolant drain cock (Engine water pump)

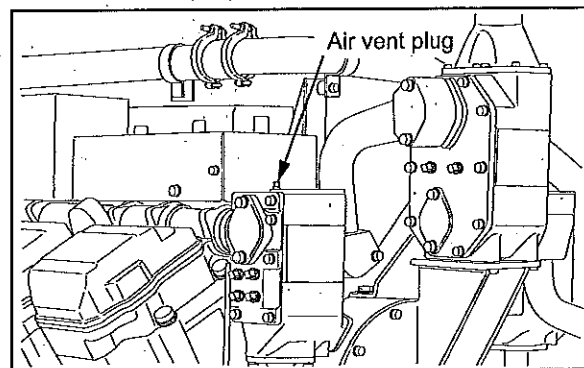


Fig. 3-10 Air vent plug (Engine cooling system)

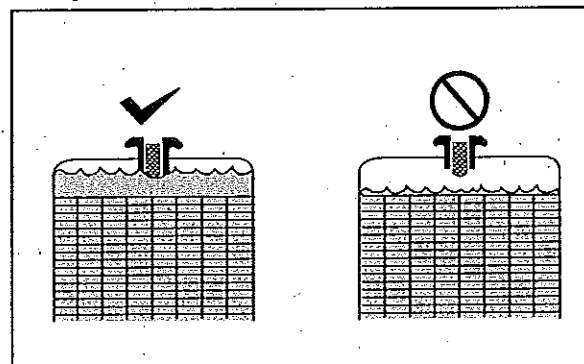


Fig. 3-11 Radiator coolant level

## Coolant - Refill (Air cooler)

### CAUTION

Always use the coolant with the same LLC concentration.

1. Make sure coolant drain cocks are closed securely.
2. Remove the radiator filler cap, and pour in undiluted LLC.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.

For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Pour in water (soft water with minimal impurities, such as tap water) slowly to the full level.  
Note: For absolute air bleeding, loosen the air vent cock and plug.
4. Check the radiator and other parts for coolant leaks. Repair leakage if found.
5. When coolant reaches the full level, close the radiator cap securely.
6. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times to bleed the cooling system.  
Note: Prepare for the lubricating system and refilling the coolant to the engine.
7. Check the coolant level in the radiator.

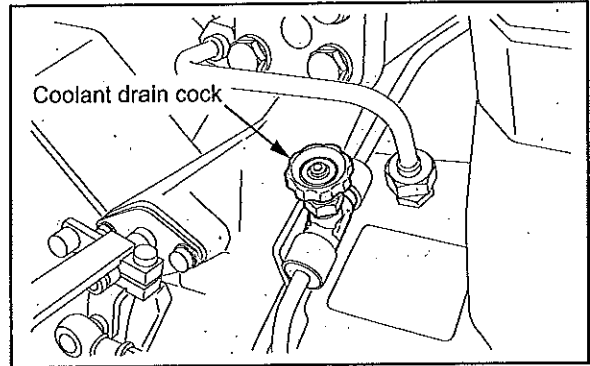


Fig. 3-12 Coolant drain cock (Air cooler)

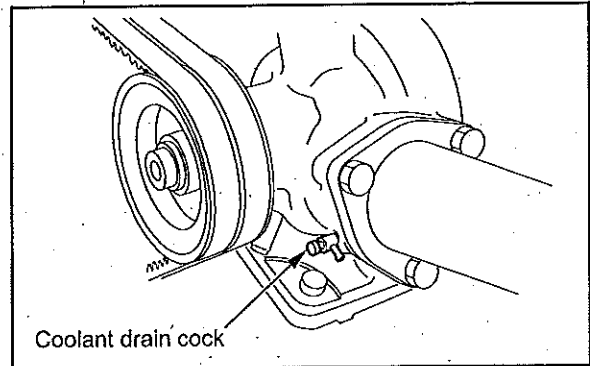


Fig. 3-13 Coolant drain cock (Air cooler water pump)

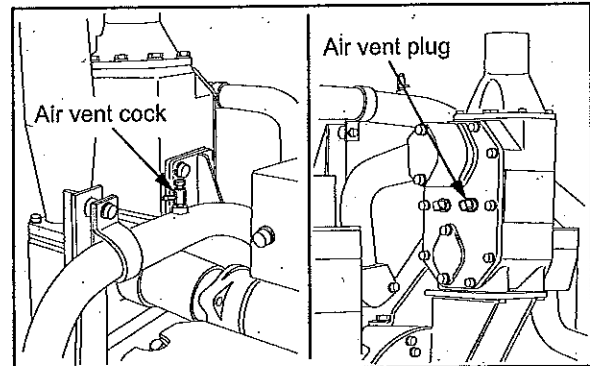


Fig. 3-14 Air vent cock and plug (Air cooler cooling system)

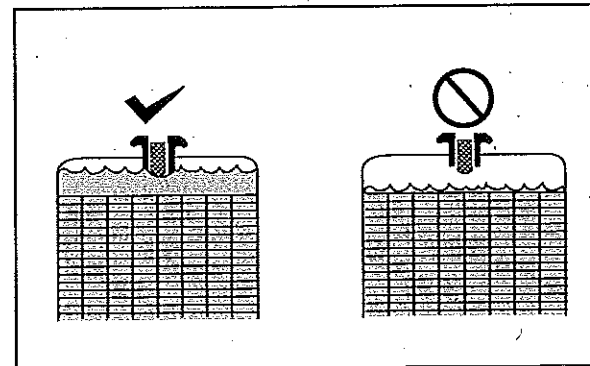


Fig. 3-15 Radiator coolant level

## Preparation of electrical system

### Battery - Inspect

#### ⚠ CAUTION

If battery electrolyte is spilled on your skin or clothes, flush immediately with plenty of water. If battery electrolyte get into your eyes, flush them immediately with plenty of water and then get medical attention.

Do not use open flames or other fire hazards near the battery. When handling the battery, be careful of sparks generated by accidental shorting.

### Battery electrolyte level - Inspect

Battery electrolyte evaporates during use and the electrolyte level gradually decreases. The proper electrolyte surface level is between the LOWER LEVEL and UPPER LEVEL lines.

For the battery without level lines, the proper electrolyte surface level is about 10 to 15 mm [0.39 to 0.59 in.] above the top of the plates.

If the electrolyte level is low, remove the caps and add distilled water to the proper level.

Note: When adding distilled water, pour in carefully.

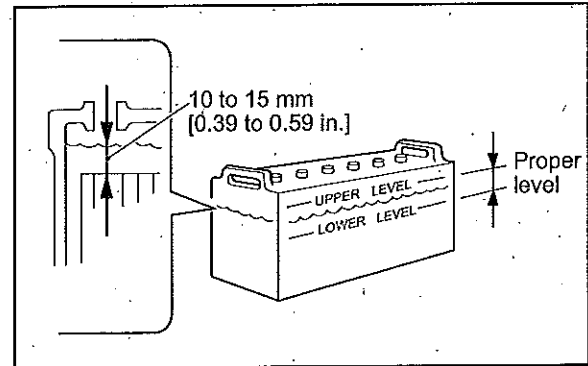


Fig. 3-16 Battery electrolyte level - Inspect

## Test operation

To conduct a test operation, follow the procedures below.

Note: For engine operation, refer to "Normal engine operation" (3-8).

### Starting and stopping

1. Start the engine.
2. Operate the engine at low idling speed under no load for 5 to 10 minutes for a warm-up operation.
3. Stop the engine.

### Inspection

1. Leave the engine be stopped for about 30 minutes.
2. During this period, check the engine and surrounding area for leaks of fuel, engine oil or coolant.
3. At 30 minutes after the engine stop, check the oil level with the oil level gauge.
4. If the oil level is low, add engine oil from the oil filler. Be sure to use the engine oil of the same brand and type.
5. Open the radiator filler cap and check the coolant level.

#### ⚠ CAUTION

Remove the radiator cap only after the engine has cooled to room temperature. Place a waste cloth over the cap, and loosen the cap about a half-turn or stand the lever to the upright position to release internal pressure. Never open the radiator filler cap while the engine is hot, otherwise the steam or hot coolant spurts out and you may be scald with it.

6. If the coolant level is low, add coolant to the specified level.

If the engine is equipped with a reserve tank, fill the reserve tank with coolant to the "FULL" level line as well.

#### CAUTION

Always use the coolant with the same LLC concentration.

## Normal engine operation

This section of the manual covers the procedures for the engine operation in normal condition.

### CAUTION

Should an engine abnormality be observed during operation, stop the engine and correct the problem, or contact a dealer of Mitsubishi Heavy Industries, Ltd.

## Preparations for operation

Always conduct the following inspection before starting the engine.

### Engine external - Inspect

#### CAUTION

Be sure to keep combustible materials away from the engine, especially from the hot engine parts such as exhaust manifolds, or the battery. Check for fuel and oil leaks. Clean the top surface of the battery. A fire can be caused by combustible materials placed near hot engine parts. If any abnormality is found, be sure to repair it or contact a dealer of Mitsubishi Heavy Industries, Ltd.

Inspect the engine exterior as described below.

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Check the whole engine for leaks of fuel, engine oil or coolant. If leaks are found, repair the leak, or contact a dealer of Mitsubishi Heavy Industries, Ltd.
3. Visually check bolts and nuts for looseness.
4. Check the electrical wiring including the starters and alternator.
5. Make sure the following valves, plugs and cocks are open or closed properly:
  - ♦Fuel feed valve: Open
  - ♦Coolant drain cock (plug): Closed
  - ♦Oil drain valve: Closed
  - ♦Air supply valve (air tank): Open

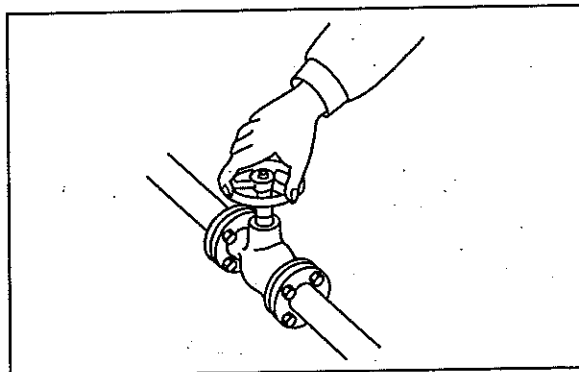


Fig. 3-17 Valves for open/closed position - Check

## Fuel tank oil level - Check

### WARNING

When working around fuel, make sure there are no open flames, heaters or other fire hazards. Wipe off any spilled fuel completely. Spilled fuel can ignite and cause a fire.

### CAUTION

Do not remove the strainer when filling the fuel tank.  
For fuel to be used, refer to "FUEL" (4-1).

Make sure the fuel tank is full.

If the fuel level is low, refill the tank to the "FULL" level line.

## Fuel tank - Drain water

### WARNING

When working around fuel, make sure there are no open flames, heaters or other fire hazards. Wipe off any spilled fuel completely. Spilled fuel can ignite and cause a fire.

### CAUTION

Do not remove the strainer when filling the fuel. For fuel to be used, refer to "FUEL" (4-1).

Bleeding water procedure described below is a commonly used procedure. Some application may be equipped with different fuel tank.

If fuel gets mixed with particles of foreign material such as dust, dirt, or water, it can cause not only decrease of output but also malfunctions of the fuel system. To avoid such a problem, drain fuel tank as described below.

1. Prepare the oil pan (capacity of 2 L [0.5 U.S. gal.] or more) under the drain cock of fuel tank.
2. Open the drain cock of fuel tank and drain fuel at least 1 to 2 L [0.3 to 0.5 U.S. gal.].
3. Make sure that water and particles of foreign material discharged with fuel. Close the drain cock.

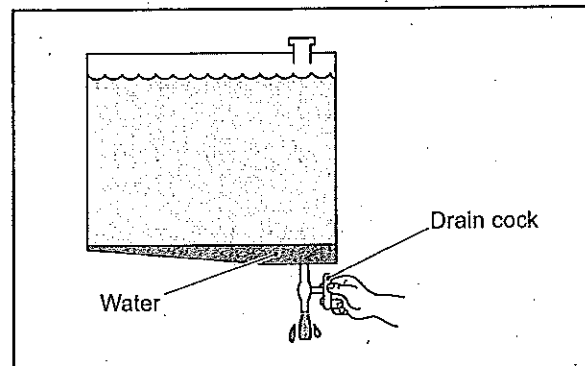


Fig. 3-18 Fuel tank - Drain water

## Engine oil level - Check

**CAUTION**

Refilling engine oil must be specified level. If the refilling oil goes over the high marks on the oil level gauge, engine oil may blow out.

1. Pull out the oil level gauge and wipe it clean using a waste cloth.
2. Insert the oil level gauge fully into the oil level gauge guide, then pull out the gauge again.
3. The proper oil level is between the high and low marks on the oil level gauge.
4. If the oil level is low, remove the oil filler cap and add engine oil of the specified type to the high level.
5. Install the oil filler cap after refilling.
6. Check the oil pan and other area for oil leaks.

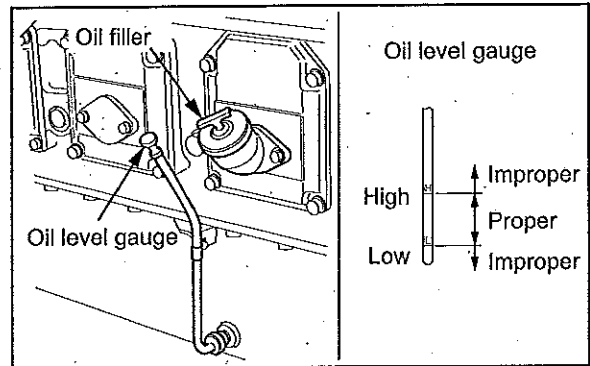


Fig. 3-19 Oil filler and Oil level gauge

## Coolant level - Check

### WARNING

Remove the radiator cap only after the engine has cooled to room temperature. Place a waste cloth over the cap, and loosen the cap about a half-turn or stand the lever to the upright position to release internal pressure. Never open the radiator filler cap while the engine is hot, otherwise the steam or hot coolant spurts out and you may be scalded with it.

1. Open the radiator filler cap and check the coolant level.
2. If the coolant level is low, add coolant to the specified level.

### CAUTION

Always use the coolant with the same LLC concentration.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.

For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. If a reserve tank is equipped, fill the reserve tank with coolant up to the "FULL" level line.

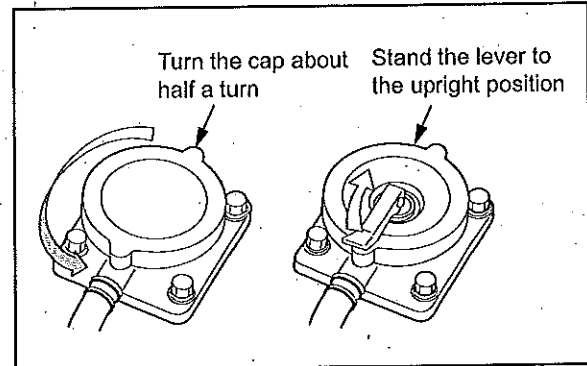


Fig. 3-20 Radiator filler cap.

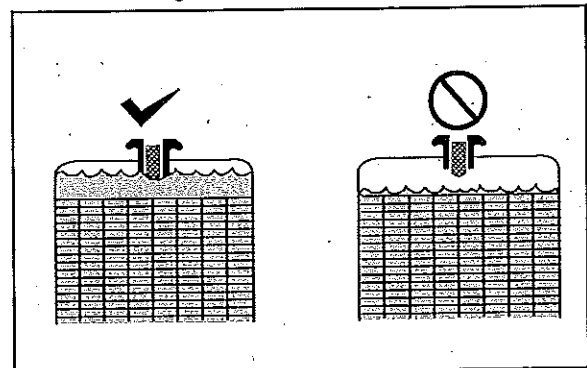


Fig. 3-21 Radiator coolant level

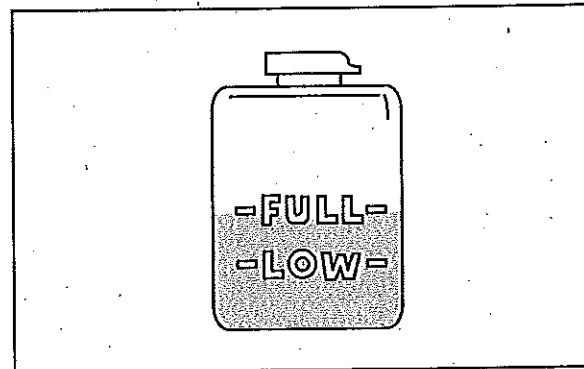


Fig. 3-22 Reserve tank coolant level

## Fuel control link - Check

Check fuel control link for smooth movement. Also check ball joint for looseness and play.

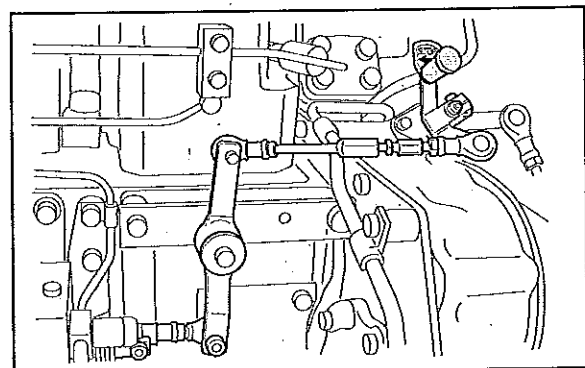


Fig. 3-23 Fuel control link - Check

## Air cleaner - Check

1. Check the air cleaner indicator for the element clog.
2. If the element is clogged, the red signal mark is visible.
3. Immediately clean or replace the air cleaner element when the signal turns red.
4. After checking, press the bottom on top of the indicator to re-set the alarm signal.

Note: For cleaning of the air cleaner element, refer to "Air cleaner element - Clean, Check and Replace" (8-19).

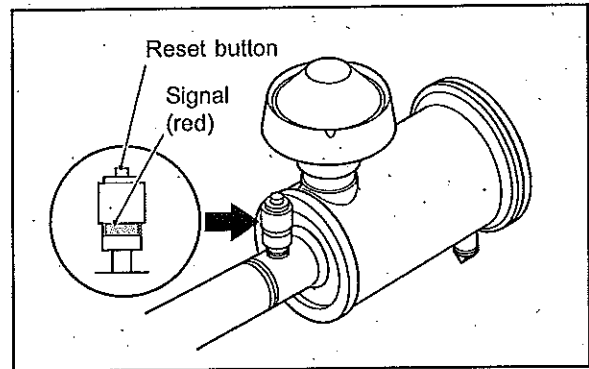


Fig. 3-24 Air cleaner - Check

## Temperature of damper - Check Damper temperature management by thermo label

It is recommended to use the thermo label for temperature management of the damper. Check the thermo label before starting engine.

1. Check the thermal part of thermo label is black.
2. Note the highest temperature of thermal part. Note the temperature periodically, and check the abnormality of temperature alteration.

### CAUTION

If the abnormality of temperature alteration is found, consult a dealer of Mitsubishi Heavy Industries, Ltd.

Note: For damper inspection, refer to "Damper - Inspect" (8-3).

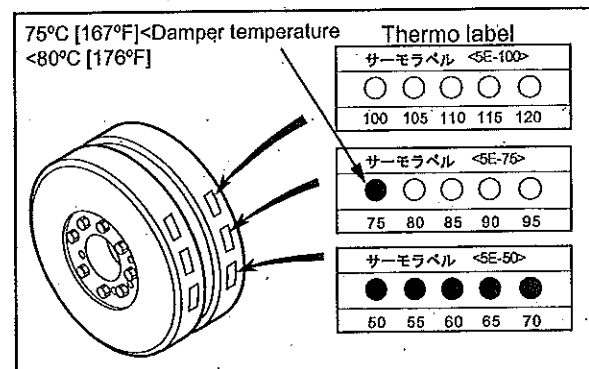


Fig. 3-25 Thermo label of damper

## Starting

The starting method changes based on the application and specifications. Start the engine according to the specified procedure.

### WARNING

Before starting the engine, check to make sure no one is near the engine and that tools are not left on or near the engine. In a loud voice, notify people in the area when starting the engine.

### CAUTION

Do not apply a load to the engine at starting. (Disengage the clutch if installed.)  
Continuous operation of the starter will drain the battery power and cause the starter to seize. Do not use the starter for more than 10 seconds at a time. When the engine does not start, return the key to "OFF" position and wait for more than 1 minute before cranking again.

## Warm-up operation

### WARNING

Do not approach rotating parts during operation. Entanglement by rotating parts can cause serious injury.

After the engine starts, operate the engine in a no load condition at low idling speed for 5 to 10 minutes to warm up the engine.

## Checking engine oil pressure

During warming-up operation, check if the oil pressure is in the range of standard value (0.15 MPa {1.53 kgf/cm<sup>2</sup>} [21.76 psi] or more).

Also, make sure the oil pressure gauge is operating properly.

Note: The oil pressure gauge may indicate a higher level than normal level immediately after the engine starts, due to the low oil temperature. The pressure gradually lowers to the normal level as the oil temperature rises.

## External inspection during warm-up

Visually check the external view of the engine for leaks of fuel, engine oil and coolant, or leaks of exhaust gas from joints.

## Operation

### Cautions when operating

#### **⚠ WARNING**

Do not approach rotating parts during operation. Entanglement by rotating parts can cause serious injury.

#### **⚠ CAUTION**

Do not touch any hot part of the engine such as exhaust pipes during operation or immediately after shut down. A hot engine can cause burns.

#### **CAUTION**

Always provide adequate ventilation in the engine room. If air supply to the engine room is not sufficient, the room temperature rises and can affect engine output and performance.

For the first 50 hours, operate the engine under a light load for break-in operation. Operating the engine under heavy load or severe conditions during the break-in period can shorten the service life of the engine.

Do not turn the battery switch to OFF when the engine is running. Turning off the battery switch during operation not only stops the instrument operations but also may deteriorate the alternator diode and regulator.

Never turn the key to the "START" position during operation. The starter may be damaged.

When operating the engine with a 30 % of rated load or lower, limit each operation to an hour. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion. Operate the engine with a 30 % of rated load or more for over 5 minutes after continuous operation for an hour to prevent causing carbon build-up.

### Inspection during operation

Carefully check the exterior of engine such as piping joints for leaks.

Check for abnormal engine noises or vibrations such as knocking.

Check the color of exhaust gas from the exhaust muffler.

Check the instruments and gauges for proper operation and make sure they indicate normal values.

Table 3-1 Standard values at rated speed

Item		Standard
Engine oil pressure		0.49 to 0.64 MPa {5 to 6.5 kgf/cm <sup>2</sup> } [71 to 92 psi]
Coolant temperature	Basic engine Cooling system	70 to 90°C [158 to 194°F]
	Air cooler Cooling system	40 to 70°C [104 to 158°F]

Note: (a) When the oil pressure drops below 0.29 MPa {2.96 kgf/cm<sup>2</sup>} [442.06 psi] in normal operation, or below 0.10 MPa {1.02 kgf/cm<sup>2</sup>} [14.50 psi] at low idling, stop the engine immediately.

Be sure to locate the cause of problem and correct it before restarting the engine.

(b) When the thermo switch is activated in normal run, idle the engine low for 5 or 6 minutes to perform the cooling operation before stopping the engine. Be sure to locate the cause of problem and correct it before restarting the engine.

## Stopping

### ⚠ CAUTION

Stopping the engine abruptly while engine parts are hot due to high-speed operation can be a cause for heat up of the engine parts and shorten the engine life. Before stopping the engine, idle the engine in low for 5 or 6 minutes to perform cooling operation, and check the engine for abnormalities.

Never accelerate the engine immediately before shutting it down.

Do not restart the engine immediately after abnormal shut down. When the engine stops with alarms, be sure to locate the cause of the problem and correct the problem before restarting the engine. After restarting the operation, check the engine for abnormalities again. If the engine has an abnormality, repair it immediately.

Engine stopping method may differ depending on the specifications.

Follow the instructions according to the specifications of the equipment.

## Emergency stop

### ⚠ CAUTION

When stopping the engine by pulling the manual stop lever, continue pulling the lever until the engine stops completely. If not, the engine may start again.

To perform the emergency stop, pull the manual stop lever to the arrow direction. Continue pulling the lever until the engine stops completely.

Note: When the engine does not stop even if the manual stop lever is pulled, stop fuel supply.

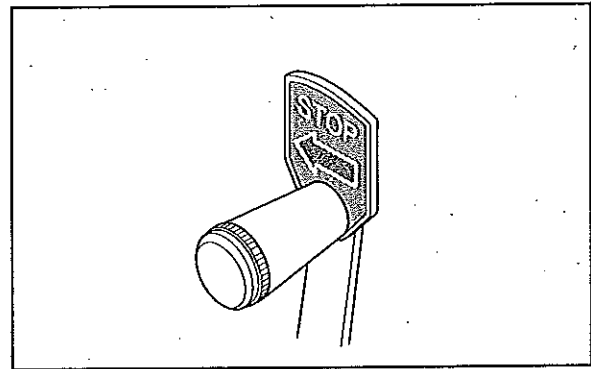
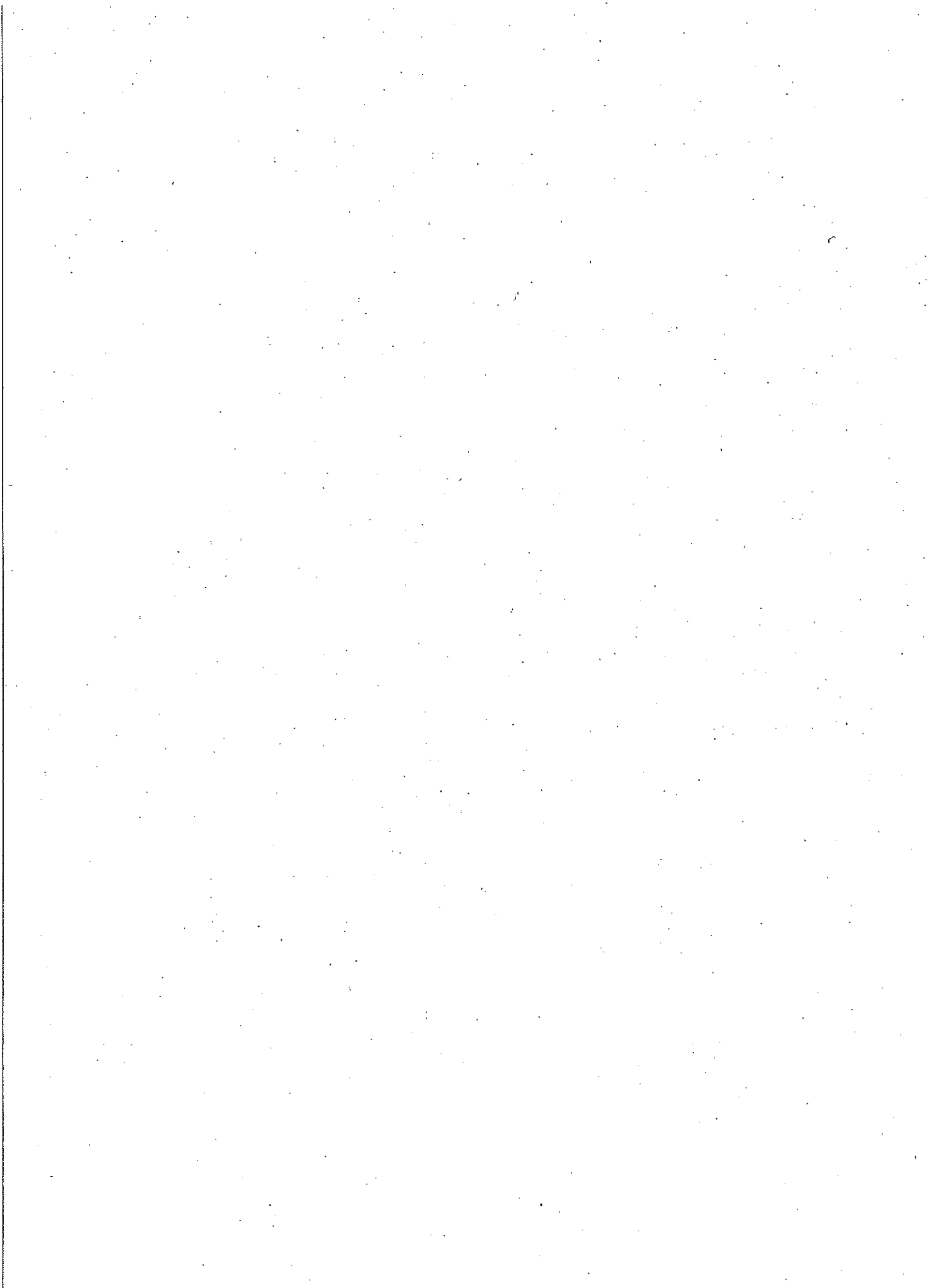


Fig. 3-26 Manual stop lever

## Inspection after stopping

Inspect the engine for leaks of fuel, oil or coolant. If any leak is found, repair the leak or contact a dealer of Mitsubishi Heavy Industries, Ltd.



## Recommended fuel

**⚠ WARNING**

Use a fuel specified in this manual only. Do not refill the fuel tank more than the specified level, as it may result in a fire.

Use fuel that meets the values specified in the following Table 4-1 of "Recommended fuel" and Table 4-2 of "Recommended and limit values of fuel property".

It is necessary to use fuel that has a pour point suitable for the ambient temperature.

Note: Please use the fuel that meet the control of the countries or areas where the engine is used, if the control is applied.

Table 4-1 Recommended fuel

Specification	Classification
ISO 8217	DMX-CLASS
ASTM D975	No.1-D, No.2-D
BS 2869	CLASS A1, CLASS A2
DIN 51601	DIESEL-FUEL
JIS K2204	TYPE1, TYPE2, TYPE3
EN 590	DIESEL-FUEL

## Handling fuel

When using fuel stored in a storage tank, leave it to sit for more than 24 hours so that dust and water can settle at the bottom. Then, use the upper clean fuel.

Fill up the fuel tank or service tank after each operation.

This prevents water from mixing with fuel in the tank and also gives time for dust and water to separate and settle at the bottom of the tank.

Before refilling, clean the areas around the caps thoroughly and remove the caps from the drum and tank. Also clean your hands and the hose before refueling. When using a hand-operated pump, be careful not to pump water or sediment accumulated at the bottom of the storage tank.

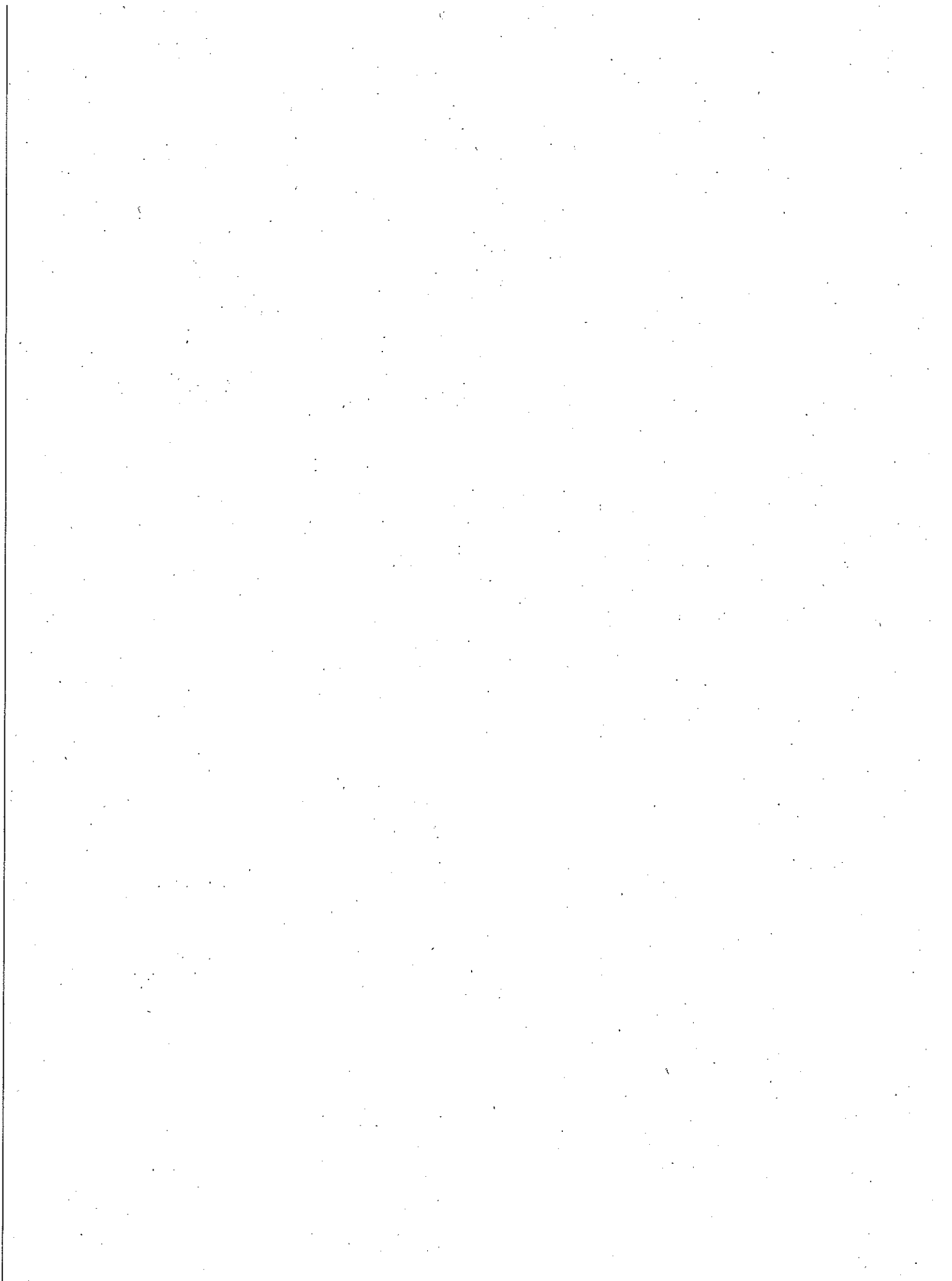
Be sure to use a strainer when filling fuel tank. For a complete filtration, it is recommended to use a clean lint-free cloth together with the strainer.

Table 4-2 Recommended limit and use limit of fuel property

Properties		Recommended limits	Use limits	Test method
Flash point		50°C [122°F] or higher (In accordance with the regulation)		JIS K 2265:2007 ISO 3769 ISO 2719
Distillation	Initial boiling point	170°C [338°F] or higher		JIS K 2254:1998 ISO 3405
	90 % distillate temperature	330 to 380°C [626 to 716°F]		
Pour point (PP)		6°C [42.8°F] or lower than ambient temperature		JIS K 2269:1987 ISO 3016
Cloud point (CP)		Below ambient temperature		JIS K 2269:1987 ISO 3016
Cold filter plugging point (CFPP)		3 °C [37.4 °F] or lower than ambient temperature		JIS K 2288:2000 IP 309/96
Carbon residue (10 % residual oil)		0.4 weight % or lower	1.0 weight % or lower	JIS K 2270:2000 ISO 6615 ISO 10370
Cetane number		45 or higher		JIS K 2280:1996 ISO 5165
Cetane index (new type)		45 or higher		JIS K 2280:1996 ISO/DIS 4264
Kinematic viscosity		2.0 mm <sup>2</sup> /s [0.0031 in <sup>2</sup> /s] or more at 30 °C [86 °F] 8.0 mm <sup>2</sup> /s [0.0124 in <sup>2</sup> /s] or more at 30 °C [86 °F]		JIS K 2283:2000 ISO 3104
Sulfur content		0.2 weight % or lower	1.0 weight % or lower (Shorten lub. oil change intervals)	JIS K 2541:2000 (The content should be as low as the diesel fuel.) ISO 4260 ISO 8754
Water content and sediment		0.1 volume % or lower		JIS K 2275:1998 ISO 3733
Ash content		0.01 % by mass or less	0.03 weight % or lower	JIS K 2272:1998 ISO 6245
Copper corrosion (3 hrs at 50 °C [122 °F])		Color change = Copper plate No.3 or less		JIS K 2513:2000 ISO 2160
Density at 15 °C [59 °F]		0.83 to 0.87 g/cm <sup>3</sup> [49.9424 to 54.3123 lb/ft <sup>3</sup> ]	0.80 to 0.87 g/cm <sup>3</sup> [49.9424 to 54.3123 lb/ft <sup>3</sup> ]	JIS K 2249:1995 ISO 3675
Caulking	24 hrs at 250 °C [482 °F]	75 % carbonization or less	80 % carbonization or less	Fed 791B
	24 hrs at 230 °C [446 °F]	55 % carbonization or less	-	
	48 hrs at 180 °C [356 °F]	Tar-free	-	
Aromatics substances (by HPLC)		38 % by volume or less		JIS K 2536:2003 ISO 3837
Polycyclic aromatic content		8 % by volume or less		
Asphaltene		0.1 weight % or lower		
Foreign substances (foreign materials at engine fuel inlet)		5.0 mg/liter or less		JIS B 9931:2000 ISO 4405

Table 4-2 Recommended limit and use limit of fuel property

Properties	Recommended limits	Use limits	Test method
Lubricity: MWSD (Measured mean Wear Scar Diameter) by HFRR wear test at 60 °C [140 °F] fuel temperature	460 µm [0.02 in.] or less (calculated wear scar diameter at WS 1.4 kPa {0.0143 kgf/cm <sup>2</sup> } [0.2031 psi])		ISO 12156-1
BDF: Biodiesel fuel (FAME: Fatty Acid Methyl Ester)	BDF quality shall meet JIS K 2390, ASTM D 3751 or EN14214 BDF blending of 5 % by volume or less is approved		JIS K 2390:2008 EN14214 ASTM-D6751 FAME for mixing ASTM D 6751 EN 14214
Engine applications	for prime, or continuous use	for stand-by use	Selection according to application



# Chapter 5 ENGINE OIL

## Recommended engine oil

### CAUTION

Use only the engine oils recommended in this manual. Never use other oils.

The use of inappropriate or inferior oils will result in sticking of piston rings, seizure between piston and cylinder, or premature wear of bearings and moving parts, and significantly shortens the service life of the engine.

Many oil standards, which are established through special engine tests, are available to determine the quality of oil depending on the engines to which they will be applied and on operating conditions. Among those standards, API (American Petroleum Institute) service classifications are mostly used to classify engine oils. SAE specifies the viscosity only, while the API service classification indicates the quality level of engine oil.

For engine lubrication oil, please use API service classification CF.

### Selection of oil viscosity

Use the following chart to select the appropriate oil viscosity according to the ambient temperature.

Excessively high oil viscosity causes power loss and an abnormal rise of oil temperature, while excessively low oil viscosity accelerates wear due to inadequate lubrication, and also causes a decrease in engine output due to leakage of combustion gas.

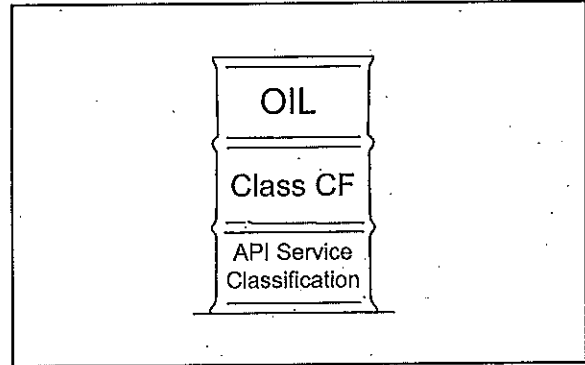


Fig. 5-1 Recommended engine oil

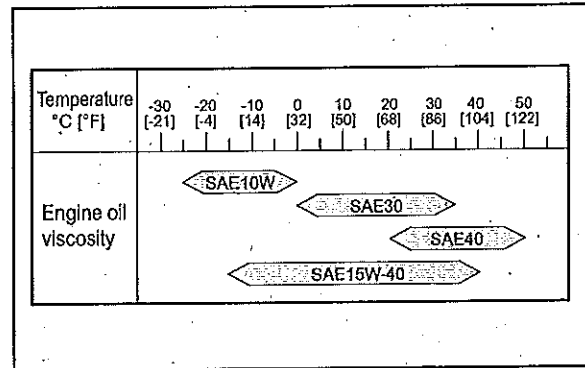


Fig. 5-2 Selection of oil viscosity

## Handling engine oil

### WARNING

Before filling the engine with engine oil, stop the engine and make sure there are no open flames and other fire hazards near the engine. Leaked or spilled oil on hot surfaces or electrical components can cause a fire. Wipe off any spilled oil immediately and thoroughly. After filling, securely close the filler cap.

### CAUTION

Never mix different brands of engine oil. Mixing different brands of engine oil may cause a chemical reaction of additives in the engine oil that could degrade the engine oil quality.

When handling oil in greater than the legally specified quantities, be sure to have the work performed by a service station in compliance with the law. When removing oil from the engine or oil can, use an oil pump. Do not suck oil with the mouth to siphon it.

Be sure to close the cap on the oil can after use.

Keep oil in a well-ventilated place and out of direct sunlight.

Be sure to obtain the MSDS of the engine oil used and follow the instructions of the MSDS.

## Engine oil performance requirements

Engine oil requires the following performances.

- Excellent dispersion performance (the ability of oil to disperse sludge in the oil) at high temperature that prevents engine oil deterioration due to sludge accumulation and soot contamination.
- Excellent acid-neutralizing performance that prevents oxidative degradation due to fuel sulfur content.
- Excellent high temperature oxidation stability that endures continuous operation under prolonged high-load.
- Sufficient viscosity concentration to maintain the cold start performance, and lubrication performance at high temperature.
- Good rust and corrosion resistance to water.
- Good foam resistance to prevent the lubricating quality from lowering due to oxidation.

## Engine oil deterioration mechanisms

- Engine oil deteriorates due to natural deterioration and due to the contamination. The natural deterioration of oil has two primary causes; one is the degradation caused by oxidation reaction or thermal decomposition of base oil and additives, and the other is the degradation in the performance due to consumption of additives during use.
- Contaminants such as fuel and combustion products (soot, water vapor or oxidation products) that intrude into oil have critical influence on oil quality. Soot adheres to the oil film of cylinder wall, and is scraped off the cylinder wall by the piston ring. Such soot increases the rate of insoluble substances in the engine oil and can cause the wear of piston rings and cylinder walls.
- Abrasion powder in the engine oil also accelerates deterioration as it can catalyze oxidation reaction. Dust and dirt entered from outside deteriorate the engine oil as well. Contamination and deterioration process accelerates with operation time.
- Deterioration products and contaminants in the engine oil, if it is a small amount, are harmless as they can be dispersed in oil. However, if it is a large amount, they become harmful. Since such products and contaminants flow out of the oil pan and start to

accumulate inside the piston and in the oil system, they eventually lead to serious problems such as piston ring sticking and bearing scuffing.

- Sulfur content in fuel is burned and transformed into sulfuric acid gas and sulfuric gas that cause corrosive wear of cylinders and piston rings. A detergent additive in the engine oil neutralizes them into harmless substances. As the detergent additive is consumed in its role of neutralizing, the engine oil total base value decreases. A decrease in the total base value indicates a corresponding decrease in soot dispersion ability. As a result, deposits on the pistons increase.
- Due to oxygen in the air, oil temperature rise under high-load continuous operation causes oxidation degradation. As oxidation degradation accelerates, oxidative products are polymerized. The polymerized oxidative products cause the oil viscosity to increase, which leads to the generation of sludge and varnish. As a result, problems such as lubrication failure and piston ring sticking occur. Also acid substances generated by oxidation can cause problems like main bearing corrosion.

## Definition of properties of engine oil

### Kinetic viscosity

Kinetic viscosity is a basic physical property of engine oil and is considered as the most important aspect when evaluating oil.

Contamination of oil by blow-by gas and deterioration of oil by its natural aging increase the kinetic viscosity and degrade the performance of viscosity, which will cause the deposition of sludge inside the engine and oil filter clogging. Contamination of oil by fuel and sheared molecules of viscosity index improver in oil decrease the viscosity and degrade the performance of viscosity, which will cause insufficient lubrication and friction/wear of engine parts.

### Total base number

Total base number (TBN) shows the ability to neutralize acids such as organic acid due to engine oil oxidation, or sulfurous or sulfuric acid due to the sulfur content of fuel.

Because TBN indicates the amount of dispersant detergent in oil, it can be used to estimate consumption of basic dispersant detergent. The ability to disperse sludge declines as dispersant detergent is used up.

### Total acid number

The total acid number in oil increases as the organic acid is being derived by the engine oil oxidation, or sulfurous acid or sulfuric acid derived by the combustion of sulfur content of fuel, or the oil becomes contaminated with imperfect combustion products.

An increase in the total acid number will result in corrosion or wear of the inner parts of the engine (such as cylinder liners or metal) due to sulfur content, and piston ring seizure due to sludge.

### Water content

Water in oil promotes corrosion/wear, and decreases lubricity in sliding parts.

### Flash point

The flash point is lowered by contamination with fuels. Flash point is measured to check the dilution of fuel. The dilution of fuel reduces oil film, and causes insufficient lubrication that will cause friction or wear of engine parts.

### Insoluble

Insoluble includes acid products of engine oil, imperfect combustion products, sludge or soot, metal abrasive particles and dust. Insoluble is an indication of degradation/contamination of oil.

Dispersant detergent, which is an additive in engine oil, absorbs sludge particles, and disperses them as fine particles in oil. Total insoluble density and remaining dispersibility can be obtained by measuring insoluble and coagulated insoluble (using chemical specialities to stop action of disperse detergent and to collect the sludge dispersed in oil) by which piston ring seizure or premature wear can be prevented before it occurs.

## Service limits of engine oil

Engine oil degrades through the use and by lapse of time.

To determine the timing of engine oil replacement, analyze the used oil, and understand the condition of oil deterioration and oil defacement. It is also required to compare the oil analysis results and the engine analysis results including inside contamination and wear condition of engine, and to consider the engine operating condition.

The engine oil affects the engine oil quality to use, the engine operating condition and the quality of fuel. Analyze the used oil, and understand the condition of oil deterioration and oil defacement. To determine the timing of engine oil replacement, the stabiration of engine is required.

Refer to the following table for the determination of engine oil performance degradation. If any of the following deviate the limit, replace the engine oil with new oil.

Table 5-1 Engine oil properties

Properties		Standard	Test method
Kinetic viscosity	mm <sup>2</sup> /s [in <sup>2</sup> /s] @100°C [212 °F]	+3.0 % or less change of new oil 10 mm <sup>2</sup> /s [0.155 in <sup>2</sup> /s] or more	JIS K 2283:2007 ISO 3107 ISO 2909
		+30 % or less change of new oil -20 % change of new oil	
Total base number	mgKOH/g	2.0 or more with hydrochloric acid (HCL) method 1/2 of new oil or more with perchlo- ric acid (PCA) method	JIS K 2501:2003 ISO 3771
Total acid number	mgKOH/g	Up to +3.0 of new oil	JIS K 2501:2003 ISO 3771
Water content	Vol %	0.2 or less	JIS K 2275:1996 ISO 9029
Flash point (open cup)	°C	180 or higher	JIS K 2265:2007 ISO 3769 ISO 2719
Pentane insoluble	Wt %	0.5 or less	ASTM D 893
Pentane insoluble coag- ulated	Wt %	3.0 or less	ASTM D 893

## Engine oil analysis service

For a long term service life of engine, it is recommended to get an engine oil analysis service.

It is a system to understand the availability of the engine oil using in your engine by sampling it with the special sampling tools.

The engine oil analysis service provides the followings:

- ◆The quantity of fine metal powder in engine oil due to abrasion, by which worn parts can be located.
- ◆Water, LLC or salt that should not be in engine oil can be detected.
- ◆Engine oil deteriorating conditions, by which appropriate engine oil renewal intervals, operating conditions, proper inspection and maintenance schedule can be planned.

The engine oil analysis service can diagnose the internal condition of the engine, which is necessary when disassembling the engine. It is highly recommended to take advantage of our engine oil analysis service so that you can learn the engine condition before any malfunction occurs to the engine.

# Chapter 6 COOLANT

Note: In this operation manual, the word "coolant" represents the liquid combined water and LLC.

## Recommended water for coolant

Use soft water for the engine cooling system. The water quality must meet the requirements in the Table below. Basically, the water quality should be within the recommended value, however, up to the limit is acceptable.

Table 6-1 Water quality standards

Item	Chemical symbol	Unit	Recommend value	Limit	Main adverse effect
pH (25°C [77°F])	-	-	6.5 to 8.0	6.5 to 8.5	Corrosion and rust, scale formation
Electrical conductivity (25°C [77°F])	-	mS/m	< 25	< 40	Corrosion and rust, scale formation
Total hardness	CaCO <sub>3</sub>	ppm	< 95	< 100	Scale formation
M-alkalinity	CaCO <sub>3</sub>	ppm	< 70	< 150	Scale formation
Chlorine ion	Cl <sup>-</sup>	ppm	< 100	< 100	Corrosion and rust
Sulfuric acid ion	SO <sub>4</sub> <sup>2-</sup>	ppm	< 50	< 100	Corrosion and rust
Total iron	Fe	ppm	< 1.0	< 1.0	Scale formation
Silica	SiO <sub>2</sub>	ppm	< 30	< 50	Scale formation
Residue from evaporation	-	ppm	< 250	< 400	Scale formation

Note: Figures in parentheses are the standard value. In addition to the items specified above, turbidity is specified to be below 15 mg/liter.

## Long life coolant (LLC)

### ⚠ CAUTION

Should coolant or LLC be accidentally swallowed, induce vomiting immediately and seek medical attention. If LLC should enter eyes, flush immediately with plenty of water and seek medical attention.

Be sure to use Mitsubishi Heavy Industries, Ltd. genuine long life coolant (LLC) "GLASSY long life coolant (Ethylene glycol type)" or "PG GLASSY long life coolant (Non-amine type)" as coolant. When using other brand LLCs by necessity, be sure to use the LLC that meets the specification in Mitsubishi Heavy Industries, Ltd. Mitsubishi heavy industries, Ltd. disclaim the warranty claim concerning malfunctions caused by the use of LLC that does not meet the following specification.

## Genuine LLC

Mitsubishi Heavy Industries, Ltd. recommends the use of our genuine long life coolant "GLASSY long life coolant (Ethylene glycol type)", and Eco-friendly product "PG GLASSY long life coolant (Non-amine type)", which are most appropriate coolant for diesel engine from Mitsubishi Heavy Industries, Ltd.

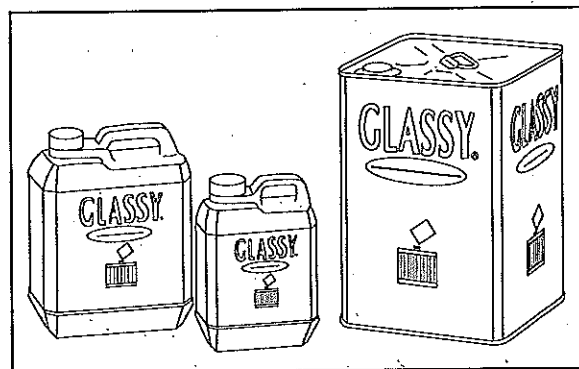


Fig. 6-1 GLASSY - LLC

## Other brand LLCs

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### CAUTION

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Never mix Mitsubishi Heavy Industries, Ltd. genuine LLC with other brand LLCs. Mixing with other brand LLCs degrades the performance of the Mitsubishi Heavy Industries, Ltd. genuine LLC.

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When using LLC other than Mitsubishi Heavy Industries, Ltd. genuine long life coolant (LLC) "GLASSY long life coolant (Ethylene glycol type)" or "PG GLASSY long life coolant (Non-amine type)", be sure to use the LLC which meets specification in Mitsubishi Heavy Industries, Ltd.

The quality and performance of commercially available LLCs as well as their component variations are the responsibility of LLC suppliers.

Before purchasing commercial LLC, be sure to discuss the suitability of LLC with the LLC supplier. Use only all-season LLC (non-amine type). Do not use antifreeze alone instead of LLC.

## Standard for other brand LLC

When using other brand LLCs by necessity, be sure to use the LLC that meets following specification. Mitsubishi heavy industries, Ltd. disclaim the warranty claim concerning malfunctions caused by the use of LLC that does not meet the following specification.

### General demands of LLC

- ♦ LLC shall be a homogeneous liquid.
- ♦ Engine cooling system shall not receive troubles such as corrosions and precipitation products etc. by LLC when the LLC is diluted to 30 to 60 % density.
- ♦ LLC shall be mixed with other LLC that satisfies this specification, and shall not separate elements each other, and shall not decrease the performance each other.
- ♦ LLC shall not allow the container to be corroded, and shall not has precipitation products etc. even if LLC is left in the container for 6 months.
- ♦ LLC shall not has extraction products etc. even if LLC is kept in -20 to -25 °C [-4 to -13 °F].
- ♦ The validity term of the quality that provides with this specification is 2 years after it delivers with the indoor normal temperature keeping.

## LLC specification

LLC shall examine according to JIS K2234 section 7 (examination methods), and satisfy this specification. General matters and the sample to the examination is shown in JIS K2234.

Table 6-2 LLC specification

Property		Standard	
External		Not precipitation	
Density		Minimum 1.112 g/cm <sup>3</sup> [69.4199 lb/ft <sup>3</sup> ] (20/20 °C) [68/68°F] (Stock solution)	
Water content		Maximum 5.0 weight % (Stock solution)	
Frozen temperature	30 vol %	-14.5°C [5.9°F] or less	
	50 vol %	-34.0°C [-29.2°F] or less	
Boiling temperature		155°C [311°F] or higher (Stock solution)	
pH		7.0 to 11.0 (30 vol %)	
Bubbling character (ASTM D3306-01)	30 vol %	4.0 ml [8.79 gal] or less	
	33 <sup>1</sup> / <sub>3</sub> vol %	150 ml [0.032 gal] or less, Disappearance of bubble within 5 sec.	
Hard water adaptability		1.0 or less (50 vol %)	
Metallic causticity (88±2°C [190.4±35.6°F], 336±2 Hr, 30 vol % (E.G), 50 vol % (P.G))	Test piece	Mass change	
		Aluminum	±0.30 mg/cm <sup>2</sup>
		Cast iron	±0.15 mg/cm <sup>2</sup>
		Steel	±0.15 mg/cm <sup>2</sup>
		Brass	±0.15 mg/cm <sup>2</sup>
		Solder	±0.30 mg/cm <sup>2</sup>
	Copper	±0.15 mg/cm <sup>2</sup>	
	External of test piece after the examination		Not corrosion on surface excluding between test piece and spacer. Discoloration is OK.
Bubbling while examination		Not bubbling overflow	
Properties of liquid after the examination	pH	6.5 to 11.0	
	pH change	±1.0	
	Precipitation	0.5 vol % or less	
	External of liquid	Not remarkable discoloration, separation and gel.	

Table 6-2 LLC, specification

Property			Standard	
Circulation metallic causticity (98±2°C [208.4±35.6°F], 1000 Hr, 30 vol % (E.G) 50 vol % (P.G)	Test piece	Mass change	Aluminum, Cast iron, Steel, Brass, Solder, Copper ±0.30 mg/cm <sup>2</sup>	
		External of test piece after the examination		Not corrosion on surface excluding between test piece and spacer. Discoloration is OK.
	Properties of liquid after the examination	pH		7.0 to 9.0
		pH change		±1.0
		Pre-alkalinity change		±15 %
		Precipitation		1.0 vol % or less
External of liquid		Not remarkable discoloration, separation and gel.		
Density of ion	Fe, Cu, Al, Zn, Pb, NH <sub>4</sub> <sup>+</sup>	10 ppm or less		
Circulation metallic causticity (88±3°C [190.4±37.4°F], 1000 ± 2 Hr, 30 vol % (E.G)	Test piece	Mass change	Aluminum	±0.60 mg/cm <sup>2</sup>
			Cast iron	±0.30 mg/cm <sup>2</sup>
			Steel	±0.30 mg/cm <sup>2</sup>
			Brass	±0.30 mg/cm <sup>2</sup>
			Solder	±0.60 mg/cm <sup>2</sup>
			Copper	±0.30 mg/cm <sup>2</sup>
	External of test piece after the examination		Not corrosion on surface excluding between test piece and spacer. Discoloration is OK.	
	Properties of liquid after the examination	pH		6.5 to 11.0
		pH change		Maximum ±1.0
		External of liquid		Not remarkable discoloration, separation and gel.
Condition of parts	Pump seal		Not trouble while the examination	
	Inside of pump case and blade		Not remarkable corrosion	
Rubber adaptability (30 vol %, 115°C [239°F], 360 Hr)	Silicon	Tensile strength change		-60 to 0 %
		Elongation change		-40 to +20 %
		Volume change		0 to +40 %
		Hardness change		-20 to +10 %
	Acrylonitrile butadiene rubber	Tensile strength change		0 to +10 %
		Elongation change		-15 to +15 %
		Volume change		0 to +40 %
		Hardness change		-10 to 0 %
	Ethylene propylene diene monomer	Tensile strength change		0 to +10 %
		Elongation change		-30 to 0 %
		Volume change		0 to +10 %
		Hardness change		-10 to 0 %
Storage stability vol % (30 vol %, room temperature, 6 Hr)			0.3 or less	

## Maintenance of LLC

### ⚠ CAUTION

Should coolant or LLC be accidentally swallowed, induce vomiting immediately and seek medical attention. If LLC should enter eyes, flush immediately with plenty of water and seek medical attention.

LLC is toxic. Never dispose of coolant containing LLC drained from engine into regular sewage. For disposal of used coolant, consult LLC distributor.

## Replacement intervals of LLC

### CAUTION

Be sure to renew LLC at the intervals specified in the maintenance schedule of this manual.

Failure to renew LLC may cause malfunctions due to performance degradation of preventing rust and cavitation.

When a coolant mixed with the LLC recommended by our company is used, replace coolant every 8000 hours or 2 years, whichever comes first.

## LLC concentration

Keep the LLC concentration of 30% (GLASSY) and 40% (PG GLASSY) on any temperature conditions. LLC of less than 30% concentration does not provide sufficient corrosion protection. If the LLC concentration is lower than 10%, it may accelerate corrosion.

When adding coolant, do not add plain water. Always use coolant with the same LLC concentration.

Table 6-3 Recommended LLC concentration

Item	Type	External	Lowest ambient temperature (°C [°F])			
			-10°C [14°F] or above	-20°C [-4°F] or above	-30°C [-22°F] or above	-45°C [-40°F] or above
LLC concentration (%)	GLASSY	Green	30	40	50	60
	PG GLASSY	Red	40	55	70	-

Note: (a) If the outside air temperature is -30°C [-22°F] or less, use "GLASSY".

(b) The concentration above is based on Mitsubishi Heavy Industries, Ltd. genuine LLC "GLASSY long life coolant (Ethylene glycol type)" or "PG GLASSY long life coolant (Non-amine type)".

For determining the accurate LLC concentration, refer to the instructions for the LLC used.

## Importance of LLC

Today's trend is toward smaller and lighter engines offering greater output, lower fuel consumption and lower exhaust emission levels.

Conditions to which engine coolant is subjected, therefore, are becoming severer due to longer operating hours, higher coolant temperature and higher coolant circulating speed.

Many different materials such as steel, aluminum, copper, solder and rubber are used in the cooling system, and they are also subjected to the severe conditions described above. Those materials have different ionization characteristics, and this difference accelerates corrosion through the medium of engine coolant. To prevent such a problem, the use of LLC that contained the additive to prevent rust is very important.

## Characteristics of LLC additive and important notes

LLC contains several chemicals in such proportions as to produce chemical reactions that suppress corrosion (ionization) of engine parts in contact with the coolant. LLC loses its effectiveness by hours of use as well as lapse of time.

Moreover, if the chemicals in LLC are not maintained, certain chemicals in the LLC become rapidly used up and result in dissolution of metals instead of protecting metals from corrosion. Consequently, other corrosion preventing chemicals react with dissolving metals and accelerate corrosion. This condition generates more severe corrosion than when plain soft water is used. This is a typical problem caused by the use of inappropriate LLC.

## Examples of abnormalities caused by LLC (amine type)

### Pitting of iron parts

Amines are generally effective in suppressing the rusting of ferrous metals, but they are said to cause problems for copper parts.

Dissolved copper (copper corrosion) in the cooling system deposits on iron parts and the copper deposits cause corrosion and then pitting on iron parts that have a high ionization characteristics due to galvanic or local-cell action.

### Corrosion of aluminum parts

Silicate is highly effective in protecting aluminum against rusting. However, it is unstable in a solution in which the pH is 9 or lower, and can turn to gel and precipitate in the solution. For this reason, the pH is usually specified to be about 10 to ensure a high alkaline level.

This means, after silicate is used up, the high alkalinity causes chemical attacks on aluminum. To prevent this problem, proper maintenance of the coolant is required. For case example, rapid wear of mechanical seals in the water pump due to secondary effects of silicate gel formed. Corrosion of aluminum parts after silicate is consumed.

### Pitting and clogging of the radiator

When LLC deteriorates or when its concentration in the coolant is too low, the anti-corrosion performance of LLC lowers and results in the corrosion of metals. Brass and solder tend to corrode faster than other metals, and corrosion of these metals is said to cause water leakage and clogs.

Example: Holes and clogs in radiator

# **Chapter 7 MAINTENANCE SCHEDULE**

## **How to use the maintenance schedule**

Periodic inspection not only extends the service life of the engine but also serves to ensure safe operation. Be sure to conduct inspections and maintenance according to the maintenance schedule.

The maintenance schedule shows the standard service intervals. If you notice any abnormalities such as abnormal noise, black exhaust smoke, white exhaust smoke, extremely high temperature of exhaust gas, abnormal vibration, and fuel, oil or exhaust gas leakage, make sure to conduct the inspection and maintenance work, regardless of recommended service intervals in the "Maintenance schedule."

Note: Appropriate service intervals vary depending on the usage and operating conditions as well as consumption of fuel, oil and coolant. Check the operating record of the engine to determine the most appropriate service intervals. (Feel free to consult a dealer of Mitsubishi Heavy Industries, Ltd. regarding service intervals.)

Service the items at multiples of the original requirement. For example, at 1000 service hours, also service those items listed under every 250 service hours and every 50 service hours.

Items marked with \* in the maintenance schedule require special tools or large equipment. For the servicing of those items, contact a dealer of Mitsubishi Heavy Industries, Ltd.

## **Periodic Maintenance Chart**

Appropriate service intervals vary depending on the engine specifications. Perform all daily inspection and maintenance items in accordance with the following 3 categories.

### **Periodic maintenance chart for regular use engine**

When the engine is used as a regular use engine, perform the periodic inspection and maintenance in accordance with the "Periodic Maintenance Chart for Engine in Regular Use".

### **Periodic maintenance chart for emergency engine**

When the engine is used as an emergency engine, perform the periodic inspection and maintenance in accordance with the "Periodic Maintenance Chart for Emergency Engine". Due to the nature of application, an engine for emergency use is subject to demanding operating conditions such as a quick startup and immediate supply of power. In addition, it must operate reliably in the event of an emergency. Therefore, be sure to perform the daily inspection and also conduct the following operation for maintenance purposes. Once every week: Operate the engine under no load (for 3 to 5 minutes). (When operating the engine for the adjustment of peripheral devices, limit the operating time to 10 minutes.) Once every month: Operate the engine under load (for 15 to 30 minutes with more than 50 % load). If the engine cannot be operated under load every month, operate the engine under load (more than 50 % load) for more than 2 hours once every year. During the engine maintenance operation, check the ease of startup, oil pressure, and exhaust color and vibration.

## **General definition of engine**

### **General definition of regular-use engine**

An engine operated with a constant base load for the purpose of generating electric power, which is used independently or in combination with commercial power supply. An engine operated under a fluctuating load throughout a day for supplying rated electric power in lieu of commercial power.

### **General definition of emergency engine**

An engine used for emergency power generation such as main power supply and commercial power supply.

## Periodic maintenance chart for regular use engine

Table 7-1 Periodic maintenance chart for regular use engine

	Interval and Service item	Refer- ence page
Every 50 service hours or every month	Fuel tank - Drain water*1	8-5
	Water separator - Drain water*1	*2
First 50 service hours for a new or overhauled engine	Bolts and nuts on the engine - Retighten	*2
	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.	8-9
Every 250 service hours	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.	8-9
First 250 service hours for a new or overhauled engine	Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*2
Every 1000 service hours	Fuel filter - Replace	8-7
	Water separator - Inspect and Replace*1	*2
	Gauze filter - Clean	8-6
	Belt and belt tension - Inspect and Adjust	8-2
Every 1500 service hours	Fuel injection nozzle - Clean	*2
Every 2000 service hours	Fuel tank - Drain water (Replace parts as necessary)*1	8-5
	Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*2
	Fuel injection timing - Inspect and Adjust	*2
	Checking Movement of the Rack (during operation) of the fuel injection pump (including the governor)	*2
	Fuel pipe - Inspect	8-8
	Oil pipe - Inspect	8-12
Every 3000 service hours	Fuel injection nozzle - Nozzle tip replacement (Check the spray condition and adjust the fuel injection pressure after replacement)	*2
Every 4000 service hours	Top end of the engine - Overhaul Remove the cylinder head, and inspect and service the combustion chambers.	*2
	Turbocharger - Inspect	8-18
	Damper - Inspect	8-3
	Starter - Inspect	8-21
	Protection devices operation - Inspect	*2
	Unit seal and Oil seal of water pump - Replace	*2
	Checking LLC concentration level in the coolant	*2

Table 7-1 Periodic maintenance chart for regular use engine

Interval and Service Item	Reference page
Every 8000 service hours	<p>Engine - Major overhaul Disassemble engine, clean, check and change major parts. [Parts to be changed] Inlet and exhaust valves, inlet and exhaust valve seats, valve rotators, valve cotters, rocker arm adjusting screws, valve push rods, bridge caps, camshaft bushings, camshaft expansion plugs, main bearings, cylinder liners, main bearing cap bolts and washers, piston rings, connecting rod bearings, damper, crankcase thrust plate and consumable items (gaskets, oil seals, O-rings, etc.) [In second overhaul, replace the following parts in addition to the parts listed above] Cylinder head bolts, valve guides, valve bridge guides, valve bridges, valve springs, tappets, camshaft thrust plates, pistons, piston pins, connecting rod bolts, connecting rod bushings, rocker bushings, fuel pipe assembly, oil pipe assembly</p> <p>Fuel injection pump - Inspect and Test (Replace parts as necessary)</p> <p>Governor - Inspect and Test (Replace parts as necessary)</p> <p>Protective Devices - Repair or Replace*1 High coolant temperature, low oil pressure, overspeeding, starting failure, water supply failure, undervoltage, overvoltage, overcurrent, low coolant level in tank, low fuel level in tank, etc.</p> <p>Auxiliary devices operation - Check*1 Water heater, oil heater, oil priming pump, fuel transfer pump, governor motor, etc.</p>
Every 8000 service hours or 2 years	Coolant - Change 8-13
As required	<p>Fuel system - Bleed air*1 3-2</p> <p>Radiator fins - Check and Clean*1 8-17</p> <p>Air cleaner element - Clean, Check and Replace*1 8-19</p> <p>Cleaning the Inside of the Engine Breathers *2</p> <p>Stop solenoid - Inspect or Replace *2</p> <p>Couplings - Inspect or Replace*1 *2</p> <p>Inspecting the vibration-isolating rubber*1 *2</p>

\*1 It is not a item supplied from Mitsubishi Heavy Industries, Ltd., however, please maintain the part regularly to use the engine securely and effectively.

\*2 Items require special tools or large equipment. For the servicing of those items, contact a dealer of Mitsubishi Heavy Industries, Ltd.

## Periodic maintenance chart for emergency engine

Table 7-2 Periodic maintenance chart for emergency engine

Interval and Service item		Reference page	
Every week	Engine external - Inspect (Check for leakage of fuel, oil and coolant)	3-8	
	Fuel tank oil level - Check*1	3-9	
	Engine oil level - Check	3-10	
	Coolant level - Check	3-11	
	Water leakage of air cooler - Inspect	-	
	Operating the engine for maintenance (operate the engine under no load for 5 to 10 minutes) Check for ease of starting, color of exhaust smoke, abnormal vibration, abnormal noise, abnormal smell and gauge indication (oil pressure gauge, coolant temperature gauge, oil temperature gauge, exhaust temperature gauge, tachometer, etc.)	-	
Every month	Engine oil for mixing of fuel and water - Inspect	8-12	
	Fuel control link - Check	3-11	
	Battery electrolyte level - Inspect*1	3-7	
	Conducting Engine Maintenance Operation (Operate the engine with more than 50 % load for 15 to 30 minutes) Check for ease of starting, color of exhaust smoke, abnormal vibration, abnormal noise, abnormal smell and gauge indication (oil pressure gauge, coolant temperature gauge, oil temperature gauge, exhaust temperature gauge, tachometer, etc.) Check fuel injection pump and governor rack movement	-	
	Damper - Inspect	8-3	
Every 6 months	Checking LLC concentration level in the coolant	*2	
	Cleaning the inside of the coolant tank*1	-	
Every 1 year	Basic engine	Belt and belt tension - Inspect and Adjust	8-2
		Bolts and nuts on the engine - Check and Retighten	*2
		Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*2
		Inspecting the vibration-isolating rubber*1	*2
		Foundation bolts - Inspect*1	*2
		Couplings - Inspect or Replace*1	*2
	Fuel system	Fuel tank - Drain water*1	8-5
		Water separator - Drain water*1	*2
		Fuel injection nozzle spray condition and Spray pressure - Inspect and Adjust	*2
		Fuel injection timing - Inspect and Adjust	*2
		Fuel pipe - Inspect	8-8
	Engine Lubricating system	Oil pipe - Inspect	8-12
		Engine oil properties - Analyze	*2
		Engine oil pressure (Maintenance operation) - Inspect and Adjust	*2

Table 7-2 Periodic maintenance chart for emergency engine

Interval and Service item		Reference page	
Every 1 year	Cooling system	Water pump - Inspect	*2
		Solenoid valve and Pressure reducing valve of the cooling system - Inspect, Disassemble and Clean*1	*2
		Strainer (including with/ball tap) of cooling water - Inspect, Disassemble and Clean*1	*2
		Coolant properties (when only soft water is used) - Inspect (Change coolant according to the analysis results)	*2
	Air intake system	Air cleaner element - Clean, Check and Replace*1	8-19
	Electrical system	Starter - Inspect	8-21
		Alternator - Inspect	8-21
		Specific gravity of battery electrolyte - Check*1	8-20
	Protection devices operation - Inspect*1 High coolant temperature, low oil pressure, overspeeding, starting failure, water supply failure, undervoltage, overvoltage, overcurrent, low coolant level in tank, low fuel level in tank, etc.		*2
	Auxiliary devices operation - Check*1 Engine control, fuel transfer pump, governor motor, room ventilating fan, solenoid, storage pump, water tank ball tap, water heater, oil heater, oil priming pump, etc.		*2
Every 2 years	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.		8-9
	Fuel filter - Replace		8-7
	Water separator - Inspect and Replace*1		*2
	Gauze filter - Clean		8-6
	Fuel control link ball joint - Inspect (Replace parts as necessary)		8-6
	Coolant - Change		8-13
	Thermostat - Inspect		*2
	Turbocharger - Inspect		8-18
Draining water from the exhaust muffler*1		8-18	

Table 7-2 Periodic maintenance chart for emergency engine

	Interval and Service item	Reference page
Every 4 years	Top end of the engine - Overhaul Remove the cylinder head, and inspect and service the combustion chambers. (If the abnormalities of first and second cylinders are found, inspect all cylinders.)	*2
	Checking oil cooler for contamination, clogging and leakage	*2
	Checking oil pump for discoloration and other external defects	*2
	Fuel tank - Clean*1	8-5
	Fuel injection pump - Inspect and Test (Replace parts as necessary)	*2
	Governor - Inspect and Test (Replace parts as necessary)	*2
	Radiator fins - Check and Clean*1	8-17
	Rubber hose - Replace	*2
	Air cleaner element - Clean, Check and Replace*1	8-19
	Instruments - Repair or Replace*1 Oil pressure gauge, coolant temperature gauge, oil temperature gauge, exhaust temperature gauge, tachometer	*2
Every 8 years	Engine - Major overhaul Disassemble engine, clean, check and change major parts.	*2
	Damper - Replace	*2
	Oil pump - Repair or Replace	*2
	Fuel injection nozzle - Nozzle tip replacement (Check the spray condition and adjust the fuel injection pressure after replacement)	*2
	Rubber parts and O-rings - Replace	*2
	Unit seal and Oil seal of water pump - Replace	*2
	Turbocharger - Disassemble and Inspect	*2
	Air cooler - Disassemble and Clean	*2
	Vibration-isolating rubber - Repair or Replace*1	*2
	Couplings - Inspect or Replace*1	*2
	Governor mortar - Repair or Replace*1	*2
	Air ventilation fan of the room - Repair or Replace*1	*2
	Stop solenoid - Inspect or Replace	*2
	Ball tap of water tank - Repair or Replace*1	*2
	Other consumables - Replace	*2

\*1 It is not a item supplied from Mitsubishi Heavy Industries, Ltd., however, please maintain the part regularly to use the engine securely and effectively.

\*2 Items require special tools or large equipment. For the servicing of those items, contact a dealer of Mitsubishi Heavy Industries, Ltd.

# **Chapter 8 PERIODIC INSPECTION AND MAINTENANCE PROCEDURES**

## **Basic engine**

### **Engine external - Inspect**

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**▲ CAUTION**

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Be sure to keep combustible materials away from the engine, especially from the hot engine parts such as exhaust manifolds, or the battery. Check for fuel and oil leaks. Clean the top surface of the battery. A fire can be caused by combustible materials placed near hot engine parts. If any abnormality is found, be sure to repair it or contact a dealer of Mitsubishi Heavy Industries, Ltd.

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Inspect the engine exterior as described below.

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Check the electrical wiring for such components as the starter and alternator for looseness.
3. Check the whole engine for leaks of fuel, engine oil or coolant. If leaks are found, repair or contact a dealer of Mitsubishi Heavy Industries, Ltd.
4. Make sure the following valves, plugs and cocks are open or closed properly:
  - ♦Fuel feed valve: Open
  - ♦Coolant drain cock (plug): Closed
  - ♦Oil drain valve: Closed

## Belt and belt tension - Inspect and Adjust

### CAUTION

If defects such as cuts or surface separations are found during inspection, replace the belt.

Keep oil and grease away from the belt. They may cause the belt to slip and shorten the service life.

Excessive belt tension can cause rapid wear of the alternator bearing and shorten the service life of the belt.

Adjust the belt tension accurately by following the procedures below.

### Belt - Inspect

1. Inspect the belt visually for separation or damage. If any abnormality is found, replace the belt with a new one.
2. Inspect belt tension (deflection).

Push the belt downward at the midway between pulleys. If the deflection is 10 to 15 mm [0.39 to 0.59 in.], the tension is correct.

Belt pushing force: Approx. 98 to 147 N {10 to 15 kgf} [22.05 to 33.07 lbf]

If the deflection of belt is not within the standard, adjust the belt tension.

### Belt tension (Alternator side) - Adjust

1. Remove the belt cover.
2. Loosen all retaining bolts of the alternator and adjusting rod.
3. Loosen the upper and lower lock nuts on the adjusting rod.

Note: That the lower nut on the adjusting rod has left-hand threads.

4. Turn the adjusting rod to adjust the belt tension.
5. After adjusting deflection, fix the upper and lower lock nuts.
6. Tighten all retaining bolts of the alternator and adjusting plate.
7. Reinstall the belt cover and front cover.

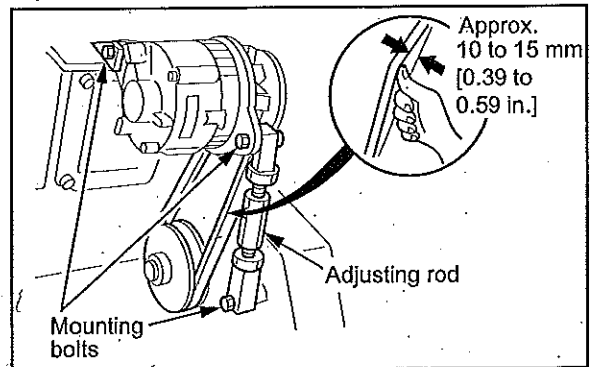


Fig. 8-1 Belt and belt tension - Inspect and Adjust

### Belt tension (water pump side) - Adjust

1. Remove the belt cover.
2. Loosen all the retaining bolts of the slide plate.
3. Loosen the lock nut of adjusting bolt, and turn the adjusting bolt. Then, adjust the belt tension.
4. After adjusting, fix the slide plate and adjusting bolt.
5. Install the belt cover.

## Damper - Inspect

### Damper - Check visually

#### CAUTION

When installing a damper protective cover to the engine, do not use a cover that encloses the damper. Installation of a closed cover can cause damper damage due to heat.

Check the vibration damper for oil leakage, scratches, deformation, discoloration and peeling of paint. Check carefully for swelling on the cover (use a scale), oil leaks from the shim, discoloration and peeling of paint due to heat.

Note: If defects are found in the damper, contact a dealer of Mitsubishi Heavy Industries, Ltd.

### Damper temperature management

For making damper function well, heat of damper must be dissipated from its surface to prevent excessive damper heating. Mitsubishi Heavy Industries, Ltd. inspects each engine before shipment to ensure proper operating temperature of the vibration damper. However, the vibration damper temperature varies depending on ambient conditions. Therefore, observe the following suggestions and provide sufficient ventilation for the vibration damper and equipment.

1. Make sure the temperature of the outside damper surface does not exceed 90 °C [194 °F] when operating the engine with rated power for an hour.
2. When installing a safety cover to damper, check ventilation carefully and make sure the damper temperature remains below 90 °C [194 °F], with the cover in place.
3. It is recommended to use the thermo label for temperature management.

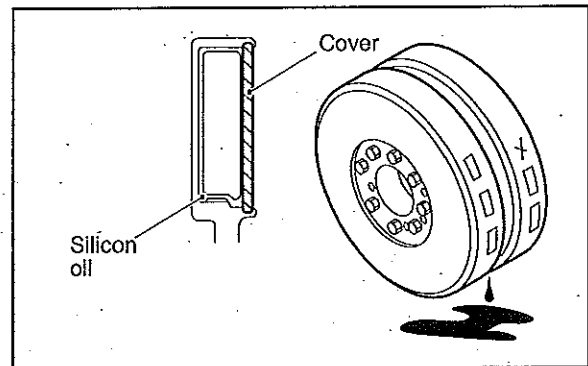


Fig. 8-2 Damper - Check visually

### Thermo label - handle

The white thermal part of thermo label becomes black when reaching the specified value.

Note: The thermal part that becomes black once does not return to white. Therefore, if the engine stops and then the temperature of damper drops, the thermo label continues indicating the maximum temperature in operation.

1. Attach a thermo label to the periphery or front end of damper.
2. Note the maximum temperature of the thermal part of thermo label when engine stops. Note the temperature periodically, and check the abnormality of temperature alteration.

Note: (a) When the temperature of thermo label increased, identify the abnormality of engine or other cause. Then, reattach new thermo label, and check the change of temperature.

(b) If the temperature indication of thermo label comes close to the limit temperature of damper or the abnormality is found in change of temperature, contact a dealer of Mitsubishi Heavy Industries, Ltd.

Table 8-1 Thermo label for temperature management

Parts name	Parts No.	Temperature measuring range
Thermo label 100-120	32522-04211 20 labels set: 32522-04200	100 to 120°C [212 to 248°F]
Thermo label 75-95	32522-04111 20 labels set: 32522-04100	75 to 95°C [167 to 203°F]
Thermo label 50-70	32522-04311 20 labels set: 32522-04300	50 to 70°C [122 to 158°F]

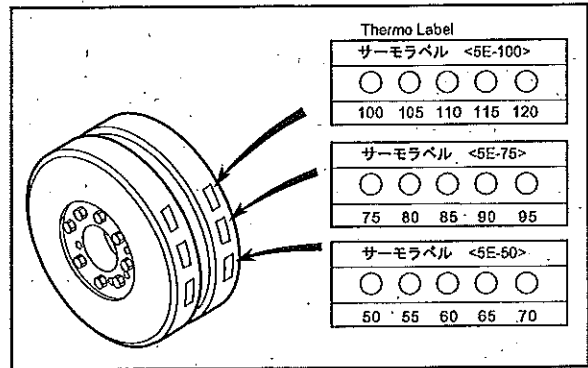


Fig. 8-3 Damper temperature management

## Fuel system

### Fuel system - Inspect

#### WARNING

When handling fuel, make sure there are no open flames or other fire hazards near the engine.  
Wipe off any spilled fuel completely. Spilled fuel can ignite and cause a fire.

### Fuel tank - Clean

#### CAUTION

Do not remove the strainer when filling the fuel.  
For fuel to be used, refer to "FUEL" (4-1).

1. Close the fuel feed valve to cut off the fuel supply to the engine.
2. Prepare the fuel receiving can, place it under the drain cock.
3. Drain all fuel in the tank from drain cock on the bottom of fuel tank.
4. Clean the inside of fuel tank.

For more information, refer to the operation manual attached to a fuel tank.

5. Add fuel to the fuel tank.
6. Open the fuel feed valve, and bleed air for the fuel system.

Note: For bleeding fuel system, refer to "Fuel system - Bleed air" (3-2).

### Fuel tank - Drain water

If fuel gets mixed with particles of foreign material such as dust, dirt, or water, it can cause not only decrease of output but also malfunctions of the fuel system. To avoid such a problem, drain fuel tank as described below.

1. Prepare the oil pan (capacity of 2 L [0.53 U.S. gal.] or more) under the drain cock of fuel tank.
2. Open the drain cock of fuel tank and drain fuel at least 1 to 2 L [0.3 to 0.5 U.S. gal.].
3. Make sure that water and particles of foreign material discharged with fuel. Close the drain cock.

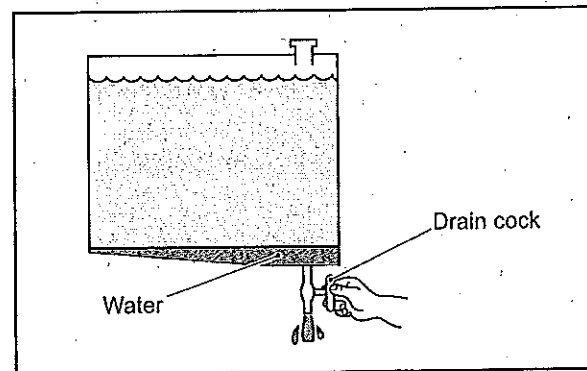


Fig. 8-4 Fuel tank - Drain water

## Fuel control link ball joint - Inspect

Check ball joint in the fuel control link for play. If the amount of play is 0.1 mm [0.004 in.] or more, replace the ball joint with the new one.

### CAUTION

If the sealed ball joints are found loosened, contact a dealer of Mitsubishi Heavy Industries, Ltd. If the seal on the ball joint is broken, the warranty is invalidated.

If the ball joints are integrated in the control link, replace the control link when the ball joints have loosened. When installing ball joints, be sure to tighten the nuts firmly.

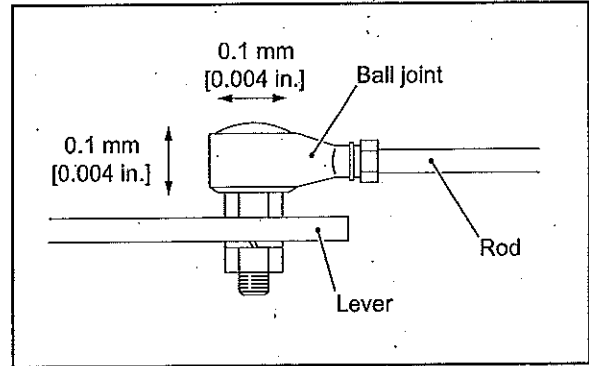


Fig. 8-5 Ball joints for looseness - Inspect

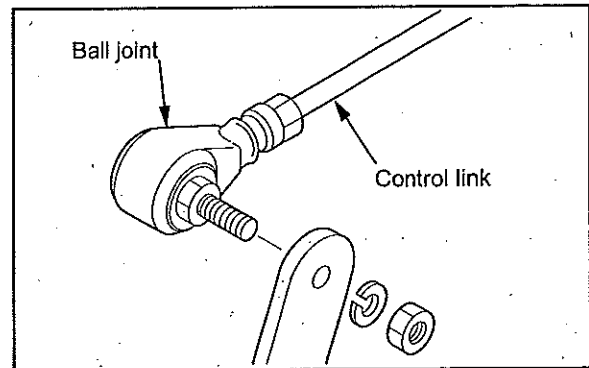


Fig. 8-6 Fuel control link - Remove

## Gauze filter - Clean

If the gauze filter is clogged, the fuel supply becomes insufficient, resulting in decrease in power output or engine stall.

1. Remove the eye bolt at the inlet port of fuel feed pump.
2. Using a screw driver, remove the gauze filter that is fitted inside the eye bolt.
3. Soak the gauze filter in the fuel, and clean it with a brush.
4. After cleaning, install the gauze filter into the eye bolt using a screw driver.
5. Install the eye bolt to the fuel feed pump.
6. Bleed the air from the fuel filter.

Note: For bleeding the fuel filter, refer to "Fuel filter - Bleed air" (3-2).

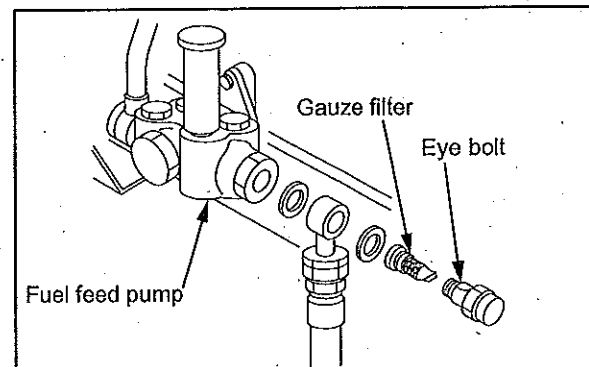


Fig. 8-7 Gauze filter - Clean

## Fuel filter - Replace

1. Clean the area around the fuel filters.
2. Prepare a drip pan, and place it under the fuel filters.
3. Using a filter wrench, remove the fuel filters.
4. Wipe off fuel on the fuel filter cartridge mounting surface of the filter bracket with a waste cloth.
5. Check new fuel filters for proper seating of the gasket.

### **WARNING**

Do not use a filter with the dented case. Filter damage or fuel leakage may occur and it can cause fire hazard.

6. Apply clean fuel to the gasket on the new fuel filter.
7. Install the fuel filter to the filter bracket. When the gasket contacts the mounting surface of the filter bracket, further rotate 3/4 to a full turn.

### **CAUTION**

Do not use a filter wrench to install the fuel filter.  
Do not dent or scratch the fuel filter surfaces.

8. After installing the new fuel filter, bleed the fuel filter.

Note: For bleeding the fuel filter, refer to "Fuel filter - Bleed air" (3-2).

9. Start the engine and let it idle for several minutes.
10. Make sure that there is no fuel leak during the engine operation. If fuel leakage is found, loosen the fuel filter and check the gaskets for damage. If there is no damage, retighten the fuel filter.

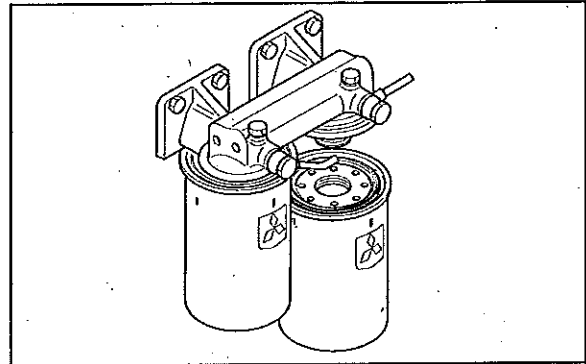


Fig. 8-8 Fuel filter - Replace

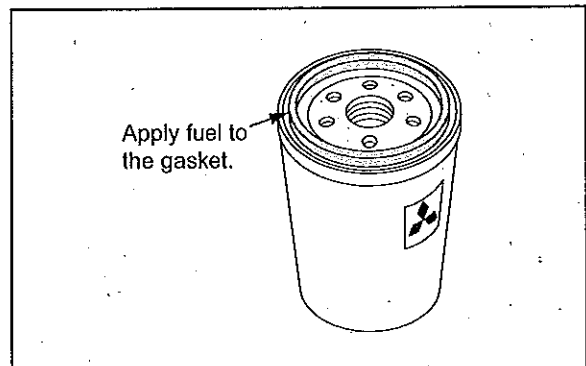


Fig. 8-9 Fuel filter

## Fuel pipe - Inspect

### High pressure fuel injection pipe and Clamp seat - Inspect

#### Visual inspection in every 2000 service hours

Check clamp seat cracks and high pressure fuel injection pipe metal contact with clamp. If defective, replace the clamp seat with a new one. Replace the high pressure fuel injection pipe with a new one as needed.

#### In every major overhaul

Replace clamp seat with a new one. Also, check high pressure fuel injection pipe metal contact with clamp. If defective, replace the high pressure fuel injection pipe with a new one.

#### In every other major overhaul

Replace all clamp seats and high pressure fuel injection pipes with new ones.

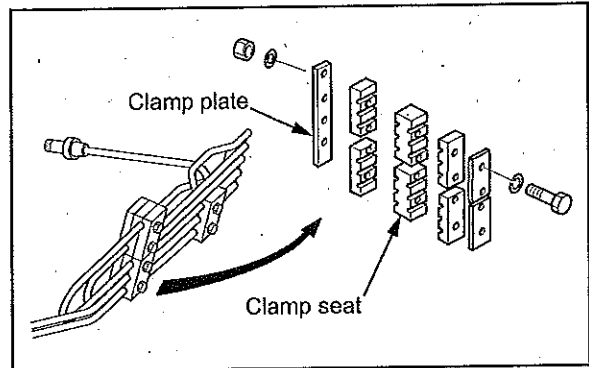


Fig. 8-10 High pressure fuel injection pipe and Clamp seat - Inspect

### Low pressure fuel pipe and Clip - Inspect

#### Visual inspection in every 2000 service hours

Loosen clamp fixing bolt and check clip wear and pipe metal contact with clamp. If defective, replace the pipe assembly with a new one.

#### In every other major overhaul

Replace the pipe assembly with a new one.

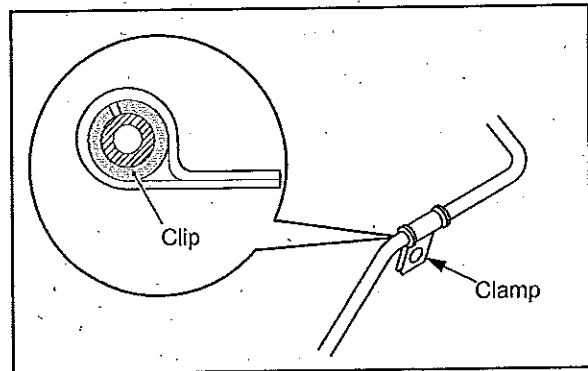


Fig. 8-11 Low pressure fuel pipe and Clip - Inspect

## Lubricating system

### Engine oil, Oil filter and Bypass oil filter - Replace

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**▲ CAUTION**

When draining oil or changing the oil filter, wear gloves. Hot engine oil and parts may cause burns.

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**CAUTION**

Do not dump waste oil. It is forbidden by law. For disposal of waste oil, consult a dealer of Mitsubishi Heavy Industries, Ltd.

Change the engine oil, oil filter and bypass oil filter at the same time.

Also checking and analyzing the oil properties is recommended when changing the engine oil.

Do not reuse the oil filter element, as it is a paper type. When replacing filters, always replace gasket with new ones.

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#### Engine oil - Drain

After the engine has stopped, drain engine oil from the engine oil drain port.

## Engine oil - Refill

### **CAUTION**

Refilling engine oil must be specified level. If the refilling oil goes over the high marks on the oil level gauge, engine oil may blow out.

1. Remove the cap from the oil filler.
2. Fill the engine oil pan with specified engine oil to the specified level.

Note: For engine oil, refer to "ENGINE OIL" (5-1). For engine oil capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Check the oil level in the oil pan as follows:
4. Pull out the oil level gauge and wipe it clean with a waste cloth.
5. Insert the oil level gauge fully into the oil level gauge guide, then pull out the gauge again.
6. The proper oil level is between the high and low marks on the oil level gauge.  
If the oil level is low, add engine oil of the specified type.
7. Check the oil pan and other area for oil leaks. Repair the oil leakage if any.
8. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times. Circulate engine oil to each engine parts.

Note: Prepare for the Cooling system.

9. Check the oil level with the oil level gauge again, and add oil to the specified level.

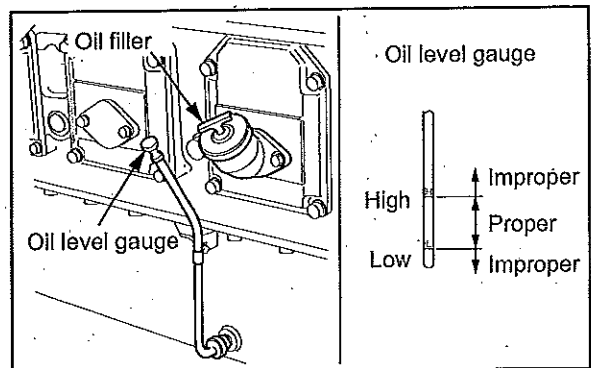


Fig. 8-12 Oil filler and Oil level gauge

### Oil filter and Bypass oil filter - Replace

1. Clean around the oil filters.
2. Prepare drip pans, and place them under oil filters and a bypass oil filter.
3. Using a filter wrench, remove oil filters and a bypass oil filter.

Note: Disconnect the removed oil filters and a bypass oil filter, and check elements for metal particles. If metal particles are found, contact a dealer of Mitsubishi Heavy Industries, Ltd.

4. Thoroughly wipe off oil on the oil filter mounting surface of the filter bracket with a cloth.
5. Check the new oil filters and a bypass filter for proper seating of gasket.

**WARNING**

Do not use a filter with the dented case. Filter damage or oil leakage may occur and it can cause fire hazard.

6. Apply clean engine oil to gasket.
7. Install oil filters and a bypass oil filter to the filter bracket. When the gasket contacts the mounting surface of the filter bracket, further rotate 3/4 to a full turn.

**CAUTION**

Do not use a filter wrench to install the oil filter and bypass oil filter.

Do not dent or scratch the oil filter surfaces.

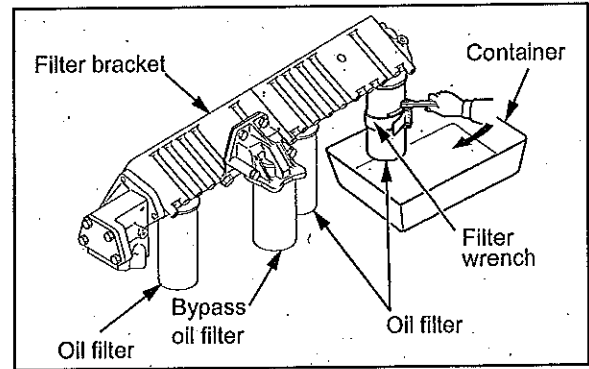


Fig. 8-13 Oil filter and Bypass oil filter - Replace

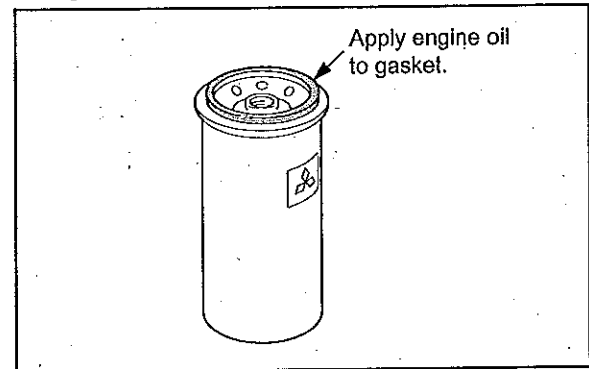


Fig. 8-14 Oil filter

## Engine oil for mixing of fuel and water - Inspect

### ⚠ CAUTION

If the engine continues to operate with engine oil mixed with fuel or water, the engine oil viscosity decreases and this can cause serious accidents such as seizing of bearings.

Sample 1 to 2 L [0.26 to 0.53 U.S. gal.] of engine oil, and check for abnormal odor and discoloration to determine the mixing of fuel and water.

If fuel is mixed with the engine oil, the oil will smell like fuel.

If water is mixed with the engine oil, the oil will be milky white.

If fuel or water is detected in the engine oil, find the cause of the problem, and repair. If the problem cannot be corrected easily, contact a dealer of Mitsubishi Heavy Industries, Ltd.

## Oil pipe - Inspect

### Oil pipe and Clip - Inspect and Replace

#### Visual inspection in every 2000 service hours

Loosen clamp fixing bolt and check clip wear and pipe metal contact with clamp. If defective, replace the pipe assembly with a new one.

#### In every other major overhaul

Replace the pipe assembly with a new one.

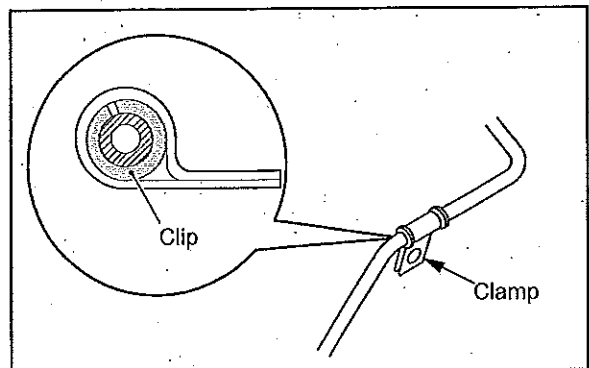


Fig. 8-15 Oil pipe and Clip - Inspect and Replace

## Cooling system

### Coolant - Change

#### WARNING

Remove the radiator cap only after the engine has cooled to room temperature. Place a waste cloth over the cap, and loosen the cap about a half-turn or stand the lever to the upright position to release internal pressure. Never open the radiator filler cap while the engine is hot, otherwise the steam or hot coolant spurts out and you may be scalded with it.

Coolant (containing LLC) drained from the engine is toxic. Never dispose of coolant into regular sewage. For disposal of used coolant, consult a dealer of Mitsubishi Heavy Industries, Ltd. or a industrial waste disposer.

#### CAUTION

The service life of LLC is 2 years. Be sure to change coolant at least once every 2 years.

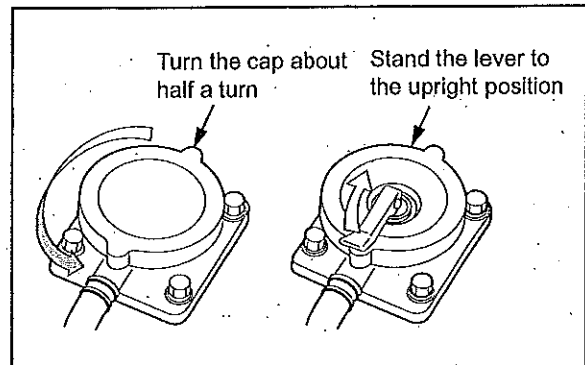


Fig. 8-16 Radiator filler cap

### Coolant - Drain

1. When draining coolant immediately after engine operation, idle the engine in low gear for 5 to 6 minutes to lower the coolant temperature to 70 to 80 °C [158 to 176 °F].
2. Open the radiator filler cap.
3. Place coolant receiving cans under the drain cocks and plugs, and open the coolant drain cocks and plugs to drain the coolant.

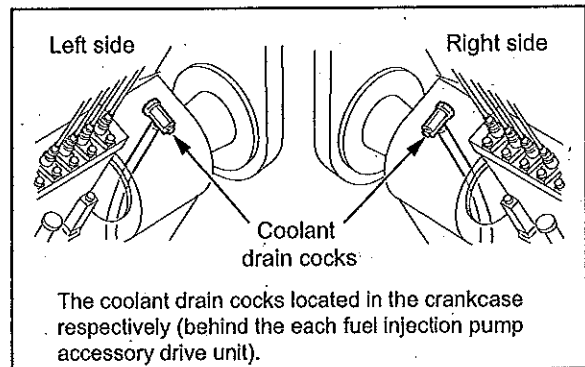


Fig. 8-17 Coolant drain cock (engine)

## Cooling system - Clean

### CAUTION

Clean the cooling system when operating the engine or heat exchange equipment first time, or restarting the engine after storage with coolant drained.

1. Close coolant drain cocks and plugs.
2. Pour in a cleaning solution (a solution that is non-corrosive to rubber and metals) in the cooling system, and operate the engine at 800 to 900  $\text{min}^{-1}$  for about 15 minutes, then drain the cleaning solution.
3. Close coolant drain cocks and plugs.
4. Pour in fresh water, and operate the engine at 800 to 900  $\text{min}^{-1}$  for about 10 minutes.  
Repeat rinsing until the draining water becomes clear and clean.

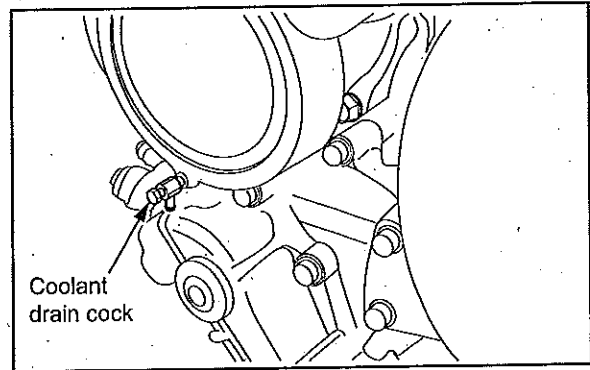


Fig. 8-18 Coolant drain cock (water pump)

## Coolant - Refill (Engine)

### CAUTION

Always use the coolant with the same LLC concentration.

1. Make sure coolant drain cocks are closed securely.
2. Remove the radiator filler cap, and pour in undiluted LLC.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.

For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Pour in water (soft water with minimal impurities, such as tap water) slowly to the full level.

Note: For absolute air bleeding, loosen the air vent plug.

4. Check the radiator and other parts for coolant leaks. Repair leakage if found.
  5. When coolant reaches the full level, close the radiator cap securely.
  6. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times to bleed the cooling system.
- Note: Prepare for the lubricating system and refilling the coolant to the air cooler.
7. Check the coolant level in the radiator.

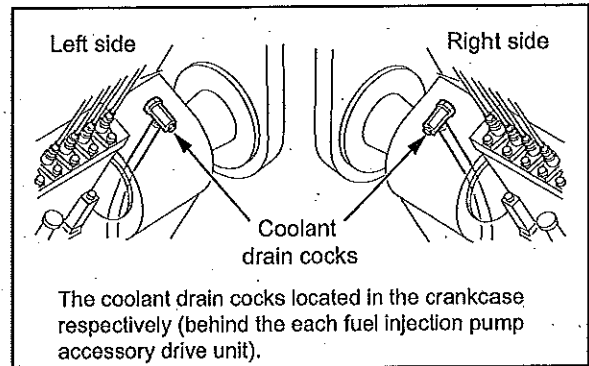


Fig. 8-19 Coolant drain cock (Engine)

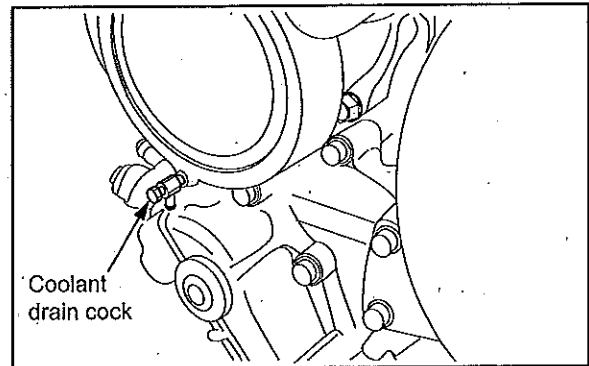


Fig. 8-20 Coolant drain cock (Engine water pump)

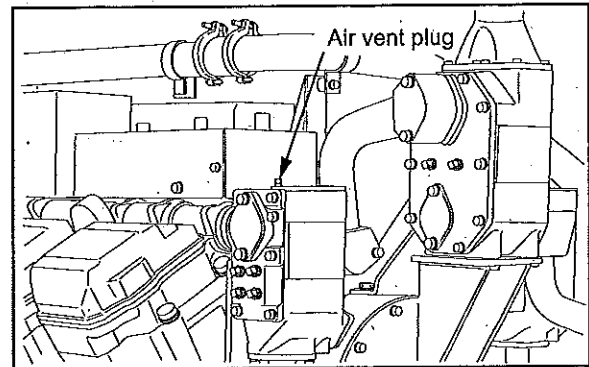


Fig. 8-21 Air vent plug (Engine cooling system)

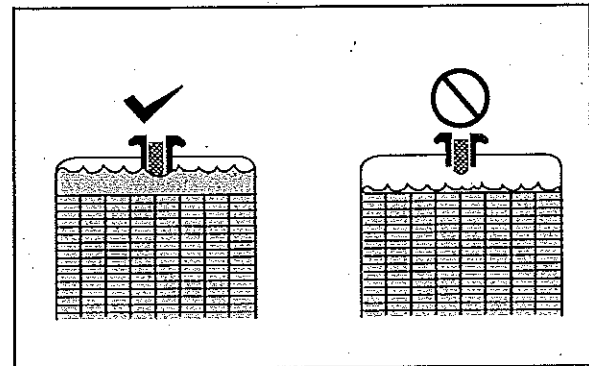


Fig. 8-22 Radiator coolant level

## Coolant - Refill (Air cooler)

### CAUTION

Always use the coolant with the same LLC concentration.

1. Make sure coolant drain cocks are closed securely.
2. Remove the radiator filler cap, and pour in undiluted LLC.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.

For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Pour in water (soft water with minimal impurities, such as tap water) slowly to the full level.

Note: For absolute air bleeding, loosen the air vent cock and plug.

4. Check the radiator and other parts for coolant leaks. Repair leakage if found.
5. When coolant reaches the full level, close the radiator cap securely.
6. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times to bleed the cooling system.

Note: Prepare for the lubricating system and refilling the coolant to the engine.

7. Check the coolant level in the radiator.

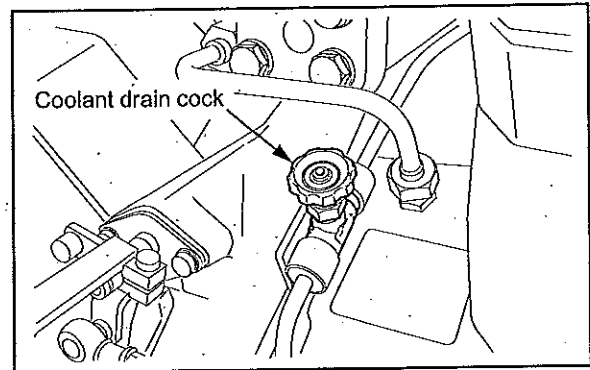


Fig. 8-23 Coolant drain cock (Air cooler)

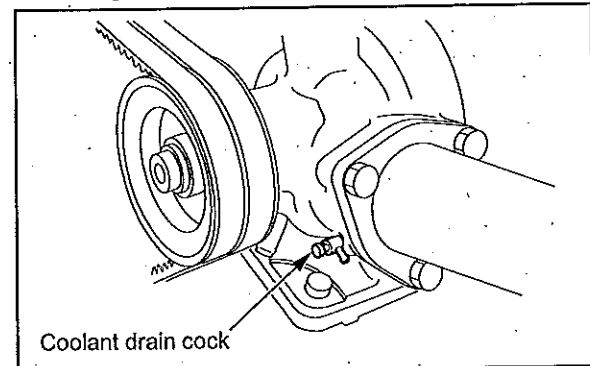


Fig. 8-24 Coolant drain cock (Air cooler water pump)

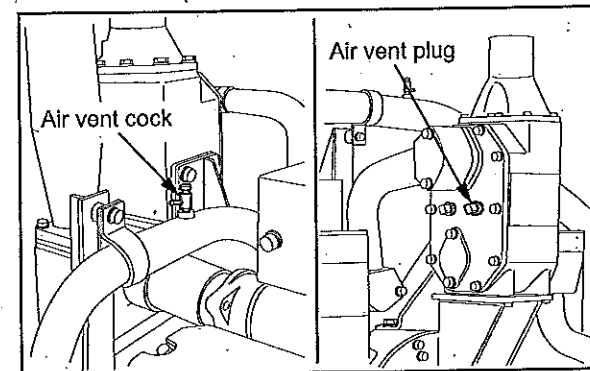


Fig. 8-25 Air vent cock and plug (Air cooler cooling system)

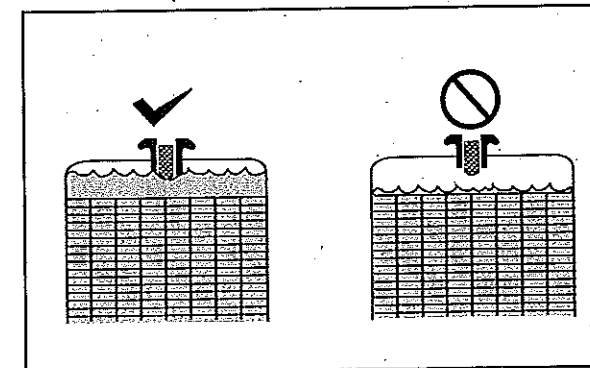


Fig. 8-26 Radiator coolant level

## Radiator fins - Check and Clean

**⚠ CAUTION**

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

Check the radiator fins for holes and cracks.

To clean the radiator fins, blow compressed air from the opposite direction of the normal air flow.

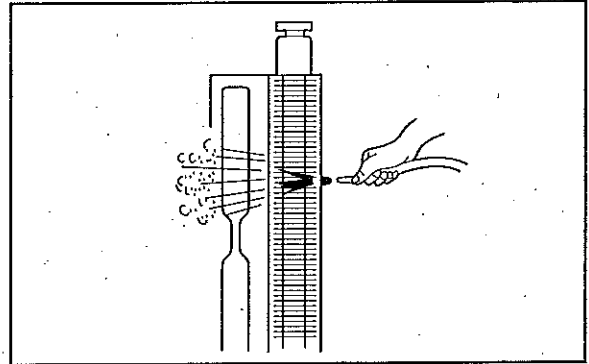


Fig. 8-27 Radiator fins - Clean

## Inlet and exhaust systems

### Turbocharger - Inspect

**CAUTION**

Check the turbocharger when the engine is cold. Also, make sure that the compressor wheel is not rotating before inspecting the turbocharger.

**CAUTION**

If the color of the exhaust gas is abnormal, also inspect the turbocharger.

Disconnect the pipe from the air inlet side. Hold the compressor wheel nut by hand and turn the wheel to check for looseness or abnormal noise. Replace the turbocharger if looseness or abnormal noise is found.

Note: When removing and inspecting turbocharger, contact a dealer of Mitsubishi Heavy Industries, Ltd.

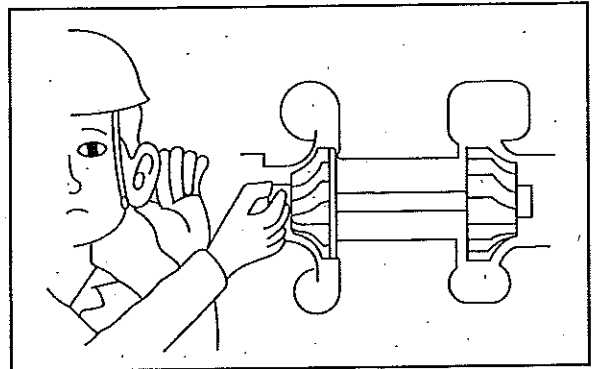


Fig. 8-28 Turbocharger - Inspect

### Draining water from the exhaust muffler

**CAUTION**

Never touch the exhaust muffler immediately after the engine stops, as it is extremely hot. To drain water, wait until the exhaust muffler cools.

Remove the drain plug and allow water to drain from the exhaust muffler.

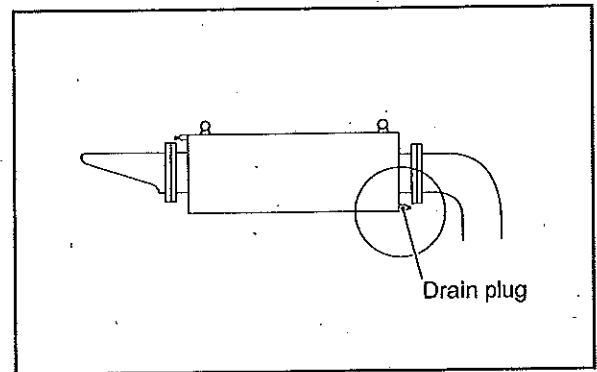


Fig. 8-29 Draining water from the exhaust muffler

## Air cleaner element - Clean, Check and Replace

### CAUTION

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

Never service the air cleaner while the engine is running. Servicing the pre-cleaner while the engine is running can cause particles of foreign material to enter the engine and result in rapid wear of parts, leading to a shorter service life of the engine. Never knock or hit the air cleaner element.

### CAUTION

Cleaning, inspecting and replacing procedure described below is a commonly used procedure. Some application may be equipped with different air cleaner.

1. Remove the air cleaner cap and wing bolt.
2. Remove the air cleaner element from the body.
3. Blow compressed air (0.69 MPa {7 kgf/cm<sup>2</sup>} [100 psi] or lower) onto the inside surface of the element to remove foreign materials.
4. To remove dust stuck on the air cleaner element, blow dry compressed air onto the outside surface from a distance.  
Blow compressed air on the inside surface toward the outside along the pleats. Then, blow compressed air on the outside and inside surface again.
5. After cleaning, hold the air cleaner element near a light bulb to illuminate the inside, to check for defects such as cuts, pinholes or local wear.
6. If any defect is found, replace the air cleaner element with a new one.
7. Reassemble the air cleaner element as it is.

### CAUTION

If defects such as cuts, pinholes or local wear are found in the element, or if the air cleaner indicator shows a red sign soon after the cleaned element is installed, change it for new one.

After cleaning or replacing the air cleaner element, press the reset button to reset the indicator.

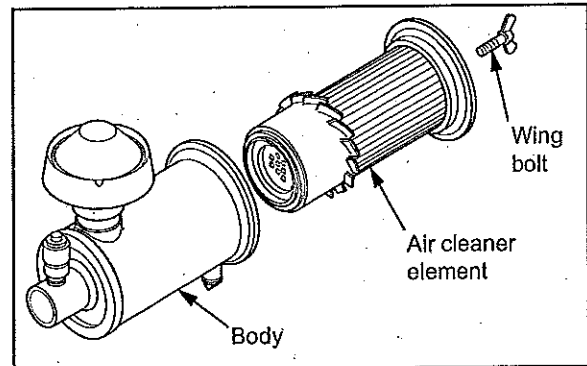


Fig. 8-30 Air cleaner element - Remove

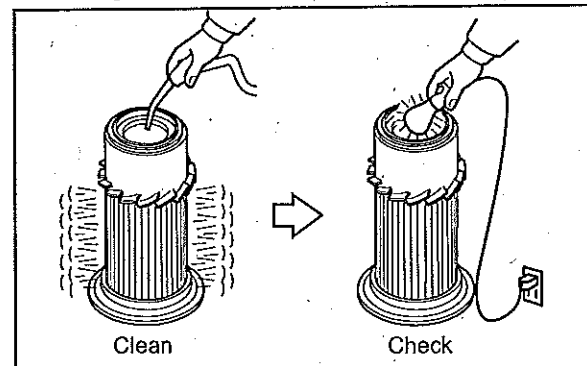


Fig. 8-31 Air cleaner element - Clean and Check

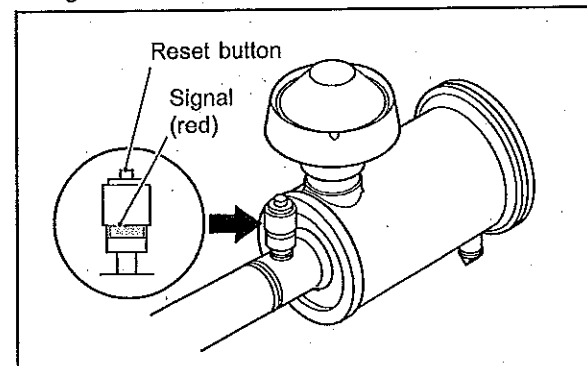


Fig. 8-32 Air cleaner - Check

## Electrical system

### Battery - Inspect

**CAUTION**

If battery electrolyte is spilled on your skin or clothes, flush immediately with plenty of water. If battery electrolyte get into your eyes, flush them immediately with plenty of water and then get medical attention.  
Do not use open flames or other fire hazards near the battery. When handling the battery, be careful of sparks generated by accidental shorting.

#### Battery electrolyte level - Inspect

Battery electrolyte evaporates during use and the electrolyte level gradually decreases. The proper electrolyte surface level is between the LOWER LEVEL and UPPER LEVEL lines.

For the battery without level lines, the proper electrolyte surface level is about 10 to 15 mm [0.39 to 0.59 in.] above the top of the plates.

If the electrolyte level is low, remove the caps and add distilled water to the proper level.

Note: When adding distilled water, pour in carefully.

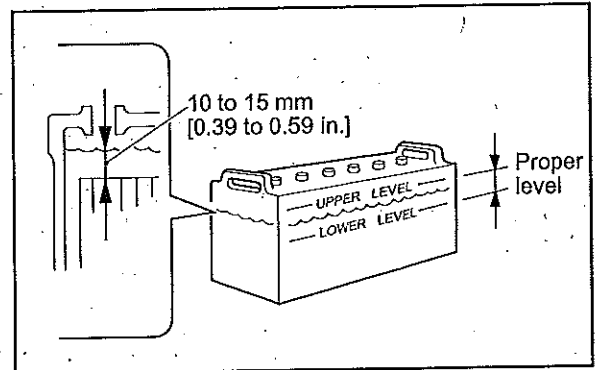


Fig. 8-33 Battery electrolyte level - Inspect

#### Specific gravity of battery electrolyte - Check

If the specific gravity measured at 20 °C [68 °F] is lower than 1.22, then charge the electrolyte.

Table 8-2 Specific gravity of electrolyte

Specific gravity at 20 °C [68 °F]	Condition	Remedy
From 1.26 to 1.28	Fully charged	-
From 1.22 to 1.26	Charged	Charge
Less than 1.22	Discharged	Charge

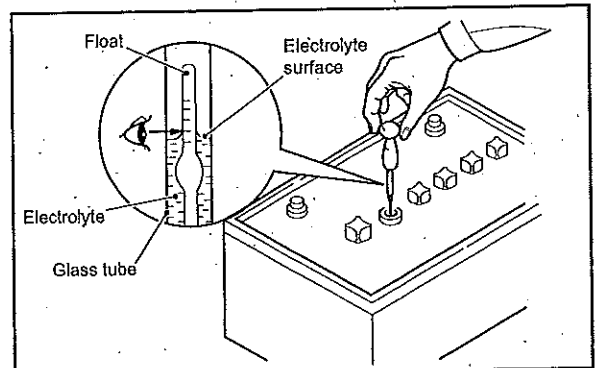


Fig. 8-34 Specific gravity of battery electrolyte - Check

### Starter - Inspect

Visually check the starter for damage.

If the starters are dusty, blow foreign material using compressed air.

Note: If the starters are defective, consult a dealer of Mitsubishi Heavy Industries, Ltd.

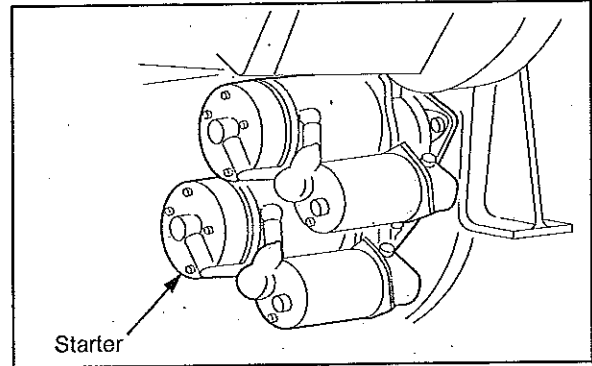


Fig. 8-35 Starter - Inspect

### Alternator - Inspect

Visually check the alternator for damage.

If the starters are dusty, blow foreign material using compressed air.

Remove the belt, and turn the pulley by hand to make sure that it rotates smoothly.

Note: If the alternators are defective, consult a dealer of Mitsubishi Heavy Industries, Ltd.

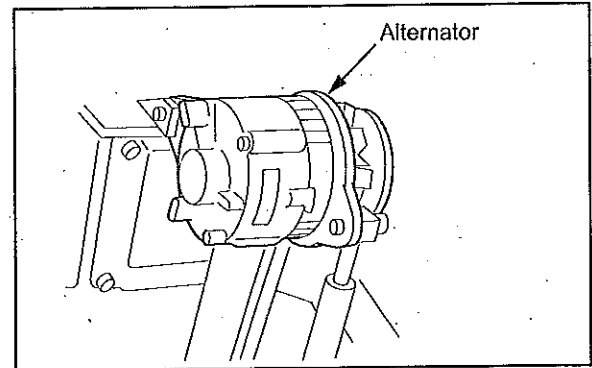
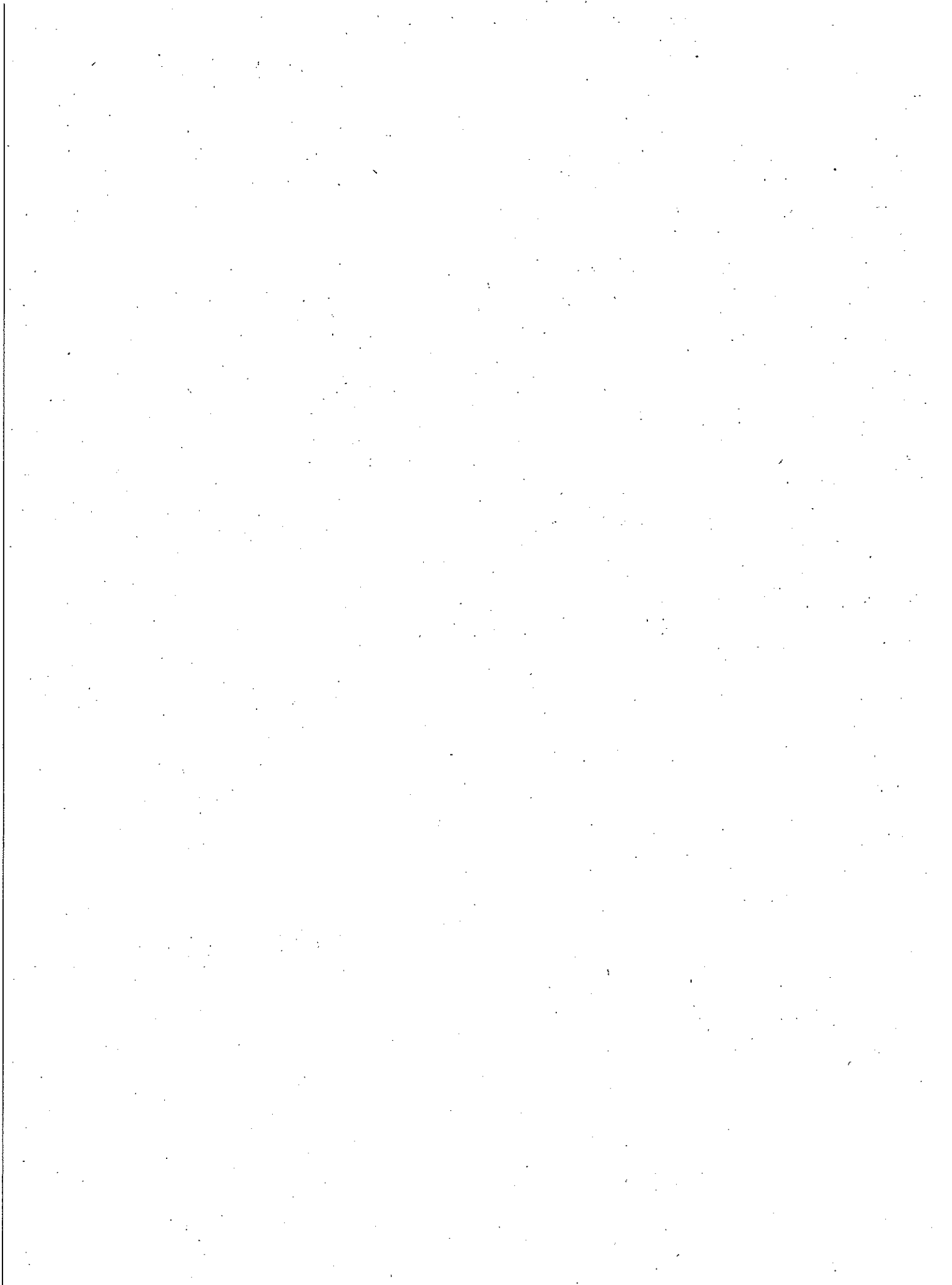


Fig. 8-36 Alternator - Inspect



# Chapter 9 LONG-TERM STORAGE

## CAUTION

If the engine has been left unattended for 3 months or more, the internal engine parts can rust, and that may cause damage to the engine.

When storing the engine for an extended period of time, be sure to follow the directions below.

## Storing the engine in an inoperable condition for 3 months or more

### Preparation for storage

1. Drain the engine oil in-use, pour new oil.
2. Prepare a fuel mixture containing 50 % rust-preventive oil (NP-9), and fill the fuel tank with it.
3. Run the engine at low idling speeds for 5 to 10 minutes.
4. Immediately before stopping the engine, spray volatile corrosion inhibitor (VCI) through the inlet port to prevent rust on the air intake system.
5. With the engine stopped, drain the fuel mixture from the fuel tank.
6. Apply rust-preventive oil (NP-3) liberally on the exposed sections of the machining.
7. Seal the air inlet, exhaust outlet, breather and other openings with an adhesive cloth tape.
8. Loosen the belt.
9. Wrap adhesive cloth tape on the terminals of the starters and alternator, and seal the openings. Cover these sections with polyethylene sheet or processed polyethylene paper, and place desiccants in the polyethylene covers.
10. Disconnect the cables from the battery terminals, and charge the battery. Clean the terminals, apply a thin coat of grease to the terminals, and store the battery in a cool and dry room.
11. Cover the whole engine.

Note: (a) Store the engine in a well-ventilated indoor area.

(b) It is not necessary to drain coolant since it contains LLC. (LLC must be specified concentration. For LLC concentration, refer to "LLC concentration" (6-5).)

(c) Post a sign at an easily noticeable place to warn that the fuel tank must be filled with fuel before operating the engine for the first time after storage.

### Recommended rust-preventive oil and corrosion inhibitor

Table 9-1 Recommended rust-preventive oil and corrosion inhibitor

JIS No.	Recommended product	Application
K2246	NP-3 Nippon Oil Corporation Anti Rust P-1600	Prevention of rust on exposed machine surfaces
	NP-9 Nippon Oil Corporation Anti Rust P-2400	Prevention of rust in fuel system
Z1519	Ryōkoku Kagaku VCI Diana ND volatile corrosion inhibitor	Prevention of rust in air intake system

### Maintenance during storage

Charge the battery once a month. First, check the battery electrolyte for proper level and then charge the battery.

## Using the engine after storage

1. Remove the cover from the engine.
  2. Connect a fully charged battery.
  3. Remove the covers from the starters and alternator.
  4. Adjust the tension of belt.
- Note: Inspect and adjust V-belt tension. Refer to "Belt and belt tension - Inspect and Adjust" (8-2).
5. Remove sealing tapes from the openings of the engine.
  6. Connect pipes.

Note: For engine oil, refer to "ENGINE OIL" (5-1).

7. Fill the fuel tank with fuel, and bleed the fuel system.

Note: For bleeding fuel system, refer to "Fuel system - Bleed air" (3-2).

8. Inspect the whole engine.
  9. Remove the rocker covers, and lubricate the valve mechanisms.
  10. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times.
  11. Make sure the engine oil pressure rises.
  12. Conduct a warm-up operation for a sufficient duration.
- Note: For starting the engine, refer to "Starting" (3-13).
13. Apply load and increase the engine speed to the rated speed.

## Storing the engine in an operable condition for 3 months or more

When the engine is not operated during storage of 3 months or more, internal engine parts can rust and lose oil film. As a result, the engine can seize when it is started after storage. To prevent such a risk, the engine must be operated periodically during storage.

## Operating the engine for maintenance

Operate the engine for maintenance at least once a month as described below.

1. While pulling the stop lever, rotate the crankshaft for approx. 10 seconds to turn on the starter. Stop the operation for 1 minute, then, repeat the operation two or three times.
2. Make sure the engine oil pressure rises.
3. Operate the engine about 5 to 10 minutes under no load as the maintenance operation.

Note: For starting the engine, refer to "Starting" (3-13).

# Chapter 10 TRANSPORTATION

## Lifting the engine

### **WARNING**

To lift the engine, use wire ropes, shackles and slings capable of supporting the weight of the engine. Attach the wire rope to the hangers provided on the engine using a correct sling. Keep the engine balanced during lifting by considering the engine's center of gravity. Keep the angle formed by slings attached to hangers within 60°. If the angle exceeds this limit, excessive load could be imposed on the hangers and this could damage the hangers and result in a serious accident. Attach wire ropes to the hangers after removing the pipe cover and the insulator near the hangers. To prevent wire ropes from contacting the engine, use a cloth or other soft padding.

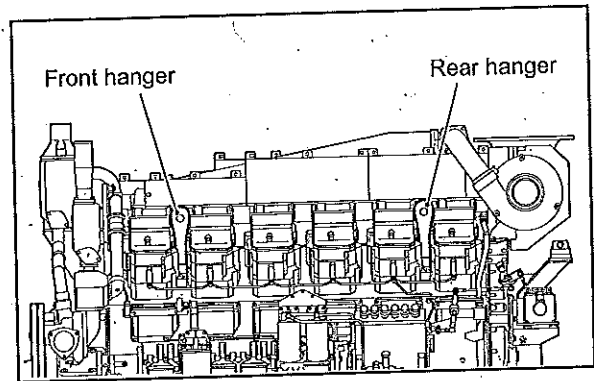


Fig. 10-1 Hangers

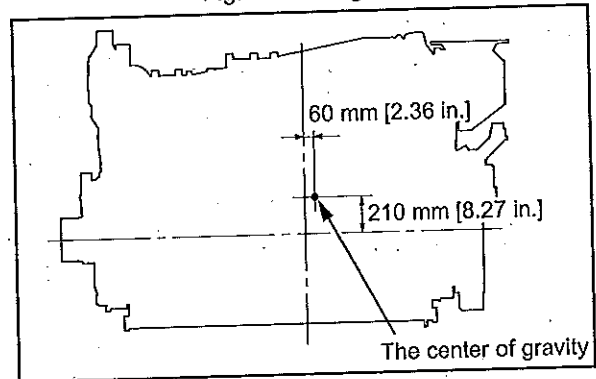
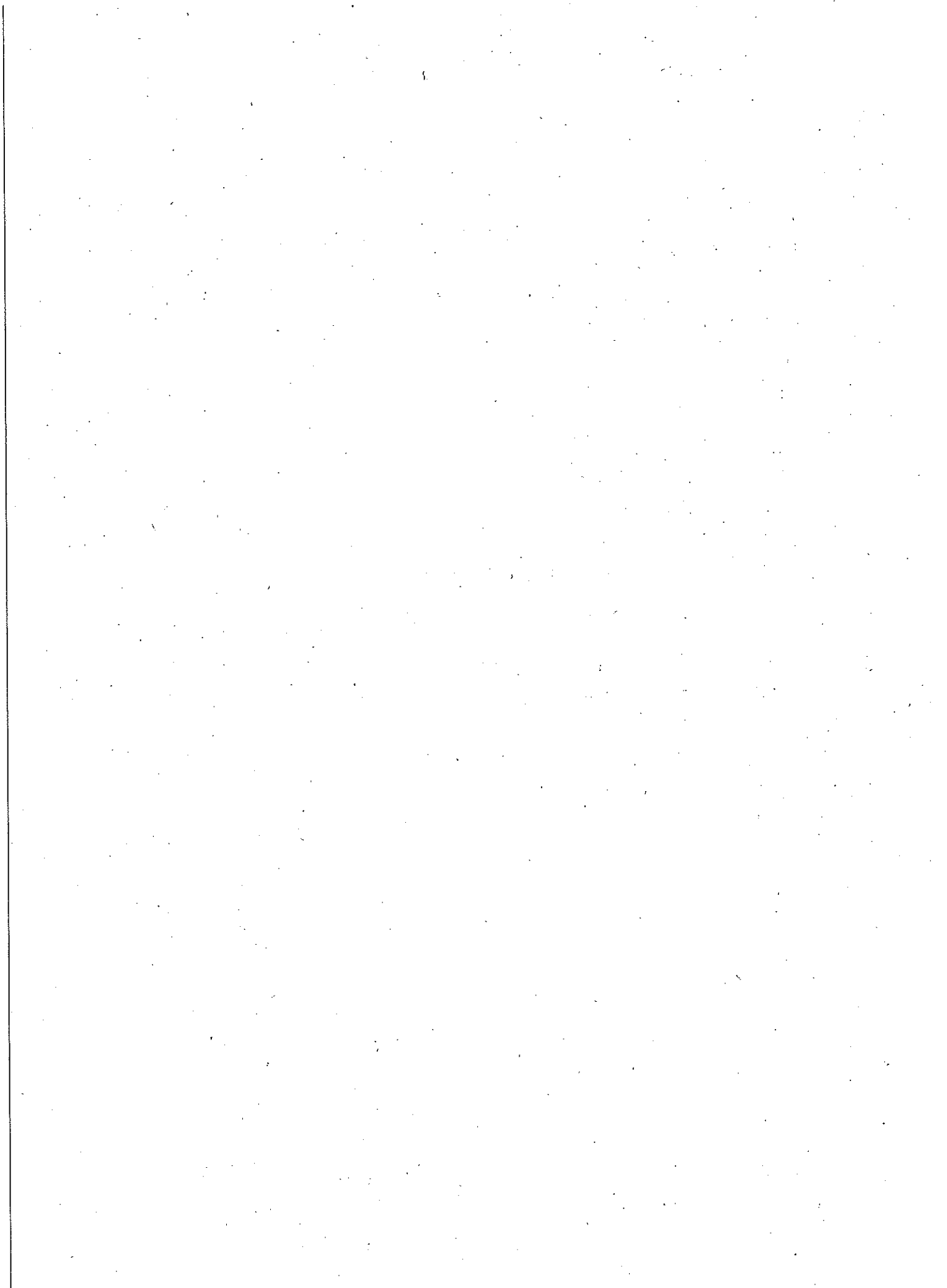


Fig. 10-2 Engine's center of gravity  
(standard specification)



# Chapter 11 TROUBLESHOOTING

## General precautions

### Contact a dealer of Mitsubishi Heavy Industries, Ltd. for repair service

Repairing a malfunctioning engine may require special equipment or involve potentially dangerous work, except for relatively simple procedures such as the change and addition of fuel, engine oil and coolant. In the event of the engine failure, contact a dealer of Mitsubishi Heavy Industries, Ltd.

### Considerations before work

Before troubleshooting, consider possible causes of the problem and try to find out if the same problem has occurred in the past.

Check the parts that may be causing the problem in the most efficient order.

When disassembling a component, pay close attention to the disassembly sequence so that you can reassemble the component in reverse order of disassembly.

### Cautions against contamination

Dust and foreign materials are the most common cause of rapid wear of parts.

When disassembling a component, take measures to prevent dust and foreign materials from entering the component being disassembled.

### Cautions regarding parts handling

Handle parts carefully.

When replacing parts, use only genuine parts by referring to the parts catalogue.

### Work safety

Be sure to use wrenches of the correct size. Using a wrench of the wrong size not only damages nuts but can also cause the personal injury.

Use correct tools and perform work with utmost caution.

Be sure to accurately estimate the weight of the part being dismantled. If the removed part is much heavier than you have estimated, it may fall down during lifting and can result in the damage to the parts or personal injury.

## Troubleshooting

### The starter does not crank or cranks slowly, resulting in start failure

Table 11-1 The starter does not crank or cranks slowly, resulting in start failure

Cause		Remedies
Electrical system	Faulty wire connection	<ul style="list-style-type: none"> <li>♦Check the DC fuse.</li> <li>♦Check wiring connection between battery, starter and starter switch</li> </ul>
	Insufficiently charged battery	<ul style="list-style-type: none"> <li>♦Check alternator. (Refer to P8-21)</li> <li>♦Check and adjust belt. (Refer to P8-2)</li> </ul>
	Faulty battery	<ul style="list-style-type: none"> <li>♦Check specific gravity of battery electrolyte. (Refer to P3-7)</li> <li>♦Charge battery</li> <li>♦Change battery.</li> </ul>
	Faulty starter or starter relay	<ul style="list-style-type: none"> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Lubricating system	Oil viscosity too high	<ul style="list-style-type: none"> <li>♦Use appropriate engine oil. (Refer to P5-1)</li> </ul>
	Excessive oil	<ul style="list-style-type: none"> <li>♦Check amount of engine oil and lubrication system. (Refer to P3-10)</li> </ul>
Basic engine	Rapid wear of sliding parts, or locked	<ul style="list-style-type: none"> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>

### The starter cranks, but the engine does not start

Table 11-2 The starter cranks, but the engine does not start

Cause		Remedies
Fuel system	Run out of fuel, blocked pipe	<ul style="list-style-type: none"> <li>♦Inspect fuel tank, supply fuel, bleed air. (Refer to P8-5)</li> <li>♦Check fuel pipes, valves.</li> </ul>
	Improper fuel property	<ul style="list-style-type: none"> <li>♦Use appropriate fuel. (Refer to P4-1)</li> <li>♦Remove dust, water impurities. (Refer to P8-5)</li> </ul>
	Fuel leakage in fuel pipes and injection pipes.	<ul style="list-style-type: none"> <li>♦Check faults and retighten fuel pipes and injection pipes.</li> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Clogged fuel filter	<ul style="list-style-type: none"> <li>♦Inspect and replace fuel filter. (Refer to P8-7)</li> <li>♦Clean gauze filter. (Refer to P8-6)</li> </ul>
	Faulty fuel feed pump	<ul style="list-style-type: none"> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Faulty fuel injection pump	<ul style="list-style-type: none"> <li>♦Check the rack movementx</li> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Faulty fuel injection nozzle	<ul style="list-style-type: none"> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Air intake system	Insufficient amount of air	<ul style="list-style-type: none"> <li>♦Clean, inspect and replace air cleaner element. (Refer to P8-19)</li> </ul>
Control system	Faulty governor	<ul style="list-style-type: none"> <li>♦Check the linkage operation. (Refer to P3-11)</li> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Basic engine	Low compression pressure	<ul style="list-style-type: none"> <li>♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>

## Output decrease

Table 11-3 Output decrease.

Cause		Remedies
Fuel system	Improper fuel property	•Use appropriate fuel. (Refer to P4-1)
	Clogged fuel filter	•Inspect and replace fuel filter. (Refer to P8-7) •Clean gauze filter. (Refer to P8-6)
	Faulty fuel feed pump	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection pump	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection nozzle	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Improper amount of injected fuel	•Check fuel injection pump rack stroke. •Check left and right bank. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Cooling system	Overheat, overcooled	•Check fan and heat exchanger. •Check control system. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Inlet and exhaust systems	Insufficient amount of air	•Check turbocharger. (Refer to P8-18) •Clean, inspect and replace air cleaner element. (Refer to P8-19) •Check intake air pressure and leakage of intake air. •Check intake air temperature and ventilation device. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Increase resistance of exhaust air.	•Check turbocharger. (Refer to P8-18) •Check exhaust pipes and silencer. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Basic engine	Low compression pressure	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty valve timing	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Rapid wear of sliding parts	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Control system	Faulty governor control	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.

**Exhaust smoke is white or blue**

Table 11-4 Exhaust smoke is white or blue

Cause		Remedies
Fuel system	Improper fuel property	♦Check cetane index, and use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	♦Check fuel injection pump couplings. ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection nozzle	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Uneven fuel injection	♦Check ignition noise, exhaust smoke temperature, left and right bank balance. ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Incorrect fuel injection timing	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Lubricating system	Combustion of engine oil	♦Check amount of engine oil and lubrication system. (Refer to P3-10) ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Cooling system	Overcooled	♦Check radiator. (Refer to P8-XX.) ♦Check control system. ♦Thermostat - Inspect ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Basic engine	Faulty valve timing	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Low compression pressure	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.

## Exhaust smoke is black or charcoal

Table 11-5 Exhaust smoke is black or charcoal

Cause		Remedies
Fuel system	Improper fuel property	•Use appropriate fuel. (Refer to P4-1)
	Faulty fuel feed pump	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection pump	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection nozzle	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Uneven fuel injection	•Check exhaust smoke temperature, left and right bank balance. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Inlet and exhaust systems	Insufficient amount of air	•Check turbocharger. (Refer to P8-18) •Clean, inspect and replace air cleaner element. (Refer to P8-19) •Check intake air pressure and leakage of intake air. •Check intake air temperature and ventilation device. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Increase resistance of exhaust air.	•Check turbocharger. (Refer to P8-18) •Check exhaust pipes and silencer. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Basic engine	Low compression pressure	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty valve timing	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Rapid wear of sliding parts	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Control system	Increase in load	•Check control system and governor controller. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.

**Fuel consumption is high**

Table 11-6 Fuel consumption is high

Cause		Remedies
Fuel system	Faulty fuel injection nozzle	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty fuel injection timing	•Check fuel injection pump couplings: •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Improper fuel property	•Use appropriate fuel. (Refer to P4-1)
	Fuel leakage in fuel pipes and injection pipes.	•Check faults and retighten fuel pipes and injection pipes. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Cooling system	Overcooled	•Check radiator. (Refer to P8-17) •Check control system. •Thermostat - Inspect •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Inlet and exhaust systems	Insufficient amount of air	•Check turbocharger. (Refer to P8-18) •Clean, inspect and replace air cleaner element. (Refer to P8-19) •Check intake air pressure and leakage of intake air. •Check intake air temperature and ventilation device. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Increase resistance of exhaust air.	•Check turbocharger. (Refer to P8-18) •Check exhaust pipes and silencer. •Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Basic engine	Low compression pressure	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty valve timing	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Rapid wear of sliding parts	•Consult a dealer of Mitsubishi Heavy Industries, Ltd.

## Engine oil consumption is high

Table 11-7 Engine oil consumption is high

Cause		Remedies
Fuel system	Faulty fuel injection timing	<ul style="list-style-type: none"> <li>• Check fuel injection pump couplings.</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Lubricating system	Oil leakage to the outside of engine	<ul style="list-style-type: none"> <li>• Check oil leakage.</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Engine oil viscosity too low	<ul style="list-style-type: none"> <li>• Use appropriate oil viscosity. (Refer to P5-1)</li> </ul>
	Engine oil temperature is high.	<ul style="list-style-type: none"> <li>• Check amount of engine oil and lubrication system. (Refer to P3-10)</li> <li>• Check oil cooler and oil thermostat</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Cooling system	Overheating	<ul style="list-style-type: none"> <li>• Check radiator. (Refer to P8-17)</li> <li>• Check control system.</li> <li>• Thermostat - Inspect</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Inlet and exhaust systems	Spread oil to intake part	<ul style="list-style-type: none"> <li>• Check oil leakage to the turbocharger.</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Wear of valve operating system	<ul style="list-style-type: none"> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Basic engine	Wear of sliding parts	<ul style="list-style-type: none"> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Control system	Increase in load	<ul style="list-style-type: none"> <li>• Check control system and governor controller.</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>

## Overheating

Table 11-8 Overheating

Cause		Remedies
Cooling system	Low coolant level	<ul style="list-style-type: none"> <li>• Check coolant leakage</li> <li>• Check coolant level. (Refer to P3-11)</li> </ul>
	Faulty water pump operation	<ul style="list-style-type: none"> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Faulty thermostat operation	<ul style="list-style-type: none"> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
	Faulty radiator operation	<ul style="list-style-type: none"> <li>• Check and clean radiator and radiator filler cap. (Refer to P8-17)</li> </ul>
Control system	Increase in load	<ul style="list-style-type: none"> <li>• Check fuel injection pump rack stroke.</li> <li>• Check control system and governor controller.</li> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>
Basic engine	Rapid wear of sliding parts	<ul style="list-style-type: none"> <li>• Consult a dealer of Mitsubishi Heavy Industries, Ltd.</li> </ul>

## Low engine oil pressure

Table 11-9 Low engine oil pressure

Cause		Remedies
Lubricating system	Insufficient amount of engine oil	♦Check amount of engine oil and lubrication system. (Refer to P3-9)
	Faulty engine oil property (viscosity)	♦Analyze oil property. Use appropriate engine oil. (Refer to P5-1)
	Oil temperature too high	♦Check coolant system. ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Oil filter clogged	♦Inspect and replace oil filter and bypass oil filter. (Refer to P8-9)
	Faulty oil pump operation	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Faulty relief valve operation	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Control system	Faulty pressure unit operation	♦Check control system and wire. ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
Basic engine	Increase in load	♦Check control system and governor controller. ♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Rapid wear of sliding parts	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.
	Increase clearance of sliding part.	♦Consult a dealer of Mitsubishi Heavy Industries, Ltd.

## When fuel has run out

When fuel runs out while engine is running and the engine has stopped, restart the engine as described below.

1. Return the starter switch to the "OFF" position.
2. Add fuel to the fuel tank.  
For filling fuel tank, refer to "Fuel tank oil level - Check" (3-9).
3. Bleed air from the fuel system.  
For bleeding fuel system, refer to "Fuel system - Bleed air" (3-2).
4. Restart the engine.  
For starting the engine, refer to (Refer to P3-13).

# Chapter 12 MAIN SPECIFICATIONS

## Main specifications

Table 12-1 Main specifications

Item	Specifications
Engine model	S12R-Y2PTAW
Type	Water-cooled 4-stroke cycle, turbocharged with air cooler
No. of cylinders - arrangement	12-V
Cylinder bore × stroke	ø170 × 180 mm [6.69 × 7.09 in.]
Displacement	49.0 L [2990 cu. in.]
Combustion type	Direct injection system
Compression ratio	14.5 : 1
Firing order	1 - 12 - 5 - 8 - 3 - 10 - 6 - 7 - 2 - 11 - 4 - 9
Direction of rotation	Counterclockwise as viewed from flywheel side
Dimensions (L x W x H)	Approx. 2490.5 x 1457 x 1646.5 mm [98.05 x 57.36 x 64.82 in.]
Dry weight	Approx. 5270 kg [11618 lb.]
Fuel	Diesel fuel
Fuel injection pump	Mitsubishi PS6A × 2
Fuel filter	Paper-element type (spin-on type)
Fuel injection nozzle	Hole type
Initial fuel injection pressure	34.32 MPa {350 kgf/cm <sup>2</sup> } [4978 psi]
Lubrication method	Forced circulation (pressure feed by oil pump)
Lubrication oil	Class CF oil (API service classification)
Engine oil capacity	Oil pan: Approx. 150 L [39.63 U.S. gal.], Whole engine: Approx. 180 L [47.56 U.S. gal.]
Oil filter	Paper-element type (with bypass oil filter, spin-on type)
Oil cooler	Water cooled multi-plate (built-in crankcase)
Cooling method	Forced water cooling
Coolant capacity	Approx. 111 L [29.33 U.S. gal.] (in engine only), Approx. 14 L [3.70 U.S. gal.] (air cooler)
Starting system	Electric motor starting
Starter	24V DC - 7.5 kW × 2
Alternator	24 V DC - 30 A
Turbocharger	Mitsubishi TF15M × 2

Note: The specification above are subject to change without prior notice.

